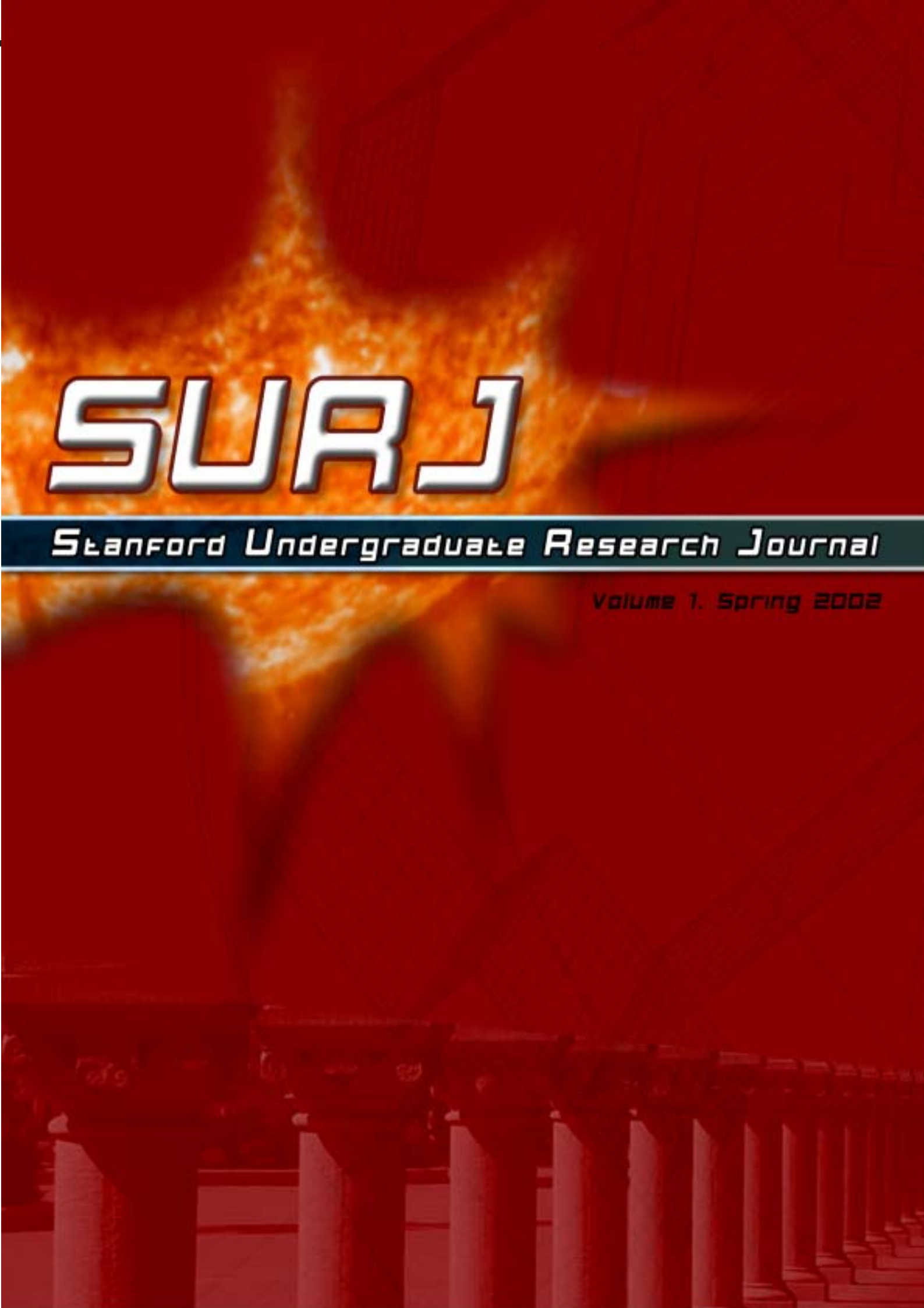
SURJ
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Letter from the Editors-in-Chief

Welcome to the premier issue of the Stanford Undergraduate Research Journal (SURJ). As Stanford's newest student publication, SURJ strives to showcase a wide array of original research conducted by current undergraduates, thus providing a forum in which individuals from diverse fields can learn about research in disciplines other than their own. Towards this end, the thirteen articles featured in this issue are written in a manner that makes them easily accessible to all members of the Stanford community.

The role of SURJ in the academic community is twofold: first, to encourage, recognize, and reward intellectual activity beyond the classroom, and second, to provide a forum for the exchange and dissemination of research and ideas. We hope that by providing opportunities for undergraduates to have their research published, we can continue to foster their pursuit of knowledge and engage their investigative spirit.

In order to acheive these ambitious goals, we have worked tirelessly over the past year to produce this first issue. We could not have done it without the amazing support we received from the members of our SURJ staff, our Advisory Board, and from the University itself. We would also like to thank the many students who submitted their work for publication. Our entire editorial staff was impressed with both the quality and quantity of the submissions we received, which speaks volumes about the diligence, creativity, and intellect of the undergraduates at Stanford.

The Journal plans to be one of the nation's premier peer-reviewed academic journals, dedicated to the presentation of original undergraduate research to the wider community. Through its activities, the Journal seeks to vitalize interest in all academic disciplines and inspire the highest quality research.

If you would like to contribute to SURJ, we invite you to submit your research next year or join our staff. For more information, please visit our website at http://™™surj.stanford.edu.

With very best wishes,

Alex Bradford
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We would like to thank the following individuals, departments, and organizations for their support of the Stanford Undergraduate Research Journal:

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Editor's Note: The Kassianidou and Sagar articles were transposed due to necessary layout issues.

He, She, and It: Aesthetics in Mary Shelley

Ulrike Buschbacher

In her novel The Last Man, Mary Shelley follows in the footsteps of Edmund Burke and Immanuel Kant by representing the beautiful and the sublime as female and male aesthetic categories, respectively. However, even though most of the characters in The Last Man embody Burke and Kant's traditional aesthetics of the beautiful and the sublime, the novel's protagonist, Lionel Venney, falls into a different aesthetic category — the Gothic idea of the uncanny. Freud's definitive 1919 essay on the qualities of "uncanniness" serves as the basis for analyzing Lionel. Throughout the text, Lionel evolves into an uncanny figure. At the same time, he loses his gender characteristics, becoming ambiguously gendered and almost hermaphroditic. His loss of gender identification, combined with Freud's conception of the aesthetic, renders the uncanny as a genderless aesthetic.

"...the novel's protagonist, Lionel Verney, falls into a different aesthetic category-- the Gothic idea of the uncanny..."

In her novel *The Last Man*, Mary Shelley follows in the footsteps of Edmund Burke and Immanuel Kant by representing the beautiful as a female aesthetic and the sublime, an entity conveying nobility, grandness, awe, and superiority, as a male aesthetic. However, Lionel Verney, the protagonist of *The Last Man*, falls into a different aesthetic category — a category formed by the Gothic idea of the uncanny. Freud's definitive 1919 essay on the qualities define "uncanny" serves as the basis for analysis of Lionel's character. As Shelley's story progresses, Lionel evolves into an uncanny figure while also losing his gender characteristics, becoming ambiguously gendered and almost hermaphroditic in the end. His loss of gender identification, combined with Freud's conception of the aesthetic, renders the uncanny as a genderless aesthetic.

Nearly all of the females in *The Last Man* are "beautiful" characters. First and foremost, Kant points out that the "beautiful" is always attractive (Kant 91), and the women in Shelley's novel are indeed physically attractive. However, Shelley only pays nominal attention to physical beauty and places more emphasis on the beauty inherent in the women's virtues and personalities. For Burke, this focus particularly genders the beautiful; he argues that only the feminine is beautiful. He states, "But…perfection [is so far] from being the cause of beauty, that this quality, where it is highest, in the female sex, almost always carries with it an idea of weakness and imperfection" (Burke 137). He further distinguishes beauty from the sublime by calling beauty weak and imperfect. Moreover, these traits make women beautiful. In the novel, Idris and Perdita are always subservient to their husbands and brothers. Presented as a frail persona, Idris ultimately dies as a result of this fragility because she cannot endure the plague raging around her and the threat of death hovering over all of her loved ones. Meanwhile, Perdita is also weak; she kills herself when Raymond dies,

feeling useless without her male half. This extreme codependence is the largest weakness in Shelley's female characters, and yet, it does not diminish them aesthetically. The gentler feminine sex serves the stronger male gender within the novel, paralleling the relationship between beauty and the sublime.

In contrast, Shelley's Lord Raymond is a prime example of masculinity, possessing all the qualities of the sublime. As Burke states, the sublime "excites ideas of pain and danger…it is productive of the strongest emotion which the mind is capable of feeling" (51). Raymond is a Byronic figure; he is a dashing soldier who goes off to fight for Greece, whose "reckless courage and comprehensive genius brought him into notice…[h]e became a darling of this rising people" (Shelley 31). Raymond also encompasses other sublime virtues such as wisdom, justice, and fortitude, as he is a good leader and a successful general. Yet, in contrast to beauty, sublimity inspires both positive and negative reactions. Raymond also incites more unpleasant emotions, like terror. His passions are described as "violent," and his focus is entirely selfish (Shelley 35). For example, he terrifies his wife with vehement reactions to her accusations of infidelity and intimidates his friends when they try to persuade him to remain calm. According to aesthetic categories, Raymond encompasses sublime qualities in the ways that only a male can, namely by being aggressive and dominant.

Lionel represents an exception to the gendered aesthetic rule that Burke and Kant established; rather than being sublime or even beautiful, he embodies the uncanny. Lionel's character undergoes several fundamental transformations to evolve into an uncanny figure. He starts out as a wild, uncivilized "beast," "an outcast and a vagabond" (Shelley 205). Adrian rescues him from this way of life by offering him a place to live along with an education and an aristocratic identity backed by property and money. Lionel describes this life-changing encounter as a hunter-prey scenario, comparing himself to a beast that had to be caught: "Adrian gently threw me the silver net of love and civilization, and linked me to…human excellence" (Shelley 205). Lionel does not say that Adrian awakens his humanity, but he says rather that he himself is linked to civilization and can start to evolve into a civilized man. "I was admitted within that sacred boundary which divides the intellectual…and animals. My best feelings were called into play in response to [Adrian]" (Shelley 22). He is rescued from an animalistic existence by the education that Adrian provides. His first evolution does not grow out of his own volition; rather, it is left to Adrian to lead him into civilization. The air of weakness that surrounds Lionel is one of the main forces rendering him incapable of being a sublime figure.

This transformation from a savage to a civilized gentleman also sets up Lionel's lack of roots. The concept of the unknown being uncanny is expressed in the German concepts of the *heimliche* and the *unheimliche* (Freud 21). The word *heimlich* denotes "home," "native," and "known." Its antonym, *unheimlich*, conveys the uncanny and means literally, "not home." Conversationally, however, it means "uneasy," "eerie," "ghostly," and "creepy." The term *unheimlich* is easily applied to Lionel. Despite being adopted by Adrian, Lionel never really has a place of his own to call "home." He only is able to join the nobility by marrying Idris, Adrian's sister. While Lionel is welcomed in the aristocracy and acts as the governing Lord at Windsor, it is never technically "his" house and he is never the real Lord of Windsor as this title belongs to Adrian. This sense of alienation, fueled by his childhood abandonment and enforced by the circumstances of his life, drives him to travel at the end of the novel. As the last man, there is little need for Lionel to continue traveling. Yet he is not comfortable leading a settled life. He cannot establish a new home and certainly will not do so without external influences.

According to Freud, the uncanny is primarily something that should be repressed or has "undergone repression and then returned from it" ("The Uncanny," 245). Lionel's emergence into society can be described by the Freudian concepts of the Ego, Id and Superego. The wilderness in which he revels at first is representative of the Id, the untamed part of a personality craving only instant gratification. Stealing and fighting, Lionel acts on every visceral impulse, and this disregard for social convention leads to his incarceration. He is pure passion, his every move fueled by his hatred for Adrian and the nobility that turned its back on his father. He has not been subjected to the taming influence of society and hence, has not developed a Superego, or conscience, to discipline the wild Id. Only the appearance of Adrian, the embodiment of an Ego — a balance between the wild Id and restrictive moral Superego — leads Lionel out of his wild manners into civilization. Lionel comes into contact almost exclusively with Adrian. As a result, Adrian's influence curbs

Lionel's Id, enabling Lionel to develop an Ego that allows him to become a normal and balanced human being. However, Lionel's primitive roots need to be repressed in order to forge the "new" Lionel. This first transformation plants the seeds of his uncanniness.

Moreover, Freud wrote that the uncanny encompasses elements of precognition and morbid anxiety (Freud 47). The strongest connection between Lionel and the uncanny element of prophecy is in the text's introduction. At the beginning, the Sybil's cave is described as the place where a document is "found," a document that is actually the novel itself. The author narrating the introduction claims only to have put the scraps of prophecy together and translated them. This makes Lionel the embodiment of the prophecy. In addition, Lionel experiences a moment of precognition shortly after the outbreak of the plague in London, before the extent of its destructivity was known. He returns home to find a small festival held in honor of his son Alfred's birthday. Lionel exclaims, "Ye are all going to die […] already the gay dance vanished, the green sward was strewn with corpses, the blue air above became fetid with deathly exhalations" (Shelley 189). Lionel presciently envisions the deaths of his wife and children, as well as the deaths of the surrounding villagers and other party attendees; he simply misidentifies the causes of the their deaths. Furthermore, his morbid anxiety over his family is mentioned numerous times throughout the novel, demonstrating that Lionel is in the midst of transforming from a man to a fully uncanny figure.

Similar to the sublime aesthetic, the uncanny can invoke negative responses due to being mean and hurtful. "We also call a living person uncanny, usually when we ascribe evil motives to him. But that is not all; we must not only credit him with bad intentions but must attribute to these intentions of capacity to achieve their aim in virtue of certain special powers" (Freud 49). In contrast to Lionel's positive qualities depicted in the majority of the novel, there are several instances when other characters accuse Lionel of being "unkind." For example, after Perdita's husband's death, Lionel drugs Perdita to put her aboard the ship, despite her express wishes to stay in Greece by his grave. She wakes up from her drugged sleep and, realizing what Lionel has done, exclaims, "Unkind! unkind!…you know not what you have done!" (Shelley 167-8). She blames him for his selfish desire to keep her close to him and for his blatant disregard for her feelings. His unkindness also drives Perdita to commit suicide. Hence, by wielding a "special power," by using a drug and then forcing an evil end, Lionel commits an uncanny act.

Finally, Lionel's survival of the plague epidemic completes his transformation from a man to an uncanny figure, for as Freud says, "we are tempted to conclude that what is 'uncanny' is frightening precisely because it is not known and familiar" (21). No one, including the reader, knows why Lionel survives the plague. There is no logic and also no supernatural explanation offered in the place of logic. Furthermore, Lionel's ambivalence towards his own death heightens his uncanniness. He is never frightened about his own demise, but he never quite embraces it either. As he nears death, he declares he is happy. The uncanny is closely related to death and man's attitude towards death, "turning something fearful uncanny" (Freud 49). Lionel's attitude towards death is foreign and unsympathetic.

Once Lionel completes his transition from a man to an uncanny figure, he also loses his gender, becoming asexual and androgynous. A large part of Lionel's sexual metamorphosis is not connected to anything he actively does; rather, it is connected to the fact that his gender is rendered useless. Gender consists primarily of three elements: biological, comparative, and social. By the end of the novel, Lionel is the only person to have survived the plague. Biologically, then, he becomes asexual as there is no hope of repopulating the earth; his physical sexuality is irrelevant, and he becomes technically impotent. His sexual physical desires are also rendered useless since there is no one, male or female, to fulfill any sexual craving. He then must fulfill the role of male and female in his own life, a trend that started while he was taking care of Clara, fulfilling both maternal and paternal roles. There is also the comparative aspect of gender, the definition of one's sex in opposition to the other. If there are two genders, one is distinguished by not being the other; hence, the categories of male and female exist. However, there is no other gender left for Lionel to compare himself to; he cannot define himself through contrast.

Finally, gender is a social construct that carries with it expectations and conventions regarding behavior and self-image. For example, in Lionel's Western society, men wore pants and took up careers while women wore dresses and stayed home raising children. To an extent, their lives were predetermined

based on their social gender, rather than a biological necessity. Yet there is no society, Western or Eastern, to establish a gender code that Lionel must follow. The only trace of social gender that still clings to Lionel at the end of the novel is his own memory of these "gender laws". He thus becomes asexual, possessing male reproductive organs that are useless, and androgynous since he must fulfill his own sexual desires and practice both the male and female spheres of life defined by his memory of gender roles.

Lionel's final step in his transformation into a full uncanny figure matches the time when his gender changes. In the novel, there is a pattern of women being beautiful, hence gendering the aesthetic to be feminine. Likewise, the cases of sublime males in the novel gender the sublime as male. Lionel, then, is a genderless, sexually irrelevant figure who is uncanny, transferring his sexual identity onto the aesthetic of the uncanny. The uncanny aesthetic's gender is defined by an irrelevance of sexuality and gender.

Shelley chooses to end the novel with a lone uncanny character. Both the beautiful and the sublime characters perish. There is a wistful autobiographical element to this turn of events, as Shelley struggled to suppress her gender in a world dominated by men who were practicing the same literary craft as she. The uncanny, the survivor trait, can be possessed by either sex. The novel suggests an equality of the sexes, a suggestion supported by the fact that the author's voice is aligned with Lionel's and that Lionel is believed to be Shelley's fictional doppelgänger. Some contemporary critics have asked, "Why not *The Last Woman*?" Shelley answers with her desire to create a genderless encasement of spirit to stress the irrelevance of gender to her contemporary society.

Works Cited

Burke E. Philosophical Inquiry Into the Origin of Our Ideas of the Sublime and Beautiful. New York: Harper & Brothers, 1863.
Freud S. Studies in Parapsychology.Ed. P. Rieff. New York: Collier Books, 1963.
Freud S. "The Uncanny." The Standard Edition of the Complete Psychological Works of Sigmund Freud, Vol. XVII. Ed. and Trans. J. Strachey. London: Hogarth, 1953.
Kant, Immanuel. Critique of Judgment. Ed. James Creed Meredith. Oxford: Clarendon Press, 1952.
Shelley, MW. The Last Man. Ed. A. McWhir. Peterborough: Broadview, 1996.

Suggested Reading

Castle, Terry. The Female Thermometer. 1995.
Freud S. Three Essays on the Theory of Sexuality. 1905.
Freud S. The Ego and the Id. 1923.
Shelley, MW. Valperga. 1823.

Figure 1: Character Map

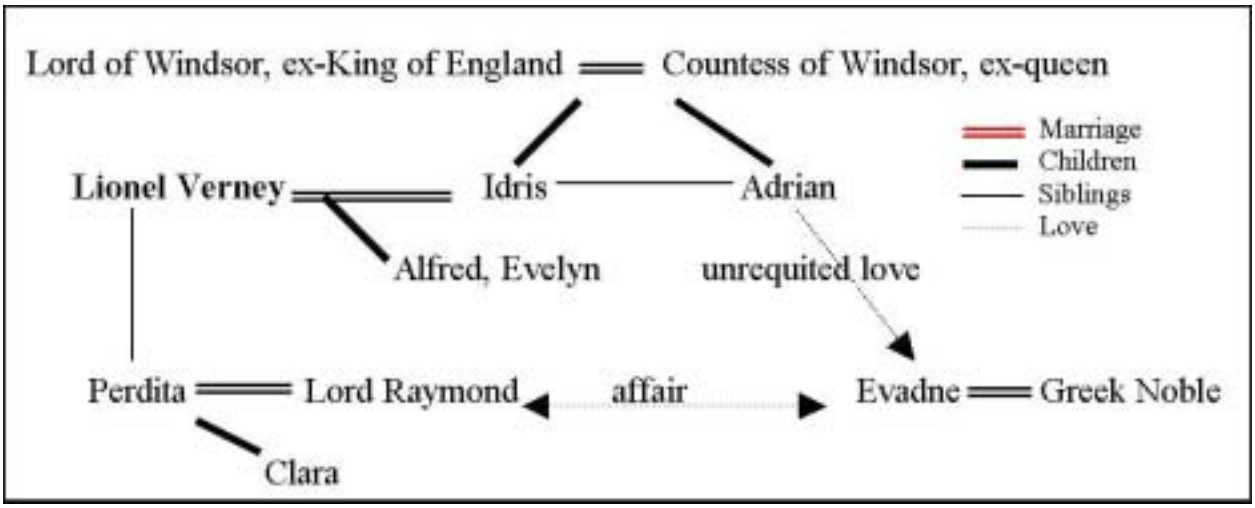


Figure 2: Novel Chronology

Lionel's association with the male gender

Lionel the Beast	Lionel meets Adrian, is adopted by him
	Lionel is educated
	Marries Idris after she escapes from her mother
	Plague breaks out
Lionel the Man	Goes to Greece with Perdita looking for Raymond
	Raymond and Perdita die
	Adrian becomes Lord Protector
	Lionel shuts himself and family in at Windsor
	Alfred dies
	Adrian decides to move rest of England to Paris
	Countess of Windsor reappears
	Idris dies
	Alfred, Lionel, and group of stragglers travel the Continent
	Countess of Windsor dies after reconciling with Lionel
Lionel the Uncanny	Everyone in the group dies, including Evelyn, Lionel's last child
	Adrian and Clara die in shipwreck
	Lionel is the last one left alive

Classical Modern Irreverence: Michael Jackson and Bubbles *Recontextualized*

Susan Cameron

The mission of this paper is to be as irreverant as the art it discusses. The research moves between high and low culture, creating a vertigo that blurs all artistic distinctions. I examine Jeff Koons's Michael Jackson and Bubbles *(1998) through the lens of Classical Greek art. The comparison shows the circularity of time, which humanizes antiquity and aggrandizes modernity. The research is particulary valuable to Stanford students because Koons's sculpture resides in the San Francisco Museum of Modern Art. When I am in the gallery there, I notice that most people walk by laughing at its gaudy absurdity. While this is certainly a valid response, it ignores the deeper implications of the piece. A plaque at the museum has some useful information about the scultpture, but it does not mention the obvious iconographic link to Dionysus. The paper's broad historical scope appeals to classicists and modernists alike, as well as the befuddled museum-goer. Koons crosses the traditions of ancient cult statues, the Parthenon, and Praxiteles with the banality of pop culture to question the materialist values of American society and blur established gender distinctions.*

"Whereas neoclassical artists borrowed reverently, Koons borrows irreverently, linking the King of Pop across time and space with the King of Theater."

For ancient Greeks, the Parthenon was the central melody on which subsequent variations were based. Every change in the artistic style was in some way a reaction to or against the Parthenonic ideal. Pericles wanted the Parthenon to flex the political muscles of Athens, so he enlisted the best sculptors to depict the conquest of the Persians in a way that made the battle appear gracefully easy. Physical imperfections, like Hephaestus's clubbed foot, were all "airbrushed" away. However, after the outbreak of the Peloponnesian War in 431 BCE and the plague in Athens in 430 BCE, the perfection of the Parthenon must have struck a dissonant chord. At the Temple of Apollo Epikourios in Bassae, the relief artists revolted bitterly against the unattainable and naive Parthenonic ideal. Although there are still visual references to the choreographed war of the metopes, Bassae shows war as the bloody chaos it really is (Fig. 1). Several years later, after the defeat of the Spartans at Sphacteria, the Athenians once again felt compelled to brag about their military prowess. They elaborately carved the Nike Temple on the Acropolis in a fashion even more luxurious and idealized than the Parthenon, while still applying Parthenonic motifs (Fig. 2 & 3). Bassae and the Nike Parapet are two examples of the opposite reactions that existed in regard to the Parthenon and its political propaganda.

What happens, however, when an artist sourly satirizes modernity in a mode that more resembles the Nike Parapet's buttery elegance than Bassae's caustic brutality? Jeff Koons created the answer in his 1988 sculpture, *Michael Jackson and Bubbles* (Fig. 4). Just like the Nike Parapet, *Michael Jackson and Bubbles* candy-coats the visual language of the Parthenon, but does so with a Bassae-like sarcasm that bluntly criticizes America's values of fame and wealth. The blaringly bright statue almost screams the importance of its surface over all intellectual content, recalling the tradition of porcelain Meissen figurines—decorative knick-knacks for wealthy

bourgeois tastes. However, Koons coyly positions Jackson in the pose of Dionysus from the East Pediment of the Parthenon (Fig. 5), thereby employing the time-honored and academically sanctioned tradition of borrowing from antiquity. Whereas neoclassical artists borrowed reverently, Koons borrows irreverently, linking the King of Pop across time and space with the King of Theater. Another convergence of time and theme is between Koons and Praxiteles, whose deity statues were as smooth in appearance and brazen in message as Koons's statue of a modern god. The publicity photo that inspired Koons shows Jackson lovingly holding his pet chimpanzee with the same S-curve hips that are the trademark of Praxiteles's statues such as *Hermes with Baby Dionysus* (Fig. 6).[1] With satiric humor, Koons combines the "high" traditions of ancient cult statues, the Parthenon, and Praxiteles, with the "low" traditions of Meissen figurines and publicity photos—the result being a menacingly proportioned pop icon, who questions the materialistic values of American society, blurs the distinction of gender, and challenges modern religion.

Part of the purpose of an ancient Greek temple was to house a colossal cult statue made of gold and ivory, like the Parthenon's Athena. *Michael Jackson and Bubbles* is painted with this exact color scheme, a choice equating modern celebrities and religious icons. Like Elvis before him, Jackson was literally worshiped by crazed fans—one headline in *Christianity Today* went so far as to proclaim "A Fringe Cult Calls Michael Jackson the Returned Christ."[2] Even mainstream media such as *Newsweek* described Jackson as "a pop idol, a demigod; a lonely prophet of salvation through the miracle of his own childlike, playful, life-giving music."[3] His music may be immortal, but his fame and public reputation are as fragile as a porcelain cult statue.

In 1992, *The San Francisco Examiner* perceptively commented, "It may not be stretching it to say that at heart Koons is a utopian, even a religious artist."[4] By calling Koons "utopian" one is inevitably reminded of Pericles, the mastermind of the Parthenon's construction. Both these men were the overseers of artistic creation, the visionaries, not the actual artist involved in production. At one point Koons directed fifty sculptors and twenty painters, who worked on twenty sculptures and sixteen paintings."[5] The comparison between classical, carveable marbles and the radioactive Michael Jackson is easier to accept when realizing the marbles were themselves once brightly painted. The effect was indeed so outrageous that Plutarch scathingly criticized Pericles's project saying,

> Greece is clearly the victim of a monstrous Tyranny; she sees us using what she is forced to contribute for the war, in order to gild and bedizen our city like a wanton woman hung round with costly stones and statues and thousand-talent temples.[6]

In Koons's sculpture, Michael looks exactly like the bedecked, wanton woman Plutarch so abhors. The sculpture is all about the exterior with seemingly nothing on the inside, which is appropriate since the general public will never know Jackson's inner workings distinct from his celebrity personality. The fact that Michael has been literally chiseled to "perfection" by a plastic surgeon is all the more ironic in the in the context of the immaculately carved Parthenon figures.

Besides referring to the Parthenon as a general ideology of perfection, *Michael Jackson and Bubbles* also appropriates the languidly reclined pose of Dionysus on the East Pediment. Whereas Dionysus likely held a *kantharos* (two-handled drinking cup), Michael holds his pet chimpanzee. Koons's selection of Dionysus as Michael Jackson's prototype is appropriate not only because they are both icons of hedonistic entertainment, but also because they both blur the distinctions of gender. We usually consider the Parthenon to be a celebration of masculinity, but the statue of Dionysus was actually a revolutionary departure, which began the process of feminizing Dionysus. In the long history of vase painting before the Parthenon, Dionysus was always shown with a beard, a clear symbol of masculinity.[7] The Parthenon was the first time Dionysus was shown sans beard.[8] The vase painters quickly followed the Parthenon's lead and began portraying Dionysus in a more feminized beardless fashion. This feminization was probably far from the intention of Pericles, who likely wanted Dionysus beardless to celebrate his youthfulness, and by extension the youthfulness of the soldiers who fought in the Persian War. However, artistic intention only goes so far, and the Parthenon's Dionysus perhaps unwittingly began the process that led to a character in Aeschylus's play Edoni calling Dionysus *gunnis* or "woman-man."[9] Michael Jackson has likewise transformed himself into a more and more feminized form. His publicity photo with Bubbles shows Michael in a nurturing and maternal pose, and his baby smooth skin looks utterly incapable of growing even a bit of stubble. A caption in *Life* magazine perceptively said, "With a touch of pancake, plenty of eyeliner—yet hardly enough beard to shave—[Jackson] has set a new

standard in androgynous allure."[10] His statue's face is delicately painted to resemble a veneer of makeup and red lipstick. The golden locks cascading over his eyes and shoulders make him look more like Petrarch's Laura than a male African American.

Koons's gender bending and hip swishing recalls Praxiteles, who also used pre-existing iconographic elements but with an iconoclastic twist. Both Praxiteles and Koons used the Parthenon's visual vocabulary to expose the futility of mindless admiration, be it of gods or celebrities. In *Hermes with Baby Dionysus,* Praxiteles used the same swish of the hips as appears on the Parthenon's frieze (Fig. 7), but instead of flexing the muscles of an idealized masculine form, it makes Apollo and Hermes androgynous and soft, hence robbing them of agency and virility. Hermes is not the forward rushing figure he was on the West Pediment of the Parthenon, but rather a static figure, content with child's play. As Xenophon warns, "Softening of the body leads to softening of the mind."[11] After the plague and brutal civil war, Praxiteles must have felt the gods no longer deserved absolute veneration, so he mockingly feminized them thereby robbing them of their agency and power. Like Praxiteles, Koons used motifs from the Parthenon, but with a similar edge that robs this mega-celebrity of his power to genuinely "heal the world," which coincidently Jackson is attempting to do with his own charitable foundation, established in 1992.

Both admirers and critics alike call Koons's work "kitsch," merely altering the tone of their voice to distinguish their positions. Although there are numerous definitions of the word, the *Oxford English Dictionary* defines kitsch as "characterized by worthless pretentiousness," and it quotes *The Observer* from February 23, 1958 as an example saying, "What is so extraordinary about some of these kitsch masterpieces is the way they can be enjoyed on two planes, both as themselves and as their own parodies."[12] The gold color, large scale, classical motifs, and its very placement in an art museum lend this Brobdingnag-scale Meissen figurine an air of pretentiousness. However, instead of being worthless, it satirizes the very concept of worth, both monetary and moral. Koons himself defines *kitsch* as "direct vulgarity and an object without function."[13] The tasteless sheen of *Michael Jackson and Bubbles* and its utter uselessness place it squarely within this definition. Considering the word *vulgar* derives from the Latin meaning "of the common people"[14] it is well applied to the "King of Pop," whose title implies Jackson's popular and hence vulgar appeal.

In the postmodern era, classical art is often viewed as a sort of "worthless pretension" in and of itself. Classical references seemed to go out of fashion with grand political history paintings. In a conflation almost akin to art-historical blasphemy, Koons's major precedents were the Parthenon and Meissen figurines. Although these two sources of inspiration are very much opposites of each other, Koons cleverly bends the art historical hierarchy to make them touch. Power and frivolity coexist, but not without satire. In *The Book of Meissen,* Robert Rontgen rightly observes, "Porcelain does not lend itself easily to the depiction of serious motifs, especially when they are conceived intellectually."[15] The Meissen figurine of a young boy reclining (in a suspiciously familiar pose) illustrate the banality of these famous collectables (Fig. 8). One of the most famous Meissen series was called *Monkey Band*, which showed monkeys playing various musical instruments, such as the contrabass.[16] The band uniforms worn by Jackson and Bubbles strongly recall these hilarious (yet expensive!) figurines. Koons aligns his cult statue of Michael Jackson with decorative art, thereby challenging the very limits of art (which recalls Marcel Duchamp's infamous *Fountain*, a porcelain urinal currently residing just down the corridor from Koons's own porcelain, in the San Francisco Museum of Modern Art).

In addition to challenging the definition of art, Koons also challenges religious faith in the modern era. The Greek statues were considered active agents of divine intervention. The word for statue in Greek, *agalma*, means literally "thing which delights" especially in reference to delighting the gods. It was a sacred word, not a just a mere noun. Koons's modern god, in contrast, is passive and impotent, more profane than sacred. Like the Bassae temple once did, Koons criticizes the status quo, but he uses the smoothness of the Nike Temple to do so. Greek art historian J.J. Pollitt says of the Nike Temple, "In these sculptures, ornamental beauty has become an end in itself and to a great degree has usurped the role of meaning or 'content' in the specific narrative sense."[17] *Michael Jackson and Bubbles* is devoid of content just like the Nike Temple, but in the more literal sense of being hollow inside. The statue implies that modern religion is more hollow than hallowed. Instead of founding faith on a rock, the vulgar populous founds its faith on fragile porcelain.

What appears to be all surface frequently has hidden layers—Jackson's lack of literal layers allows for metaphorical ones. The Parthenon was similarly accused of being all surface by Sir Mortimer Wheeler[18], but it had a profound impact on the whole history of art because it was so perfectly conceived and executed. With only a thin crust of porcelain and glaze

Koons addresses modern materialism, gender roles, and religious futility. With the tone of Bassae and the smoothness of the Nike Temple, Koons turns the language of the establishment against itself. Koons is at once a modern incarnation of Pericles as well as Praxiteles. The method of production, the pose, and the color scheme all reference Periclean ideals, while the iconographic twist and feminization of the figure recalls Praxiteles. The equation of Jackson with Dionysus sets up Koons's satire because Dionysus was the god associated with satyrs, from whence *satire* is derived. The disconcerting blend of limbs, in which one of Bubbles's legs could easily be mistaken for Jackson's third arm, gives the sculpture a half-man half-animal motif found in the satyrs of antiquity. This statue is brilliant, both with its golden glow and in its artistic conception. It is beautiful in its own kitschy way and yet also acutely disturbing. In a statue so rich in paradoxes, the conflation of the classical and kitschy is both fresh and provocative.

Works Cited

[1] Publicity Photo of Michael Jackson and Bubbles. "1980's Photos Page." *Exclusively Michael Jackson*. 2001: http://www.exclusivelymj.com/gallery80.html.

[2] *Christianity Today* 28 (9 November 1984): 64.

[3] Miller, Jim & Janet Huck. "The Peter Pan of Pop," *Newsweek* 10 January 1983: 54.

[4] *San Francisco Examiner* December 11, 1992. Qtd. in D.S. Baker, "Jeff Koons and the Paradox of a Superstar's Phenomenon" *Bad Subjects* 4 (February 1993): http://www.eserver.org/bs/04/Baker.html.

[5] Bowie, David. "Super Banalism and the Innocent Salesman," *Modern Painters* 11:1 (Spring 1998): 29.

[6] Ashmole, Bernard. *Architect and Sculptor in Classical Greece*. New York: New York University Press, 1972: 91.

[7] Carpenter, Thomas. *Dionysian Imagery in Fifth-Century Athens*. Oxford : Clarendon Press, 1997: Plate 9B.

[8] Carpenter, Thomas. "The Beardless Dionysus." *Masks of Dionysus*. Ithaca: Cornell University Press, 1993: 206.

[9] Carpenter, *Masks of Dionysus,* 204.

[10] Griffin, Nancy. "The Most," *Life Magazine* (September 1984): 100.

[11] Xenophon. *On Household Management* IV, 2-3. Qtd. in Alison Burford. *Craftsmen in Greek and Roman Society*. Ithaca: Cornell University Press, 1972: 12.

[12] "kitsch", *n.*[2] *Oxford English Dictionary*. Ed. J. A. Simpson and E. S. C. Weiner. 2nd ed. Oxford: Clarendon Press, 1989. *OED Online*. Oxford University Press. 4 Apr. 2000. http://dictionary.oed.com/cgi/entry/001217100?query_type=word&queryword=kitsch&edition=2e&first=1&max_to_show=10&sort_type=alpha&search_id=zH4y-wwcpkx-444&hilite=00127100

[13] Siegel , Jeanne. "Jeff Koons: Unachievable States of Being," *Arts Magazine* 60 1/2 (Oct 1986): 68.

[14] "vulgar, adj." *Oxford English Dictionary*. Ed. J. A. Simpson and E. S. C. Weiner. 2nd ed. Oxford: Clarendon Press, 1989. *OED Online*. Oxford University Press. 4 Apr. 2000. http://dictionary.oed.com/cgi/entry/00279455?query_type=word&queryword=vulgar&edition=2e&first=1&max_to_show=10&sort_type=alpha&search_id=zH4y-ULmpdC-851&hilite=00279455.

[15] Rontgen, Robert. *The Book of Meissen*. Exton, PA: Schiffer Publications, 1984: 14.

[16] Rontgen, Plate 243.

[17] Pollitt, J.J. *Art and Experience in Classical Greece*. Cambridge: Cambridge University Press, 1972: 123.

[18] Wheeler, Mortimer. "Size and Baalbek," *Antiquity* 36 (1962): 7.

Purity Viewed through the Eschatological Framework of Qumran

Sara Ferry

Modern notions of Judaism generally stem from the Hebrew Bible and the various literary and historical contributions of Jewish sects from the first century C.E. onward. Despite a plethora of insightful historical and literary accounts, a pervasive discontinuity in time exists between the later texts of the Hebrew Bible (c. 250 B.C.E.) and the emergence of Rabbinic Judaism at the turn of the first century C.E. The discovery of the Dead Sea Scrolls near Qumram, reflect the religious and social sentiments of a Jewish community, possibly the Essenes, that serves as a developmental link between the later Biblical texts and Rabbinic Judaism. Consequently, the previously accepted notion that Rabbinic Judaism is an authoritative indicator of Jewish sentiment prior to the first century has been seriously challenged.

This paper addresses a specific issue of purity laws viewed in light of the community's preoccupation with the final events in the history of humankind and the world. By analyzing the content of specific texts, this paper will demonstrate that the purity laws found at Qumran deviate from the purity laws of the Torah, from which they were derived. Additionally, this paper addresses the reasons for this community's re-interpretation of such laws. In a more general context, this paper will also argue that such re-interpretation and amplification of Biblical laws depend on the circumstances of specific communities.

"...the time the community spends preparing for the day of vengeance is also preparation for an age of absolute purity and perfection."

While many details about the community at Qumran remain shrouded in mystery, the literature associated with the sectarian group has allowed researchers to come to some consensus about the nature of their beliefs and practices. For instance, researchers have never questioned the prominence of the community's eschatological[1] beliefs or the emphasis of those beliefs on the observance of purity laws. The variety and richness of the literature discovered at Qumran, which includes biblical sources, apocrypha, and documents written by members of the sectarian group, provide researchers with a unique opportunity to trace the evolution of Jewish beliefs and practices. Containing at least one copy of every biblical book, with the exception of Esther,[2] it is clear that the religious sentiments of this group are grounded in the Hebrew Bible.[3] Consequently, the community's eschatological beliefs and ritual practices suggest that many of their references were to biblical sources. However, the eschatological beliefs and adherence to purity laws projected by the community do not parallel biblical accounts precisely. Instead, the presentation of such beliefs represents an amplification of the textual sources from which they were derived. In many instances, the purity laws recorded in the sectarian literature, such as the Manual of Discipline,[4] are much more stringent than those found in the Torah. Additionally, the community's documented records show that some purity laws instituted at Qumran did not originate from biblical sources. Such amplification and alteration of biblical sources evolved in tandem with the community's eschatological beliefs. An analysis of the content of the Manual of Discipline, a primary document that reflects the fundamental beliefs of the Dead Sea sectarians, will show that the altered

status of purity laws within the Qumran community were conditioned by the community's eschatological beliefs.

The Manual of Discipline (1QS), also referred to as the Rule of the Community, contains two other documents that outline the rules for the community and serve as the core text in scholarly understanding of the sectarian group at Qumran. The Rule of the Community establishes the rules, regulations and theological basis for a community living in anticipation of the eschaton, or End Time, an event that would herald the coming of the Messiah. The Rule of the Congregation (1QSa),[5] another part of the larger body of the Manual of Discipline found in cave one, reflects the nature of the community at the final period of the End time. A second text included in the body of cave one's Manual of Discipline scroll, The Rule of the Blessings (1QSb),[6] provides blessings that are reserved for the final session of the eschatological age when the "Sons of Darkness" no longer represent a threat to the "Sons of Light" who will receive "all of the everlasting blessings."[7] In addition to the nearly complete Manual of Discipline Scroll found in cave 1, at least ten other fragmented copies have been discovered in other caves near Qumran.[8] The abundant copies of this scroll suggest that this document was pivotal in establishing the communal codes. James Charlesworth, a prominent Dead Sea Scroll scholar, notes that the terms and phrases characteristic of the Manual of Discipline influenced many documents composed at Qumran.[9] Consequently, the references to the eschaton, purity laws, and observances constitute pervasive themes throughout the literature at Qumran. An analysis of the relational dynamic between these two themes, namely the extent to which eschatological anxiety conditions and dictates purity laws, should be indicative of the sentiments of other sectarian documents found near Qumran.

The Rule of the Community is intended to be a guide for the community present in an eschatological age, living in anticipation of the coming of the Messiah.[10] As a result, the laws and regulations within the document were conceived as a means for ushering in the eschaton. Furthermore, the document itself states that the only way to "cross over into the covenant before God" (1QS 1.16) is "by the Rule of the Community" (1QS 1.16), which emphasizes the importance of this document as the essential guide to live appropriately. Allusions to biblical sources within the Rule of the Community also establish the eschatological framework to examine purity laws. The text tells the community to "depart into the wilderness to prepare there the Way of the Lord" (1QS 8.13-14). This allusion to Isaiah 40:3 is decisive and purposeful. This passage, along with others from the later prophets, is utilized by the New Testament evangelists to heighten eschatological expectations. John the Baptist, the referent in this case, heralds the coming of the Messiah. Similarly, the earlier use of this phrase in the Rule of the Community is intended to arouse a sense of awareness about the motives for the community's separation from the Temple cult, replacing it with a more stringent adherence to purity laws. Living in exile from the Temple, the members of the community experienced the call to "depart into the wilderness," an exile that projected the imminence of the eschaton. Additionally, the Rule of the Community provides further evidence that the members' strict adherence to the laws were oriented towards the eschaton: "He shall be a man zealous for the statute[11] and prepared for the day of vengeance"[12] (1QS 9.23). This verse explicitly states that the stringent adherence to the laws and rules of the community is a means of preparation for the End time. Additionally, this verse suggests that the time the community spends preparing for the "day of vengeance" is also preparation for an age of absolute purity and perfection. Thus, the eschatological expectations of the community reflect a simultaneous effort towards absolute purity through a "zealous" adherence to purity laws. Consequently, the eschatological framework established in this document is pivotal in understanding the nature of purity laws within The Rule of the Community.

In contrast with the biblical texts from which they were derived, the purity laws and ordinances at Qumran assume both ritual and moral implications. Jonathan Klawans, a scholar of Judaism, notes that while ritual and moral impurity were once considered distinctive conditions, the two have merged and are completely identified as one in the Qumran texts.[13] The resolution for moral impurity – atonement – is equated with the resolution for ritual impurity – purification.[14] Similarly, the defilement resulting from moral impurity is often associated with the contagious aspects of ritual impurity. The Rule of the Community states that "no man among the members of the Covenant of the Community who deliberately, on any point whatever, turns aside from all that is commended, shall touch the pure Meal of the men of holiness or know anything of their counsel until his deeds are purified from all falsehood and he walks in perfection of way" (1QS 8.16-18).

The deeds, or moral actions, that need to be purified from falsehood suggest that this is a case of moral impurity. The consequences of these deeds, however, reflect the consequences of both moral and ritual impurity. The text states that the individual whose "deeds" must be "purified" will not "know anything of the counsel," suggesting that he will in some way be set apart or excommunicated. This is a consequence commonly associated with moral impurity in biblical sources. The text, however, also states that he shall not "touch the pure Meal," suggesting that his "touch" would render the pure Meal impure. Here, for what is commonly characterized as moral impurity stemming from the deeds or moral actions of an individual, the resulting consequence is both moral and ritual impurity.

The sharp dichotomy between members of the community and outsiders further stresses that moral and ritual impurities are closely united in Qumran literature. The text states that, "all [the outsiders'] deeds are defilement before Him, and all their possessions are unclean" (1QS 5.19-20). Here, the text suggests that outsiders are both morally and ritually impure. "Defilement" resulting from deeds implies moral impurity, and the "unclean" possessions reflect that the outsider has transferred impurity to personal property. Thus, ritual impurities are also implied. The text states that the community members' property "shall not be merged with the men of falsehood who have not purified their life by separating themselves from iniquity and walking in the ways of perfection" (1QS 7). Again, the concern here is both moral and ritual impurity. Biblically, contracting impurity is usually associated with ritual impurity. However, this textual amalgamation of both ritual and moral impurity within The Rule of the Community extends the contagious consequences to moral purity as well. Consequently, the text conveys the importance of maintaining both ritual and moral purity. As the text shows, being in a state of either impurity will bear the effects and consequences of both forms of impurities. In Leviticus, ritual impurity is characterized as contagious, but temporal.[15] In contrast, moral impurity is not considered contagious, though it can result in the permanent ruin of the sinner, and even the sanctuary of God and the land of Israel.[16] Thus, because ritual impurity is equated with moral impurity in the texts of Qumran, the purity laws appear more stringent than those found in earlier biblical sources. Additionally, when viewed through an eschatological framework, one can understand the possible reasons for the unification of ritual and moral impurity. However, this will become more evident following an analysis of the Rule of the Congregation.

Although only fragments of the text have survived, the Rule of the Congregation[17] provides insight into the unification of ritual and moral impurity. The text presents a scenario in which the community is present in the final session of the End time.[18] Both the invitation to the Council and the Messianic banquet represent the culmination of the strict purity laws conveyed in the Rule of the Community. In the Rule of the Community, the appeal to walk in the "way of perfection" represents the ultimate goal of moral and ritual purity.[19] Accordingly, the Rule of the Congregation provides the present community with a written record of the age to come. Although the community's eschatology was pre-messianic, James Charlesworth notes that, "[the community's] liturgy and concept of time allowed them to live proleptically as if the Messiah had already come."[20] This insistence on the community's presence at the End time explains their adherence to such strict purity laws. Although the consequences of ritual impurity are made more severe when unified with moral impurity, these consequences serve as a protective measure ensuring the purity of all members within the community during the crucial days before the eschaton.

Purity laws and ordinances at Qumran differ in severity and content from biblical sources on purity laws. Because several copies of the Books of Moses have been found in the Qumran library, suggesting their importance within the community, one may be driven to understand more clearly why these differences in purity laws exist. After all, the Rule of the Community explicitly emphasizes the importance of adhering to the laws of the Torah. It advises to "seek with all heart and soul doing what is good and right before him, as he commanded through Moses…" (1QS 1.2-3). Why, then, would the laws need to be any different? The answer lies in the fact that the sectarian group at Qumran is addressing a different situation. Living in exile from the Temple, the imminent coming of the eschaton is a very present reality for the community. As a result, the authors of documentssuch as the Rule of the Community and the Rule of the Congregation feel compelled to address this present reality while still maintaining continuity with Jewish tradition. Accordingly, biblical sources are re-interpreted and amplified in various ways to reflect the needs and circumstances of this

community.[21] In an age where the eschaton is imminent, amplification and re-interpretation of biblical sources concerned with purity laws are responsible for the variant forms of laws present in the community's literature. The unification of the concepts of moral and ritual purity within the Rule of the Community is shown to be heavily conditioned by the eschatology of the community, and justified through the eschatological framework of the Rule of the Congregation.

Works Cited

1 Derived from the Greek *eschatos* ("last things") and *logos* ("knowledge of"), eschatology refers to knowledge of the last days, or final events of history and mankind. Doctrines of eschatology find prominence within late Jewish and early Christian literature. Some typical elements of these doctrines include a divine judgment and the establishment of a new divine order.

2 James VanderKam, The Dead Sea Scrolls Today (Grand Rapids: Wm. B. Eerdman Publishing Co., 1994) 21.

3 Numbers in parenthesis indicate copies of each text found near Qumran: Genesis (15); Exodus (17); Leviticus (13); Numbers (8); Deuteronomy (29); Joshua (2); Judges (3); 1-2 Samuel (4); 1-2 Kings (3); Isaiah (21); Jeremiah (6); Ezekiel (6); Twelve Prophets (8); Psalms (36); Proverbs (2); Job (4); Song of Solomon (4); Ruth (4); Lamentations (4); Ecclesiastes (3); Daniel (8); Ezra (1); 1-2 Chronicles (1)

4 Manual of Discipline (1QS) discovered in Cave 1, 1947. Translated by Barthelemy and Milik (1955).

5 James Charlesworth, The Dead Sea Scrolls: Hebrew, Aramaic, and Greek Texts with English Translations, vol. 1,4 (Louisville: Westminster John Knox Press, 1991) .

6 Charlesworth, vol 1,4.

7 The titles "Sons of Darkness" and "Sons of Light" refer to the two opposing that will ultimately clash in the final battle of the eschaton. This confrontation is fully outlined in the War Scroll, an eschatological document central to the community. The "Sons of Light" refer to members within the Qumran community, while the "Sons of Darkness" refer to every member of the human race outside of the sectarian group. For more information see Schiffman's Reclaiming the Dead Sea Scrolls: The History of Judaism, The Background of Christianity, the Lost Library of Qumran.

8 VanderKam 22.

9 Charlesworth 4.

10 Charlesworth, vol.1, 2.

11 Geza Vermes' translation for "statute" reads "Precept"; his usage of "Precept" connotes, along with the physical action associated with "statute", a law that prescribes moral guidance. This will bear on the following discussion of both moral and ritual implications of purity laws in the Rule of the Community.

12 Geza Vermes' translation for "day of vengeance" reads "Day of Revenge"; Vermes' more emphatic translation asserts more clearly the emphasis on the ushering in of the eschaton.

13 Jonathan Klawans, Impurity and Sin in Ancient Judaism (Toronto: Oxford University Press, 1991) 75. While Klawans does a survey of the notions of ritual and moral impurity within several Qumran texts, my examples will be specific to the texts addressed in this paper.

14 Klawans, 87.

15 Klawans, 27.

16 Klawans, all.

17 Translated by James Charlesworth

18 Charlesworth 108.

19 Lawrence Schiffman, The Eschatological Community of the Dead Sea Scrolls (Atlanta: Scholars Press, 1991) 52.

20 Charlesworth 108.

21 James A. Sanders, Canon and Community (Philadelphia: Fortress Press, 1984). *Sanders might refer to this re-interpretation of the sectarian community as an eschatological hermeneutic.

When Information Flow in Project Organizations Becomes Turbulent: Toward an Organizational "Reynolds Number"

Michael Fyall

When managers try to develop complex products with many interdependent subsystems quickly, the high informational processing load created can cause organizational failure. There is currently no way for managers to tell when the demands placed upon a project team are great enough that the risk of organizational failure has reached unacceptable levels. Engineers use the Reynolds number in fluid mechanics as a metric that predicts whether the flow of a fluid will be smooth and stable versus turbulent and chaotic. This paper describes an initial attempt to define a similar metric for project information flow, an "organizational Reynolds Number" that uses various organization and work process parameters to predict whether a project team is approaching the turbulent flow region and is at risk of organizational failure.

"Engineers use the Reynolds number in fluid mechanics as a metric that predicts whether the flow of a fluid will be smooth and stable...Information flow...acts in the same way..."

When managers try to develop complex products with many interdependent subsystems quickly, the high informational processing load created can overwhelm an organization. Errors, poor decisions, and bad communication can quickly spread through the work processes and project teams, resulting in additional coordination and downstream rework that can cause quality meltdowns and organizational failure.

Project failure can lead to product failure as well. The prototype Lockheed Launch Vehicle called for five-to-one schedule shrinkage from Lockheed's prior military launch vehicles and required outsourcing of a key component to save costs. The vehicle launched four months late and had to be detonated in the atmosphere in 1996.[1] The failure was not due to a technical challenge or the use of inexpensive materials; the problem arose from a small cable harness team in Alabama that was under intense time pressure. In the face of frequent changes to the concurrently evolving avionics design, the cables subcontractor became overwhelmed with coordination responsibilities and was unable to complete its task successfully.

Engineers use the Reynolds number in fluid mechanics as a metric that predicts whether the flow of a fluid will be smooth and stable (laminar flow) versus unstable and chaotic (turbulent flow). Information flow throughout an organization acts in the same way – sufficient organizational capacity will allow for good information flow through a team while an overwhelmed group will suffer from turbulent information flow and risk total failure.

The SimVision® work process and organization simulation framework developed by the Virtual Design Team research group at Stanford is utilized to describe and quantify this behavior in project teams.[2] One objective of the research is to find a metric similar to the Reynolds number that would allow project managers to predict whether

their teams are approaching the turbulent flow region and are at risk of organizational failure. This paper summarizes my research to define an "organizational Reynolds number" using various organizational and work process parameters that predict the "edge of chaos."

An Information Processing View of Organizations

In 1974, Jay Galbraith introduced an information processing view of organizations.[3] The model abstracts work, whether it be assembling components to build a car or attending a project kick-off meeting, as simply a quantity of information to be processed. Organizations can then be thought of as information processing machines with a defined capacity to process information. The organization should be designed to have sufficient capacity to satisfy the demands placed upon it or it is at risk of organizational failure. However, Galbraith did not attempt to quantify either the capacities of teams or the requirements of the work to be processed.

The SimVision simulation framework quantifies and extends Galbraith's theory and models the organization as an information processing machine. Participants are arranged in an exception handling hierarchy in which each participant has specific characteristics that determine his capacity and rate of work. A work breakdown structure is created to model the work to be done by the organization. A Monte Carlo simulation is run combining the defined characteristics entered into the model with team participant behavior data created from years of research by the Virtual Design Team group. The simulator predicts the total duration of the work and computes measures of process quality.

This model makes it possible to quantify the capacity of the team and the amount of direct work as well as indirect work (coordination, rework, and waiting time) to be processed. In the search for an organizational Reynolds number, the capacity of the team and the direct work are held constant, while the interdependency of the work process and the rate at which errors occur within tasks increase. As the organization is overwhelmed with indirect work, the effect on the total duration of the project as a function of the increase in information to be processed is examined.

When Organizations Become Overwhelmed

Each participant in SimVision can be thought of as an information processing machine. Work to be done is placed into a participant's inbox, where it enters a queue and waits to be processed. If the length of a participant's inbox grows, he falls behind and is unable to complete his tasks on schedule. A backlogged participant is less likely to attend meetings and answer requests by others for information, and often fails to receive the information necessary to complete his own tasks. This behavior leads to poor decision making and an increase in the probability that the participant will make errors in the future.

As a participant falls further and further behind, he delays others and causes the overall work process quality to deteriorate and errors to spread throughout the organization. Other participants whose tasks rely on information from the backlogged participant suffer as well. Management participant backlog has an even more drastic effect as subordinate participants have to wait for managers to make decisions. If they are forced to wait long enough, they make the decision by default using their best judgment. This results in poorer quality decisions causing costly downstream rework.

SimVision is able to accurately reproduce the real effects of backlogged teams and has been extensively validated on numerous projects over the last ten years.[1] Its greatest success was the prediction of the Lockheed Launch Vehicle failure described earlier. The Virtual Design Team's model of the Lockheed organization showed that the concurrent work process placed additional coordination responsibility upon the cables subteam, causing significant backlog and leading to both the four month schedule delay as well as the quality breakdown that required the vehicle to be detonated.

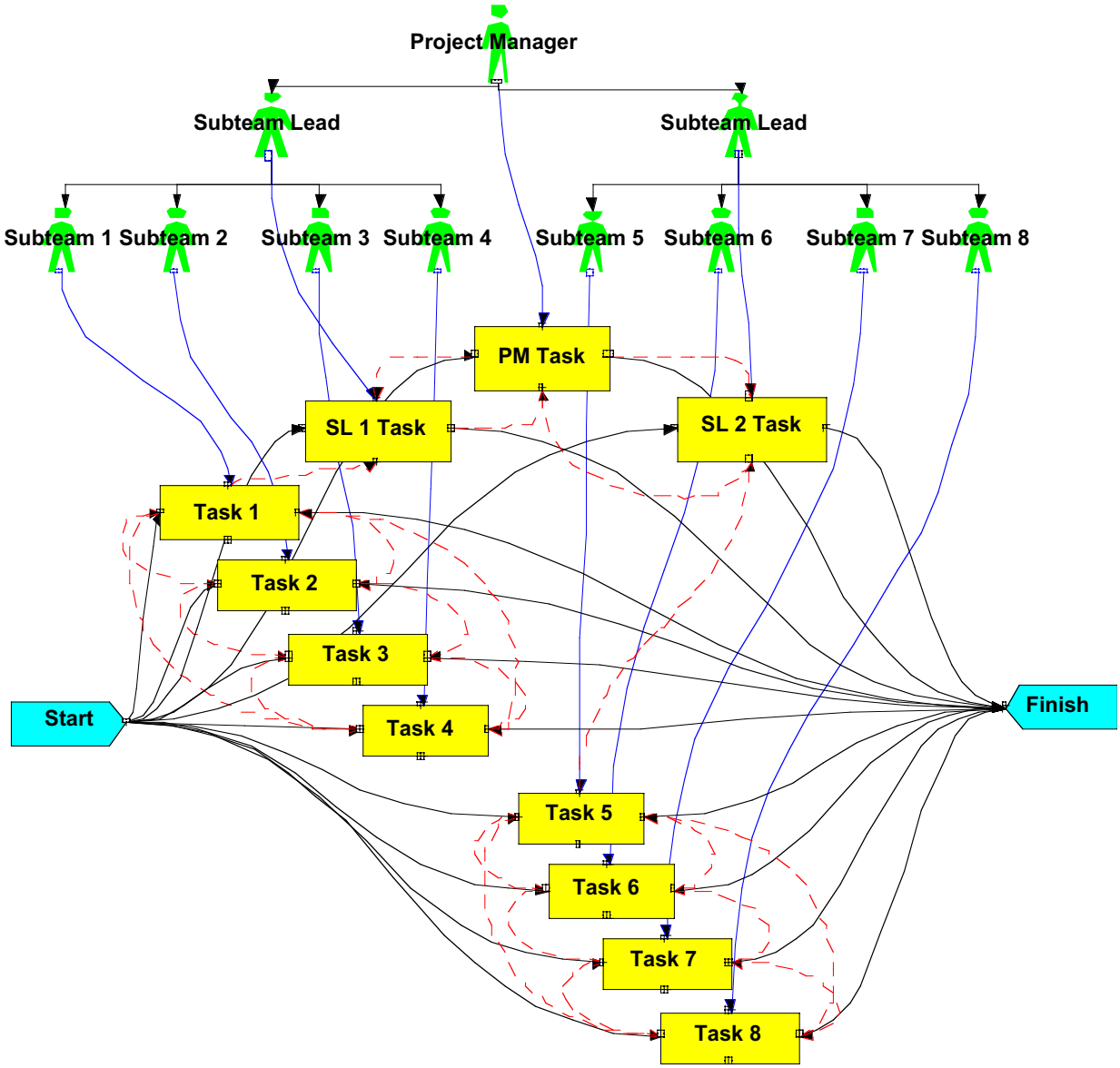
Defining Reynolds Behavior in Organizations

As mentioned above, the Reynolds number in fluid mechanics predicts when fluid flow changes from laminar to turbulent. The Reynolds number is dependent on the inertia and viscosity of the fluid; a value less than 2000 indicates laminar flow and a value over 2300 indicates turbulent flow. At low velocity, the fluid flows in a straight line, generating only small eddies that are damped out rapidly. The energy loss to the system due to friction is directly proportional to the velocity of the liquid. As the velocity of the fluid increases, a transition period occurs within 10% of the value of the Reynolds number, at which point the liquid might flow in either state (about 2000 to 2300). At higher velocities, the small eddies propagate and fluid flow is turbulent, or chaotic, with

continual fluctuations in both velocity and pressure. The energy loss due to friction in turbulent flow is immediately increased and varies with the square of the velocity. Piping is designed to carry the highest volume of water possible without risking the possibility of turbulent flow.

Suppose that information flow throughout an organization is analogous to fluid flowing through a pipe. If the capacity of the organization is large enough to handle the information flowing through it, indirect work should vary with the rate of information to be processed. As more work is forced upon the organization, the amount of time spent on rework and coordination increases. In this case, the additional indirect work is proportional to the increased work volume. However, when an organization becomes overwhelmed, information flow throughout the organization stagnates. Indirect work increases exponentially with an increase in the amount of work required, and the organization is at serious risk of failure. Does the information flow through an organization change from laminar to turbulent at a predictable point? The Reynolds number is dependent upon the diameter of the pipe, the velocity, and the viscosity of the liquid. If turbulent behavior does exist within organizations, which variables and characteristics would define the capacity of the organization (pipe diameter), the rate at which work needs to be processed (velocity), and the decision making culture of the organization (viscosity)? If turbulence is to be avoided at all costs, organizations should then be designed to process the greatest amount of work in the shortest time period possible without risking chaotic information flow.

Figure 1: Baseline Model



Simulation Data and Analysis

In order to search for an organizational Reynolds number, we created a project team and work process in SimVision and ran simulations to determine the amount of indirect work required to complete the project. Using the same model, we ran several more simulations with an increased probability of errors in the work process. By keeping the capacity of the team constant, we were able to compare the increase in indirect work with the marginal increase in the difficulty and uncertainty in the work process represented by the increased error probability.

Figure 1 shows the simple and idealized Baseline Model as represented in SimVision. The project team consists of one project manager, two subteam leaders, and eight subteam participants. Each participant is responsible for one 40 day task and all tasks start in parallel with each other. The red-dashed lines connecting tasks are rework links that cause an error in one task to create an error in another dependent task. The interdependency of the work process is measured by the ratio of rework links per task, and the Baseline Model has two rework links per task.

Each data point on Figure 2 represents a single simulation with an initial error probability (x-axis) plotted against the number of days of indirect work required to complete the project (y-axis). With an error probability of 0.05, the project will take 57 total days to complete; 40 days of direct work and 17 days of indirect work (rework, communication, and wait time). As the error probability is increased, additional indirect work is required to complete the project. The slope of the line represents the incremental increase in the amount of indirect work versus the increase in the error probability.

Figure 2: Baseline Scenario

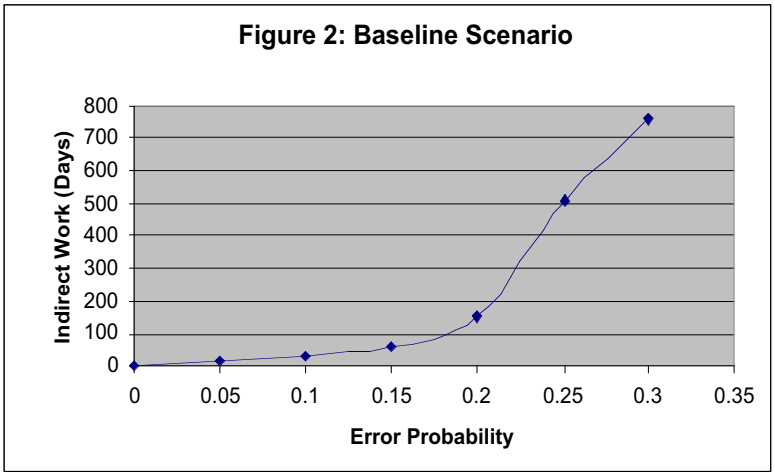
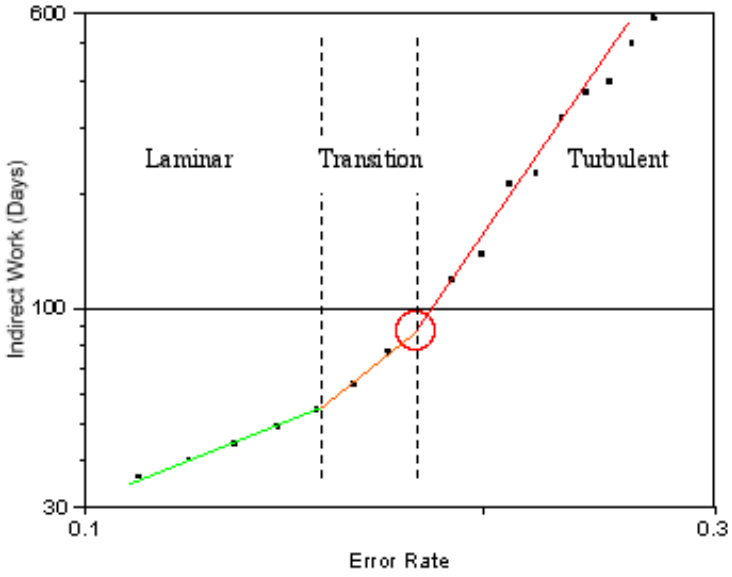


Figure 3: Transition to Turbulent Information Flow



The curve increases linearly until an error probability of between 0.15 and 0.2, at which point the curve increases exponentially. Information flows smoothly through the project team while the effect of an increase in the error rate on the amount of indirect work is constant. During exponential growth, the team is in a turbulent state and the amount of indirect work needed to complete the project dwarfs the amount of initial work required. Managers clearly want to minimize the amount of costly indirect work, and want to keep their projects out of the turbulent region. For example, an increase in error probability from 0.1 to 0.15 would cost about 20 days of indirect work, while an increase in error probability from 0.2 to 0.25 would cost about 250 days of indirect work and cause absolute project failure.

Figure 3 uses the same Baseline Scenario as Figure 2, but the data points graphed are in increments of an increase in error probability of 0.01 and it is plotted on a logarithmic scale to more clearly show the definition between the laminar, transition, and turbulent regions. The organizational Reynolds number occurs at the point on the logarithmic graph at which the change in slope is greatest, circled on Figure 3. The experiment was repeated with rework links per task of 1, 3, and 4,

and the error rate at which the slope discontinuity occurred in each scenario was determined. As the rework link ratio increased, the error probability at which the discontinuity occurred decreased, and the slope of the turbulent region became steeper.

The centralization level of an organization determines at which level in the hierarchy most decisions are made. In a highly centralized structure, more decisions are made by management, who tend to demand higher quality and order more rework than subordinates. A team with a low level of centralization tends to make decisions at the team level, requiring less communication, although subordinates have the tendency to ignore errors rather than taking the time to fix them.

We ran experiments with low and high centralization in SimVision. Low centralization increases the capacity of the team to operate under stressful situations by extending the turbulent region to a higher error rate; however, there is no transition period before the turbulent region begins and the exponential increase is greater than with medium centralization. The high centralization scenarios do not exhibit turbulent behavior because errors are controlled by management requiring rework, although they do require additional indirect work in the laminar region.

The goal of these experiments was to find an organizational Reynolds number (OR_N) that would predict the "edge of chaos"– the point at which information flow turns turbulent. By analyzing data from the eight scenarios that exhibited turbulent behavior, we found the following equation:

$$OR_N = \mu/C + 0.25 * Log(D) = 0.25$$

μ: error rate, C: centralization factor (medium=1, low=1.2), D: rework links per task

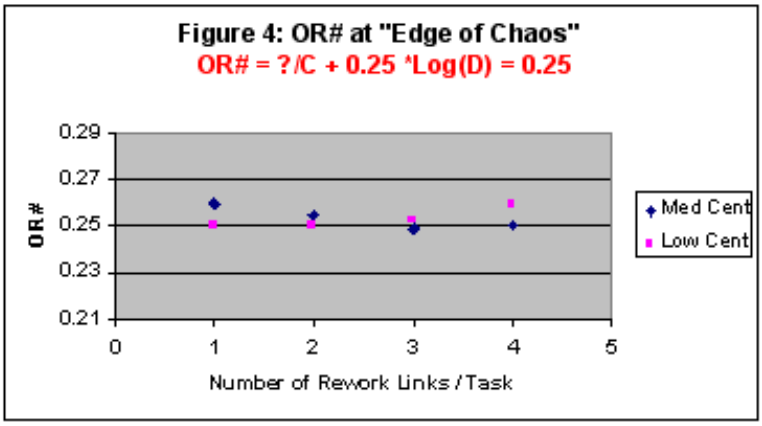
The computed OR_N at the edge of chaos for each of the eight scenarios occurs within 5% of the value 0.25. This suggests that as the OR_N for an organization approaches 0.25, it is at risk of failure, and a value above 0.25 signals that turbulent information flow is imminent.

Conclusion

The managerial implication of an organizational Reynolds number is that it would predict the level of organizational risk for a project given its team characteristics and workflow parameters. Project managers can estimate an OR_N for their organization by creating a work flow diagram to approximate the level of interdependency of the process and by assuming an error rate that is justified by the level of task uncertainty. If the estimated OR_N for a project approaches the turbulent region, management can proactively mitigate the risk by changing project parameters before turbulent behavior occurs.

This research is an initial attempt to quantify the organizational and workforce characteristics that would contribute to the organizational Reynolds number. Using the SimVision simulation environment, we were able to discover an equation that includes the probability of errors in tasks, the degree of task interdependence, and level of centralization that predicts the edge of chaos to occur at an organizational Reynolds number of 0.25. If the estimated OR_N approaches 0.2, a manager should monitor the situation carefully and avoid any changes to the project plan, such as increasing product complexity or shortening the schedule, that would bring the organization closer to the turbulent region. If the OR_N exceeds 0.25, the process parameters should be immediately changed to bring the workflow into the laminar region. Possible interventions could include changing the level of centralization or placing tasks in series to decrease the level of interdependency.

Future research should examine the effect of other organizational and work process variables on the OR_N such as management span of control, availability of slack resources, and skill level of participants. The next step would be to validate the OR_N on actual project models and calibrate it to fit the performance data of real projects.



References

1. Levitt RE, Thomsen J, Christiansen TR., et al. Simulating Project Work Processes and Organizations: Toward a Micro-Contingency Theory of Organizational Design. Management Science 1999; 45:1479-1495.

2. Jin Y, Levitt RE. The Virtual Design Team: A Computational Simulation Model of Project Organizations. Computational & Mathematical Organization Theory 1996; 2:171-196.

3. Galbraith JR. Organizational Design: An Information Processing View. Interfaces 1974; 4:28-36.

References 1 and 2 describe the initial Virtual Design Team simulation engine in great detail. SimVision® is the commercially distributed version developed by Vite Corporation. Go to http://www.vite.com for more information about SimVision®.

Pattern Characterization of Running and Cutting Maneuvers in Relation to Non-contact ACL Injury

Brenna Hearn

During running and cutting maneuvers, the anterior cruciate ligament (ACL) is commonly injured by varsity athletes and recreational players alike. Previous work by Andriacchi and Camarillo named and kinetically defined two main types of cutting: Pattern 1 and Pattern 2. Pattern 1 is characterized by a positive spike in hip abduction moment followed by a maximum force straight through the knee. This is a stable landing as the subject changes direction, with the center of mass directly over the supporting limb. Pattern 2 is defined as any cut lacking the Pattern 1 characteristics. It is less mechanically stable, with the center of mass offset. Pattern determination through this method is based on analysis of motion capture and kinematic data gathered in the lab environment. The purpose of this study was to investigate whether a portable, video-based method could be used to categorize the subject's run and cut patterns instead of needing the lab environment and equipment. A video-based method would make it possible to test a large population of subjects in a short span of time and would allow testing outside the 'lab environment'– on the field or in the courts.

"The purpose of this project is to determine if a video-based method of determining run-to-cut style type is as accurate as the pattern determined through the kinetic method."

Non-contact anterior cruciate ligament (ACL) injuries are common among both elite and recreational athletes. Research shows that such non-contact knee ligament injuries typically involve sudden changes in direction while the body is either accelerating or decelerating.[2,3] This sort of motion, performed when a player sidesteps to change direction quickly, is referred to as a 'cut.' Thor Besier of the University of Western Australia recently completed two studies on the external loading of the knee joint during running and cutting maneuvers, which show that cutting while running puts the knee joint at higher risk of injury due to the heightened internal/external rotation forces perpendicular to

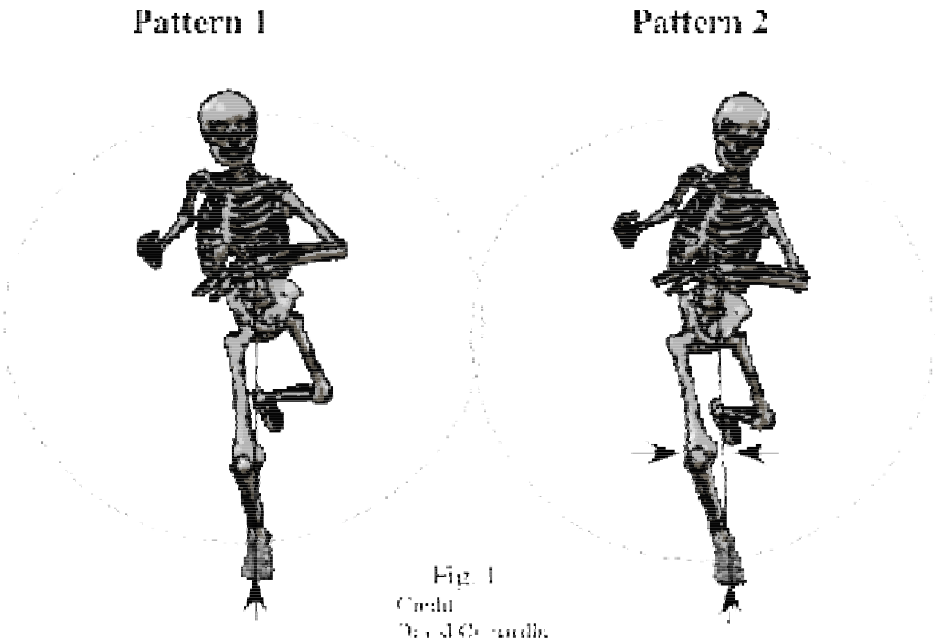


Fig. 1
Credit

Figure 4: Pattern 1 ankle-to-knee and ankle-to-center-of-mass vectors. They are aligned. (Maltese 2001)

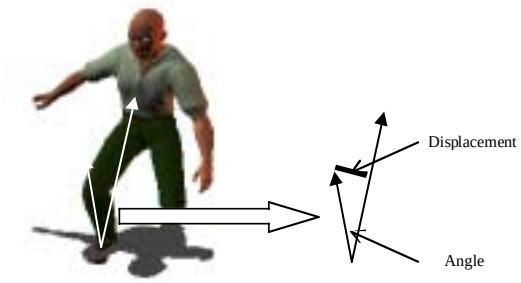


Figure 5: Pattern 1 ankle-to-knee and ankle-to-center-of-mass vectors. Notice they are not aligned. (Maltese 2001)

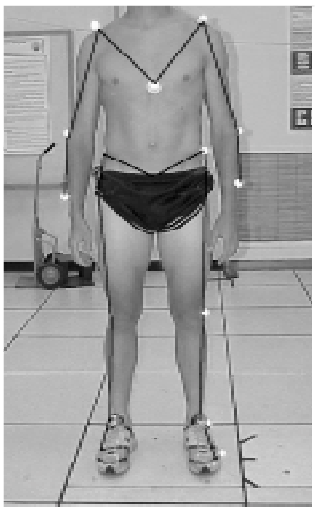


Fig. 2. Full Body Marker Set Link Model

cutting movement.[4] These rotational forces perpendicular to the knee are known as 'moments.' Besier also suggests that loads experienced at the knee joint could also be related to the position of the foot with respect to the body's center of mass, as his study indicates the lean of the upper body leaned affected the stress of outward rotation at the knee.[4] Recent work by Professor Thomas Andriacchi's Biomotion Research Lab at Stanford University supports Besier's findings concerning the relation of the moment at the knee to the location of the body's center of mass.[5]

In the work of both Andriacchi and Besier, a three-dimensional motion capture system and force plate were used to quantify forces and moments of subjects as a function of the location of their center of mass during run-and-cut maneuvers. This method of data collection, using the link model and the force plate, will be referred to as the kinetic method. The kinetic method allows cutting maneuvers to be biomechanically classified as one of two types: Pattern 1 and Pattern 2 (Fig 1). In a Pattern 1 cut, the center of mass remains along the tibial axis during the change in direction, while in Pattern 2 the center of mass is offset from the supporting limb. Pattern 2 cutting is expected to increase the possibility of knee buckling at landing.[5]

Andriacchi's study also compared the patterns of cutting by gender - 9 out of 10 male subjects exhibited Pattern 1 cutting, while 5 out of 9 female subjects demonstrated the more dangerous Pattern 2 cutting. This may indicate that women are more likely to cut in the less stable way. Interestingly, women are more than twice as likely to injure their ACL than men, and during military training, the odds of injury for women increase to 9.74 times the relative male injury risk.[1] The high difference in ACL injury rate has been attributed to differences in male/female hip width, hormonal affects on ligament properties, increased joint laxity, and many other causes. Seventy percent of women's ACL tears are non-contact injuries, leading to the conclusion that perhaps the risk of ACL injury will decrease in women if they can be taught the Pattern 1 cutting style. Before acting toward this conclusion, however, the human factors that cause differences between the cutting patterns should be determined by examining the general population's overall incidence of Pattern 2 cutting. The kinetic method is, however, not an optimal method of data collection due to its time-consuming nature and equipment-intensive methodology. In order to determine a subject's cutting style more quickly, Jim Maltese has experimented with a visual method of categorizing cutting styles that examines direction and placement of the tibia in relation to the placement of the center of mass *(Maltese, J., unpublished project report, 2001)*. Using conventional digital video technology, Maltese videotaped subjects performing cutting maneuvers and evaluated their motion frame-by-frame to categorize their pattern of cutting. If this video-based method is as accurate as the kinetic method, efficiency of testing subjects will increase greatly.

Purpose

The purpose of this project is to determine if a video-based method of determining run-to-cut style type is as accurate as the pattern determined through the kinetic method.

Methods and Materials

The kinetic and video-based methods were used simultaneously to evaluate the run-to-cut motion of the

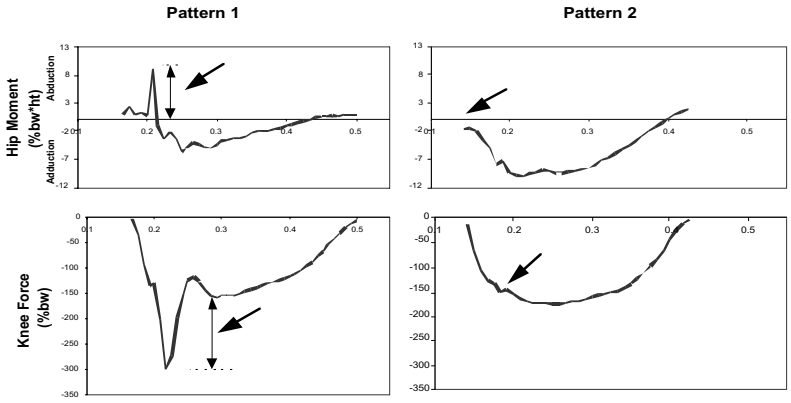


Fig. 6: Characteristic Moment and Force Curves
Credit: David Camarillo

subjects. The kinetic data collection method used a three-dimensional optoelectronic system for motion capture and a multi-component force plate to register the corresponding ground reaction force. Reflective markers were placed at 16 bony landmarks on each subject to allow full body tracking (Fig 2). Intersegmental forces and moments at the joints were then calculated using kinematics and kinetics as done in the Andriacchi - Camarillo project.[6]

After reflective markers were placed on the upper body and one leg of the subject, subjects followed verbal instructions from test personnel to begin from a black tapeline, 12 feet away from the plate, and run at a steady speed until they reached the force plate. With the foot planted squarely in the center of the plate, the subject was asked to perform a 90-degree side-step cut. This is a cut perpendicular to the direction of progression and away from the planted foot. This procedure was then repeated for the other leg.

For the video-based collection method, a digital video camera was set up such that the subject's frontal plane would be captured during the run-and-cut maneuver (Fig. 3). The camera was placed approximately 15 feet away from the subject at the point of cutting. After data collection, the tapes were viewed at normal and reduced speeds. In accordance with Jim Maltese's method, each lateral cut was first qualitatively categorized visually by watching the motion of the subject at normal speed (Fig. 4; *unpublished project report, 2001*). A second categorization was also made at a slow-motion playback, consisting of a quantifying displacement measurement was made using frame-by-frame pictures of the subject's deceleration (Fig 5). Both methods of categorizing based on video-based collection data are examined for their accuracy.

All data from the video-based method was analyzed before the kinetic analysis. This allowed for a blind comparison of pattern characterization based on video images alone before definite conclusions were drawn from the kinetic data.

The kinetic data was analyzed according to the process described by Andriacchi and Camarillo.[5] Analysis focused on the lower limb intersegmental forces and moments during the landing phase. All forces and moments were normalized by body weight and height. Forces were expressed as a percentage of body weight, and moments as a percentage of the product of body weight and height.

Andriacchi and Camarillo identified two patterns of limb loading during the landing phase of the run-to-cut maneuver. Pattern 1 was defined as having a hip abduction moment spike in the landing phase immediately followed by the absolute maximum component of the inter-segmental axial force vector at the knee (along the axis of the tibia; Fig. 6). Pattern 2 was defined by the absence of the two Pattern 1 characteristics, i.e., not having the combined hip abduction moment and peak knee force in the landing phase (Fig 6). The intersegmental forces at the knee and moments at the hip were evaluated for each trial of each subject. The subjects were then categorized according to the above Pattern 1 and Pattern 2 definitions

To evaluate the video-based system, two female subjects (avg. age 21, height 73 inches, and weight 181) and five males subjects (avg. age 24, height 71.6 inches, and weight 179.1 lbs) volunteered for this study and were tested during walking, slow walking, fast walking, run, run to stop, and run-to-cut maneuvers following normal consent procedures†. All subjects were free of musculoskeletal diseases or injuries that would influence function. Data collection took two hours per test in the Stanford Biomotion Laboratory.

Both described procedures, kinetic and video-based, were used simultaneously to categorize the cutting pattern of each subject. The results from the two methods were then compared.

Results

For the seven subjects, 36 total trials were collected for data comparison (both video and kinetic data were recorded for the same run-to-cut maneuver). Of the 36 trials, 14 were characterized correctly using the quantitative displacement measurement and 28 were characterized correctly with the qualitative visual method (Table 1). Statistical sensitivity, specificity, and odds ratios were also calculated for the visual characterization and displacement-measurement data

Video-Based Characterization Method	# of Total Trials	# of Matches with	% Matching
Visual	36	28	78%
Displacement	36	14	39%

Table 1: Pattern Characterization

Video-Based Characterization Method	Sensitivity (Matching Pattern 2) (Kinetic Pattern 2)	Specificity (Matching Pattern 1) (Kinetic Pattern 1)	Odds Ratio
Visual	0.5556	0.8519	7.1875
Displacement	0.3333	0.4000	0.3333

Table 2: Statistical Analysis

sets (Table 2). The qualitative visual categorization method was shown to be most sensitive, most specific, and have the best odds.

The maximum displacement measurements for each trial were also analyzed against their corresponding kinetically determined patterns to see if there was any distinguishable trend. For example, though the negative displacement does not always indicate a Pattern 2 cut, there may be points where the cutting characterization could be made. Though between a peak displacement of (-0.10) and (+0.10) the data sets seems overlap, it is possible that any maximum displacement less than (-0.15) is always a Pattern 2. This possibility was investigated by graphing the maximum displacement measurement for each trial against the corresponding kinetic characterization (see Figure 3). As can be observed, however, there was no distinguishable correlation.

Discussion

Both video-based methods' results were not consistent with the results of the kinetic method. Comparison and statistical analysis show the qualitative visual categorization method to be more successful than the categorizations based on the quantitative displacement measurements. Categorization based on displacement vector was accurate only 39% of the time, while 78% of the time the visual categorization based on the digital video did match the kinetic method categorization.

Though none of the Sensitivity, Specificity, and Odds Ratio analysis was especially encouraging for either video-based method, the tests results may not be representative of our success, due to the small data set. However, even with this small data set, the Specificity rating and Odds Ratio for the visual method were considerably higher than for the displacement method. This, along with the comparative percentages of correct characterizations, indicates general promise for the video-based, visual categorization method as well as direction for further development.

An interesting observation was made in that many cutting trials declared Pattern 2 based on visual data but kinetically determined to be Pattern 1 were also noted to have the subject's arm raised in the opposite direction of the cut. This arm position could change the location of the subject's center of mass, so although the body is out to the side of the knee, the extended arm may keep the center of mass directly over the knee and foot in a more stable position (Fig. 7). Future research may develop this idea and may also reveal a link between freedom of motion of the arm in a sport and the incidence of ACL injuries, which are more common among basketball and volleyball players than among soccer players. In these sports players' arms are tied up in the game and not free to be used for balance or aligning their center of mass over the leg as they cut.

Collecting more data will clarify these issues as well as facilitate the development of a successful video-based, visual characterization method. Other factors affecting pattern type, including knee flexion, hip flexion, and upper-body posture, could be examined in order to find further identifiers for characterizing run-and-cut maneuvers. A second video camera could be added in order to record the subject's motion from a side view. Both lateral and frontal planes would then be observed during each trial, allowing the knee

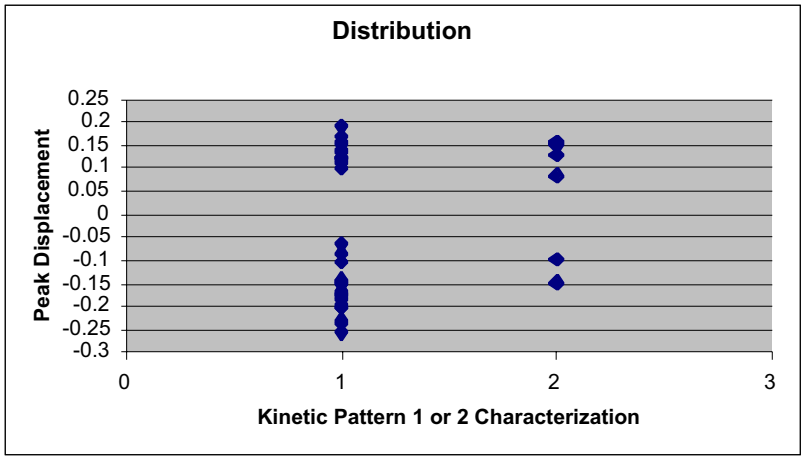


Fig. 3 Unitless Displacement of the knee versus time per cutting style

Fig. 7 Cut with Extended Arm

flexion angle to be seen more clearly.

Though the full body marker set was used to track the motion of the subject's torso, arms, and legs, the data collected on the upper body has not yet been analyzed. A larger link model needs to be developed first. The location of the center of mass could then be tracked more accurately throughout the run-and-cut maneuver. A dynamic model would allow the mass and motion of the subject's arms to be taken into account when estimating the location of the center of mass and would perhaps bring out additional, useful criteria for the video-based pattern categorization.

The results of this study indicate promise in developing a video-based, visual method for characterizing running and cutting patterns. In addition, observing videotapes of the testing allows additional details to be gathered concerning the subjects' motion during test runs. These observations point toward new avenues for development of a visual method - including arm position and lateral videotaping. The importance of arm placement for stability when cutting and the importance of consistent cutting patterns within individuals are additional directions for investigation. These topics could be investigated more easily once an accurate video-based method is completed. Large populations could then be tested using only one or two digital cameras. Data collection with the digital camera, video-based method is more efficient than the kinetic method, as digital cameras are relatively inexpensive and quite portable. A visual method of categorization would require relatively little testing time, as opposed to the hours necessary for the specialized motion capture and force plate system of the kinetic method. Using a video-based method, future research could quickly and easily determine trends across large populations and even conduct longitudinal studies in training and injury prevention, characterizing athletes at the beginning of the summer and checking on them throughout their training. For those who suffer non-contact ACL injuries, the results of this study and potential for future non-contact ACL injury biomechanics research are promising enough to warrant further work towards an accurate video-based approach to running and cutting pattern characterization.

References and Notes

[†]Three of the male subjects were players on Stanford's Varsity Men's Soccer Team, one was the Varsity Men's Soccer Assistant Coach, and the final male subject was an average 28 year old. The two female subjects were players on Stanford's Varsity Women's Basketball Team.

1. Gwinn, D., Wilckens, J., McDevitt E. et al. Relative incidence of anterior cruciate ligament injury in men and women at the United States Naval Academy. Am J Sports Med 200l, 28:98-102.
2. Ryder, S.H., R.J. Johnson, B.D. Beynnon et al. Prevention of ACL Injuries. J Sports Rehabilitation 1997, 6:80-96.
3. Colby, S., Francisco, A., Yu B. et al. Electromyographic and kinematic analysis of cutting maneuvers: implications for anterior cruciate ligament injury. Am J Sports Med 2000, 28:234-240.
4. Besier, T. F., D.G. Lloyd, J.L. Cochrane et al. External loading of the knee joint during running and cutting maneuvers. Med Sci Sports Exerc 2001, June: 1169-1175.
5. Andriacchi, T. Camarillo, D., Alexander E. et al. Gender Differences in the Biomechanics of Running and Cutting Maneuvers Relative to Non-Contact ACL Injury. Orth Res S 2001, Feb:25-28.
6. Andriacchi, T.P., Birac, D. Functional testing in the anterior cruciate ligament-deficient knee. Clin Orthop 1993, 288:40-47.

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Perceptions of Ranavalona I: A Malagasy Historic Figure as a Thematic Symbol of Malagasy Attitudes Toward History

Alison Kamhi

Ranavalona I was a nineteenth century Malagasy queen whom textbooks almost unanimously portray as a barbaric and xenophobic tyrant for refusing to cooperate with European rulers. Since the majority of Malagasy history texts are written by French, British, or American authors—and not by Malagasy ones—I traveled to Antananarivo, Madagascar to interview inhabitants about their own perceptions of the famous queen. My hypothesis was that Malagasy views of Ranavalona would be more positive. After speaking with around fifty Malagasy citizens, professors, pastors, and lower government officials, I found that many Malagasy do indeed laud Ranavalona I as patriotic and heroic for fighting European attempts at control of the island; many Malagasy, however, use these same struggles between the queen and the Europeans to condemn her as anti-progressive and anti-Christian. Even one hundred and fifty years after her death, Ranavalona's legacy remains extremely complicated because Malagasy sentiment of her place in history largely depends on citizens' perceptions of Malagasy religion, ethnic group conflicts, and Malagasy history as a whole.

"...Ranavalona survives today not only as a historical figure, but also as a current political influence."

Though one hundred and fifty years have passed since Ranavalona I, of the dominant Merina ethnic group, ruled in Madagascar, the controversy surrounding her reign continues in the present day capital of Antananarivo. During her reign, Ranavalona reversed several of the policies of her late husband, the previous king, who had hastily westernized the island and welcomed European settlers. Diplomatically, her intentions were clear: she prohibited the renewal of the visas her husband had eagerly issued to foreign missionaries and tradesmen. Domestically, she was more ruthless, ordering the deaths of Malagasy citizens who refused to relinquish their newly acquired Western Christianity. In the nineteenth century, Ranavalona's efforts were unsuccessful; after her death, Madagascar was taken over culturally and politically by Europe. However, as the political chaos over the Madagascar's elections in 2001 demonstrates, her rejection of European influence is still a controversial topic today. Two men, each claiming to be president, one adhering to the status quo of French influence, the other advocating true independence for Madagascar, represent the rupture in Malagasy society that Ranavalona instigated. As the first to perceive the threat of European control, Ranavalona survives today not only as a historical figure, but also as a current political influence. In light of the controversies still surrounding Malagasy Christianity, past colonization, and present nationalism, how do contemporary Malagasy citizens view Ranavalona I?

Western historical perspectives of Ranavalona tend to portray her in an understandably negative light for obstructing "undeveloped" Madagascar's entry into capitalistic, Christian, and Western civilization.[1] A Malagasy historian recently noted this unilateral European condemnation of the queen: "Foreign historians . . . could not forgive her for breaking with Europe."[2] The French historian La Devève refers to the queen as "Ranavalona la Sanguinaire" ("Ranavalona the Bloody").[3] As the last significant Malagasy ruler before French colonial conquest, Ranavalona, in the eyes of many European historians, embodies the final bulwark against the spread of European "enlightened" culture in

Madagascar.

Ranavalona is remembered in Madagascar, however, in more complex ways. Her reign marks the transition among a myriad of different historical movements: the emergence of indigenized Christianity, domestic anti-European purges—in essence, the culmination of eighteen different ethnic groups attempting to preserve its cultures against an increasingly imposing West. The cultural divisions created by differing peoples and a succession of differing governments may very well contribute to these multiple interpretations of Ranavalona that exist in Antananarivo. As of the elections on December 16, 2001, Malagasy citizens are sharply divided in their support of a president who promises to lead them into true independence from France, in efforts vaguely reminiscent of Ranavalona. The reactions of modern day Antananarivo citizens to Ranavalona and politicians who evoke her legacy prove that her role now in Malagasy political heritage is just as vibrant as her role in nineteenth century reality.

Study Design

In July 2001, with support from a President's Scholar Grant, I traveled to Madagascar to investigate Ranavalona's legacy by examining how she is portrayed in textbooks, documents, and personal accounts. My goal was to compare historical records of the queen with forty contemporary inhabitants' perceptions of her controversial rejection of European culture in an attempt to delineate how contemporary Malagasy views of Ranavalona correlate with national identity. The interviews consisted of a series of questions covering factual knowledge of the queen and personal perceptions of her. My interviewees were all Antananarivo residents, although several of the them had provincial backgrounds and only lived in the capital for education or work purposes. My subjects ranged an age span of 40 years and an educational background span of anywhere from no schooling to doctorate degrees. Even though I completed my interviews six months before the presidential elections, I was able to sense much political divisiveness. I had expected to find that while Western history portrays Ranavalona as a negative force in Madagascar's development as a modern country, local perceptions would paint Ranavalona as a hero who attempted to withstand European intrusion.

Findings

Contrary to my hypothesis, over half of my subjects expressed a negative opinion of the queen. However, my interviews revealed that Ranavalona continues to fascinate contemporary residents and influence current politics, transcending expectations for the influence of a woman who lived 150 years in the past. Even those subjects who strongly disagreed with her politics admitted a begrudging acknowledgment of her strength as a ruler.

Ranavalona "le Diable Incarné": Negative Views of Ranavalona

Though several other members of nineteenth-century Malagasy royalty have their names enshrined by landmarks, streets, or even occasionally as first names of current-day residents, no street is called "Ranavalona," and subjects laughed when I asked if they knew a person with the same name as the infamous queen. Her name is often employed as an insult, a derogatory term used for demanding women or strict mothers.[4] One subject even recognized Ranavalona's name as an insult before he remembered her exact place in Malagasy history.

The negative responses among the subjects were frequently marked with vehemence laden with Christian overtones: "She was the devil incarnate."[5] Many responses were based on Ranavalona's infamous executions against her political enemies: "You just can't kill people like that."[6] Disapproval stemmed most strongly from her anti-Christian bias. When asked why he thought Ranavalona was cruel, one subject replied, "I'm not in agreement with any of her actions because they were all against Christianity."[7] Another subject simplified Ranavalona's persona: "It's obvious she was a bad queen—she didn't believe in God!"[8] Most of the subjects' knowledge of the queen was limited to her "paganism" and her violent purges directed against Christianity.

A significant number of subjects blamed their mostly negative impressions of the queen on European educational influences and Malagasy lack of interest in local history. According to my interviewees, during the time of French colonization, school curricula in Antananarivo were limited to European history. Some Malagasy subjects in this study had not been taught their country's history at all and claimed that they could list the sovereigns of Madagascar's colonizers, the French, more easily than they could the rulers of their own country.[9] If present at all, the few facts taught about Malagasy history usually did not include Ranavalona; when she was mentioned, it was only to emphasize her savagery toward Europeans. Many subjects of all ages recounted memories of primary school teachers portraying Ranavalona as a cruel dictator.

Ranavalona the Defender of the Malagasy: Her Position Against European Powers

Subjects were divided on their opinions of Ranavalona's policies

toward the French colonialists. Thirty-eight percent of my interview subjects lauded the Queen for her endeavors to ward off European influence. These subjects tended to see Ranavalona as a strong and insightful ruler who protected Malagasy culture as much as she could before European takeover. Forty-seven percent of the subjects condemned her anti-European actions, however, blaming her instead for obstructing progress. They even attributed current Malagasy technological lags to her nineteenth century intolerance of European immigrants, who might have brought more scientific knowledge to the island. Seventeen percent of subjects actually held Ranavalona responsible for much of the misery of colonization, claiming that her hostility toward foreigners provoked vengeance and the colonizers' subsequent cruelty toward the Malagasy. Others denounced her actions as attempts to stall the inevitable. One subject stated bluntly, "In my opinion, she didn't help anything. Colonialism wasn't a thing to be stopped."[10] These subjects' disagreements about Ranavalona reflect the continuing controversy over colonization today.

Ranavalona the "Xénophobe": Her Influence on Modern Nationalism

In my study, views on nationalism corresponded with perceptions of Ranavalona. Those citizens who expressed an appreciation for European culture and who recognized Malagasy dependence on Europe were harsh in their evaluations of Ranavalona, echoing the portrayals most Western historical texts create of the queen. They saw her expulsion of European peoples and ideas as a rejection of proffered relations with the outside world. One subject considered Ranavalona a "xénophobe" and criticized her isolationist policies because "foreigners bring civilization."[11] Another subject stated the Malagasy need for foreigners even more simply, summarizing the relationship: "There is no development in Madagascar if there are no Europeans in Madagascar."[12] These negative opinions of the queen reflect local perception that the island is inevitably economically dependent on other countries. Subjects who felt this way obviously disapproved of the xenophobic queen.

On the other hand, subjects who demonstrated a strong pride in Malagasy culture expressed admiration for the queen. One subject, who promoted the memory of Malagasy history ("We should be proud; we should not forget"), also advocated a reappraisal of Ranavalona: "She was the smartest and most powerful ruler, and we should all learn from her."[13] For these patriots, Ranavalona represents a legendary ideal to imitate and admire.

Conclusion

My research in Madagascar points to strong—though often conflicting—feelings about a queen who represented the turning point for the island, especially the Merina tribe, as it entered what Western civilization deems the modern era. Even though the conventional Western perception of Ranavalona's negative influence on her country dominates Malagasy historical views, a strong undercurrent of admiration perseveres. This is evident in the significant number of subjects who approved of her extreme devotion to Malagasy, especially Merina, tradition. In fact, as the research suggests, Malagasy views of Ranavalona in the historical past are inevitably linked to Malagasy religion, colonialism, and nationalism.

Recently a campaign has been launched to change Ranavalona's negative image through informational segments on television and radio. These bulletins give alternative reasons as to why Ranavalona persecuted Christians and expelled the Europeans, explaining that she suspected a European desire for control and believed that Madagascar needed to develop internally before it could expand externally.[14] This conscious redirection of the nineteenth-century queen's legacy in the present capital attempts to restore—or rewrite—the history of an anti-European and anti-Christian royal figure in the context of a Francophone Catholic nation. Whereas the queen battled European military and missionary forces during her lifetime, her legend still struggles for a respectable place in history against European ideological forces. Her very existence as "the most contested sovereign in Malagasy history" reflects the unresolved conflicts she sparked against Western culture, which still engulf the nation today.[15] In this way, her legend serves as both as the memory of a powerful queen and as the naissance of an acknowledged opposition between European and Malagasy cultures. Antananarivo citizens might never agree on Ranavalona's historical influence, but very few of those same citizens would protest that the controversy over her legacy is not representative of the divided ethnic, religious, and nationalistic positions on Malagasy history. In this sense, she is more symbolic of the Malagasy people now, as a legend, than she was as a nineteenth-century queen. As events unfold in recent months, Ranavalona's views become even more crucial to Malagasy self-identity; her determination for a true Malagasy independence is being reenacted on the current political scene, while further studies will determine whether her legacy is being molded yet again to serve the nation's purposes.

Works Cited

[1]Allen PM. *Madagascar: Conflicts of Authority in the Great Island*. Boulder: Westview Press, 1995: 18-22.
Ayache S. *Omaly Sy Anio*. Antananarivo: Revue d'Etudes Historiques, 1975: No. 1-2.
Brown M. *Madagascar Rediscovered: A History from Early Times to Independence*. Hamden: Archa Books, 1979: 165-222
De La Devèze le P. *Aux Prises avec Ranavalona la Sanguinaire.* Paris: Bloud and Gay, 1936: 188 p.
Prou M. *Le Royaume de Madagascar au XIXe siècle.* Paris: l'Harmatten, 1987: 67-161
[2] Translated from the Malagasy by Mami Razifikoto. July 13, 2001.
Ayache S. *Omaly Sy Anio* (Yesterday and Today). Antananarivo: Revue d'Etudes Historiques, 1975: No. 1-2.
[3]De La Devèze le P. *Aux Prises avec Ranavalona la Sanguinaire*. Paris: Bloud and Gay, 1936: 188 p.
[4] Interview # 12 July 7, # 13 July 7, # 19 July 9, 2001.
[5] Interview # 27, July 18, 2001. Original in French: "C'était le diable incarné."
[6] Interview # 19, July 9, 2001
[7] Interview # 20, July 9, 2001
[8] Interview # 18, July 9, 2001
[9] Interview # 8, July 7, 2001
[10] Interview # 22, July 12, 2001
[11] Interview # 2, July 6, 2001
[12] Interview # 10, July 6, 2001
[13] Interview #24, July 12, 2001
[14] Interview # 14, July 8, # 15, July 8, # 19, July 9, # 22, July 12, # 23, July 12, # 25, July 13, # 26, July 16, # 27, July 16, 2001, and Interview with Marc Rakoto, Malagasy Minister and Christian Film Director, July 10, 2001
[15] Ayache S. *Omaly Sy Anio*. Antananarivo: Revue d'Etudes Historiques, 1975: No. 1-2.

Suggested Reading

Allen PM. *Madagascar: Conflicts of Authority in the Great Island*. Boulder: Westview Press, 1995.

Brown M. *History of Madagascar: A History from Early Times to Independence.* Hamden: Archan Books, 1979.

Gow BA. *Madagascar and the Protestant Impact*. New York: Holmes and Meier, 1980.

Kent RK. *Madagascar in History: Essays from the 1970's*. Berkeley: Typesetting and Publishing House, 1979.

Prou M. *Le Royaume de Madagascar au XIXe siècle*. Paris: l'Harmatten, 1987.

Raison-Jourde F.'*Le Bible et le Pouvoir à Madagascar au XIXe siècle: Invention d'une Identité Chrétienne et Construction de l'Etat, 1780 - 1880*. Paris: Karthala, 1991.

Manifestations of Overt and Covert Aggression in Women with Bulimia Nervosa

Ashwini Sagar

This study examined the prevalence of covert and overt aggression in women with bulimia nervosa and determined whether manifestations of these behaviors were linked to an individual's unhealthy relationship with food, body, and exercise. A sample population of 40 women (ages 18-23) completed written questionnaires and verbal assessments regarding their relationships with food, body image, and self-esteem. Results indicate that bulimic women display significantly more aggressive behaviors than non-bulimic women. In written accounts about their behavior, bulimic women's descriptions of aggression are often closely linked to their eating disorder. Recognizing aggression in women with this disorder can be of clinical significance, because aggression has not been established a hallmark of bulimia. Future studies should examine whether there is a causal relationship between aggression and bulimia or whether there are other interactions that lead to this prevalence.

"A link between eating disturbances and aggression is shown in an empirical study about increased irritability in those who restrict calories."

Clinical literature shows a strong association between bulimia and impulsivity, with individuals showing considerable problems with impulse control.[1,2] Although increased levels of novelty-seeking and low degrees of frustration tolerance have been well studied in the bulimic temperament,[3,4] not as much attention has been devoted to the relationship between bulimia and aggressive behavior. A link between eating disturbances and aggression is shown in an empirical study regarding increased irritability in those who restrict calories.[5] Also, rats are more prone to fight competitively when food restrictions are imposed upon them.[6] In humans, a significant association between eating disturbances and aggressive conduct in adolescent girls has been shown.[7] Such studies, taken together, suggest a strong link between aggression and bulimia.

For clinical purposes, animal research has resulted in several different classifications for aggression: territorial, maternal, intermale, irritable, fear-induced, and instrumental.[8] These can further be labeled as either "covert" or "overt" subtypes. My research study focuses on women with bulimia nervosa, and their behavioral manifestations of these two aggressive subtypes. I work with the definition of overt aggression as involving confrontational and often affectively charged and poorly controlled behavior. This includes acts such as hitting, violent conflict resolution, and assault. The other category is covert aggression, which is non-confrontational and involves acts such as stealing and other surreptitious behavior. Bulimic women not only feel a loss of control when it comes to their eating habits, but they often struggle with interpersonal relationships, rules, and regulations. Bingeing and purging is one mechanism used by these women to regulate their emotions and cope with stress. One might expect, then, that aggression would be yet another outlet for their frustrations and struggles.

This study hypothesized that bulimic women are more likely to display covert as well as overt aggression in comparison to women without eating disorders. Bulimic female subjects, as well as non-bulimic female controls, were asked to complete a structured set of questions describing their most recent aggressive behaviors, binge/purge episodes, and other activities. The research does not claim that aggression leads to bulimia or that the disorder fos-

ters aggressive behavior. Causal relationships can only be identified once the prevalence of a certain personality trait is established, and it is this prevalence that I hope to demonstrate.

Participants consisted of 40 women, aged 18-23, who responded to flyers and emails advertising the study. Recruiting was done at Stanford University, Menlo College, Foothill College, Canada College, and Santa Clara University. Separate flyers were used for recruiting bulimic women (n=20) and women without eating disorders (n=20). All participants received $20 compensation for 1 hour of their time, and individual sessions were conducted in the Psychiatry building at Stanford Medical Center. Excluded from the study were females who were currently anorexic or who were not currently enrolled in school. Individuals with co-morbidity for other psychiatric problems, such as depression, were allowed in the study. Within a given population of bulimic women, co-morbidity with other illnesses is common, and exclusion of such individuals would not provide representative results. There were 3 international bulimic women (Estonia, Malaysia, and China) and one international control participant (Egypt). A $3000 Undergraduate Research Opportunity grant from Stanford University was used to cover costs of compensation and publicity.

After approval from Stanford University's Human Subjects Committee, flyers and emails were posted on college campuses, as well as local gyms, restaurants, counseling centers and sororities. During the 1-hour interview session, a consent form was read out loud to all women, notifying them of risks associated with this study, as some subjects might feel discomfort when recalling personal information from their past. They were allowed to leave the study at any time, or they could refrain from answering any questions participants enjoyed describing emotional events in their lives, and it may have had some benefit for them. The act of constructing a narrative can often help individuals better understand their experiences by making complex issues more simple and understandable.

The following is a list of common psychiatric assessments, listed in order of use during individual interviews. Three written questionnaires, one oral assessment and one free-write method composed each session. The JWHS and EDE are well-reviewed tools developed by Stanford's Department of Psychiatry and Behavioral Sciences. All of the published assessments have been repeatedly tested for validity and have been used in their most current versions:

Juvenile Wellness & Health Survey[11] (JWHS-76): 19 questions from this assessment were asked that focused on recent alcohol use, drug abuse, exercise routines, relationship behavior, sexual activity and menstrual patterns.

Modified Aggressive Acts Questionnaire (MAAQ, Sagar A. Unpublished 2002): This questionnaire has five separate categories of overt and covert aggression including specific behaviors, thoughts and acts. Subjects were asked to mark any acts that occurred in the past 4 weeks, and also to identify whom the behavior was directed towards in the case of overt aggression. Self-injurious behaviors were also noted. Acts on the MAAQ are weighted according to their level of aggression, and a separate score is provided for overt acts and overt acts from resultant data.

Aggressive Acts Questionnaire[12] (AAQ): Subjects were asked to identify their most aggressive overt act and their most aggressive covert act that they listed on the MAAQ. Then, this assessment identifies the acts as it relates to premeditated, impulsive, mood-based and agitated aggression. The AAQ asks participants to rate the act on a 5-point scale of Definitely No to Definitely Yes. The act can then scored as to its level of aggression, and it can be placed into the four aforementioned categories.

Eating Disorder Examination[13] (EDE): This oral interview involves the researcher and subject working together to obtain an accurate picture of the subject's eating behaviors and attitudes. Thirty-three questions from the EDE are administered during this study. Questions regarding restrictive behavior, exercise, obsessive thoughts about food, bingeing, purging, laxative use, and body satisfaction are asked. Investigators scale answers between 0 (healthy behavior) and 6 (extremely unhealthy behavior).

Pennebaker Method[14]: At the end of the session, subjects are first asked to free-write for a period of 4 minutes about the overt act of aggression, and then they are asked to free-write about the covert aggressive act for 4 minutes. The Pennebaker method states that in their writing, subjects should really let go and explore their very deepest emotions and thoughts, writing about the same experience the entire time. Ideally, they will also write about significant experiences or conflicts that they have not discussed in great detail with others.

Of the bulimic subjects, 18 women employed self-induced vomiting as their form of purging. Two women used intense exercising alone as a method of purging after binges. The EDE conducted on bulimic women indicates a range of 1 bulimic episode per week to 5 bulimic episodes a day, everyday of the month. Some experimental women did not use laxatives at all as a method of purging, although 15% of them used 1 to 6 laxatives a day in addition to vomiting. Only three females used diuretics.

A t-test performed on results from the MAAQ and AAQ indicated that the bulimic women in this study scored significantly higher on the scales of aggression than non-bulimic women did.

Overall, bulimic women scored higher for displays of and levels of aggression, with statistical significance in all four categories when compared to the control population. As expected, bulimic women also scored higher on the assessment of the EDE. One control participant's data was removed from the pool because scoring on the EDE revealed that she had recently recovered from anorexia. Bulimic women also scored significantly higher on the JWHS, specifically with regard to alcohol intake.

Qualitative analysis of the Pennebaker free-write indicates that 72.5% of the entries from bulimic women discussing aggressive acts are related to issues of food, body image and exercise. In the control population, 17.5% of the entries related the aggressive behavior to these topics. The most recurring themes for both control and experimental participants during the free-write period included fights with parents, partners, and friends, as well as activities surrounding alcohol.

Many psychological, educational, medical, and forensic studies have focused on aggressive behavior. Rates of impulsive and aggressive behavior, such as suicidal gestures, parasuicidal gestures, extreme alcohol abuse, sexual promiscuity, and shoplifting, are elevated in bulimic individuals.[10] However, aggression itself is not a DSM-IV diagnostic category[9] for bulimia nervosa. If aggressive behavior can be observed as a sign of bulimia or other self-destructive behavior, then medical professionals and psychologists can better diagnose individuals.

The results support the hypothesis that manifestations of overt and covert aggression are more common in women with bulimia. If the aggressive behavior is indeed closely linked to the binge-purge cycles, than future investigations should examine whether reducing levels of aggression can be successful in helping women recover from bulimia. In order to examine this however, longitudinal studies need to be conducted on whether or not a causal relationship does exist between the behavior and the disorder. Also, participants should be diagnosed for co-morbidity of other illnesses in order to see how those factors contribute to the aggressive personality. Additionally, the Pennebaker free-write indicates that, for many bulimic women, aggression is linked to issues of food, body image and exercise. It can be valuable for therapists to acknowledge this connection while helping a patient overcome bulimia. Therapy that focuses on reducing levels of aggression or channeling aggression in healthier ways could

Table 1: Results of the MAAQ & AAQ for Control and Experimental Subjects

	CONTROL *(n=20)*	**BULIMIC** *(n=20)*	**t-value**	**p-value**
MAAQ score for covert acts	**Avg=**7.1 SD=5.95	**Avg=**15.9 SD=8.25	**3.87**	**0.0040**
AAQ scaled rating for most covert act	**Avg=**52.3 SD=8.07	**Avg=**64.05 SD=7.10	**1.96**	**0.0578**
MAAQ score for overt acts	**Avg=**7.95 SD=4.80	**Avg=**16.25 SD=18.36	**4.89**	**0.0001**
AAQ scaled rating for most overt act	**Avg=**53.2 SD=11.01	**Avg=**61.47 SD=7.26	**2.80**	**0.0079**

Table 2: Results of the EDE. A score of 0 indicates extremely health eating habits, the maximum score is a 246 indicating severe bulimic behavior.

	CONTROL *(n=20)*	**BULIMIC** *(n=20)*
	EDE	**EDE**
Avg.	45.65	141.7
SD	14.26	28.1

have a profound impact. Aggressive behavior can be released through self-injurious behavior, bingeing, and other acts listed on the AAQ. However, it can also be released through alcohol, sex, drugs, and exercise. It is important to factor these levels of activity into any analysis. In any study of psychiatric disorders, researchers must rely on self-report methods from participants. The level of willingness of individuals varies, with the shame and frustration of such disorders affecting the collected data.

With regards to overt and covert displays of aggression, one can also hypothesize that different types of treatment are more suitable for reducing levels of aggression based on the subtype. Future studies can be conducted to see if bulimic women displaying more overt aggression are more responsive to pharmacological and psychosocial intervention, whereas those displaying more covert aggression may be better suited for cognitive-behavioral therapy. In treating bulimia, drug therapy has been used more often than cognitive-behavioral approaches, yet drugs have been comparably less effective.[10] Future studies, structured similarly to this one, can hopefully shed light on how different types of aggressive behavior in bulimic women may require different types of therapy, which are based on different etiologies of the disorder. Ultimately, it is clear that bulimic women need to have outlets for their aggressive behavior, and they must be taught alternative methods of coping so that bingeing and purging are no longer the most ideal options in their minds. In addition to further exploration of the bulimic temperament, researchers should conduct more randomized control experiments regarding treatment-based approaches to bulimia nervosa.

Works Cited

1) Norman DK, Herzog DB. Bulimia, anorexia nervosa and anorexia nervosa with bulimia: a comparative analysis of MMPI profiles. *International Journal of Eating Disorders* 1983; 2:43-52.
2) Weiss SR, Ebert MH. Psychological and behavioral characteristics of normal weight bulimics. *Psychosomatic Medicine* 1983;45: 293-303.
3) Brewerton TD, Hand LD, Bishop ER Jr. The Tridimensional Personality Questionnaire in Eating Disorder Patients. *International Journal of Eating Disorders* 1993; 14:213-218.
4) Waller DA, Petty F, hardy BW, Gullion C, Murdock MV, Rush AJ. Tridimensional Personality Questionnaire and serotonin in bulimia nervosa. *Psychiatry Res* 1993; 48:9-15.
5) Keyes A, Brozek J, Hensched A, Mickelsen O, Longstreet PH. *The Biology of Human Starvation*, *Volumes I and II*. Minneapolis: University of Minnesota Press, 1950.
6) Adams DB, Cowan CW, Marshall ME, Stark J. Competitive and territorial fighting: two types of offense in the rat. *Physiological Behavior* 1994; 55:247-254.
7) Thompson, KM et al. The Neglected Link Between Eating Disturbances and Aggressive Behavior in Girls. *Journal of the American Academy of Child and Adolescent Psychiatry* 1990; 38:10.
8) Vitiello, B., & Stoff, DM. Subtypes of Aggression and Their Relevance to Child Psychiatry. *Journal of the American Academy of Child & Adolescent Psychiatry* 1997; 36, 307-315.
9) Mitchell et al., 1985; Pyle et al., 1981; Welch and Fairburn 1994; Wonderlich and Swift, 1990.
10) Steiner, H, Lock, J. Anorexia Nervosa and Bulimia Nervosa in Children and Adolescents: A Review of the Past 10 Years. *Journal of the American Academy of Child and Adolescent Psychiatry* 1998.
11) Steiner H. et al. Juvenile Wellness and Health Survey-76, Version 1.1 in Child Psychiatry & Human Development. 1998
12) Barratt E, The Aggressive Acts Questionnaire. University of Texas-Galveston.
13) Agras, W.S, The Eating Disorder Examination. Stewart Agras MD Publications. 2000.
14) Pennebaker, J., Pennebaker Method. Erlbaum Publishers. 2001.

Suggested Reading

Agras, W.S., & Apple, R. F. Overcoming eating disorders: A cognitive-behavioral treatment for bulimia nervosa and binge eating disorder, Therapist guide. San Antonio, TX: The Psychological Corporation, 1997.

Brown GL, Ebert MH, Goyer PF et al. (1982), Aggression, suicide, and serotonin: relationships to CSF amine metabolites. *American Journal of Psychiatry* 130:741-746.

Levitan RD et al., (1997), Hormonal and subjective responses to intravenous meta-chlorophenylpoperazine in bulimia nervosa. *Archive of General Psychiatry* 54:521-527.

Linnoila M et al., (1983), Low cerebrospinal fluid 5-hydroxyindoleacetic acid concentration differentiates impulsive from nonimpulsive violent behavior. *Life Science* 33:2609-2614.

Rivzi, S. L., Stice E., & Agras, W.S. Natural history of disordered eating attitudes and behaviors over a 6-year period. *International Journal of Eating Disorders* 26: 406-413, 1999.

Stice, E., & Agras, W.S. Subtyping bulimic women along dietary restraint and negative affect dimensions. *Journal of Consulting & Clinical Psychology* 67: 460-469, 1999.

Figures from: *Classical Modern Irreverence:* Michael Jackson and Bubbles_*Recontextualized*

Susan Cameron

[Fig. 1] *Temple of Apollo Epikourios at Bassae, Battle of Lapiths andCentaurs*, ca. 425-420 BCE. (ArtServe, *Classical Art and Architecture*. http://rubens.anu.edu.au/htdocs/laserdisk/GREEK2/060.JPG).

[Fig. 2] *Parthenon Metope #2*, 447-442 BCE (Hellenic Electronic Center. *The Parthenon Marbles.* 1997. http://www.greece.org/parthenon/marbles/IMG0080b.jpg).

[Fig. 3] *Parthenon Metope #27*, 447-442 BCE. (Hellenic Electronic Center. *The Parthenon Marbles.* 1997. http://www.greece.org/parthenon/marbles/IMG0075b.jpg).

[Fig. 4] Jeff Koons. *Michael Jackson and Bubbles***.** 1988. 42 x 70 1/2 x 32 1/2 in. (San Francisco Museum of Modern Art).

[Fig. 5] *Dionysus from East Pediment of Parthenon*, ca 438-432 BCE. (Hellenic Electronic Center. *The Parthenon Marbles.* 1997. http://www.greece.org/parthenon/marbles/IMG0071b.jpg.)

[Fig. 6] Praxiteles. *Hermes with Baby Dionysus*, ca. 340BCE. (Orazio Centaro 1998-2001. http://www.ocaiw.com/galenug379.htm)

[Fig. 7] *Parthenon Frieze Youth*, ca 440-442. (Hellenic Electronic Center. *The Parthenon Marbles.* 1997. http://www.greece.org/parthenon/marbles/IMG0033b.jpg).

[Fig. 8] *Meissen Reclining Youth Bowl*, c. 1850-1900. (A Moment in Time, http://pages.tias.com/50/PictPage/1920868367.html).

Figures from *Eduardo Kac: Challenging Norms through Art*

Thomas Loverro

Figure 1. Kac, Eduardo. A-Positive. 1997. Courtesy Julia Friedman Gallery.

Figure 2. Kac, Eduardo. Genesis. 1999. Courtesy Julia Friedman Gallery.

Figure 3. Fontaine, Chrystelle. Eduardo Kac and GFP Bunny. Courtesy Julia Friedman Gallery.

Figure 4. Kac, Eduardo. GFP Bunny. 2000. Courtesy Julia Friedman Gallery.

Eduardo Kac: Challenging Norms through Art

Thomas Loverro

Eduardo Kac has presented the world with increasingly controversial pieces of art. He has transformed Biblical passages into genetic code and then purposely mutated them, and he has even transformed a cute little bunny into a living glow-stick. Is this what happens when modern art and science go awry? Or has this challenging artist produced genuinely laudable art? While traditional art may be valued for the beauty of the object itself, the true significance of Kac's work is in the dialogue it initiates. He forces us to take a fresh look at the relations humans have created among themselves, animals, and machines. In order to understand Kac's works, we must abandon our preconceptions and reevaluate what it means to be human.

"Eduardo Kac forces us to take a fresh look at the relations humans have created among themselves, animals and machines"

Calling Eduardo Kac (pronounced "Katz") unconventional is an understatement. His artwork challenges traditional notions about science, art, ethics, and just about anything else one can imagine. A superficial view of Kac's works may lead to quickly dismissing them as trite or downright offensive. On September 25, 2000, *The San Francisco Chronicle* published some of the responses that it had received concerning GFP Bunny, one of Kac's recent works involving genetic engineering. Those writing to the paper called the work, "some kind of twisted statement about technology" and also commented, "Mr. Kac has been visiting too many new age galleries."[1] Yet, thoughtless iconoclasm and esotericism are not Kac's way; he has consistently challenged norms with flair and provocative genius. Some of the responses to *The Chronicle* were positive, however. One reader insightfully commented: "Like many unforgettable artists before him, Kac has managed to shake up a jaded world which believes it has seen it all."[2] Shaking up the world can either be negative, if it causes damage to no end, or positive, if it dislodges anachronistic viewpoints. Kac is successful at accomplishing the latter.

It is useful to group Kac's artwork in two categories. The first group is composed of works that explore the relationships among humans, animals, and plants via the medium of telecommunications. The second category is so-called "transgenic" art: art that involves DNA manipulation and even the creation of new forms of animal life. Analyzing a sampling of Kac's art from each of these two categories reveals that through these works he asks us to rethink fundamental assumptions concerning what it means to be human, animal, robot, computer, and hybrids of each.

In Kac's 1989 interactive exhibit, Ornitorrinco, a one-eyed robot is remotely controlled through the use of a telephone and modems (utilizing the tones generated by the keys on the keypad as directional commands) in an environment set up by another group of artists. Ornitorrinco was one of Kac's earliest forays into telepresence, "the experience of presence in an environment by means of a communication medium." [3] Through its use of a remote control robot, Ornitorrinco was designed to explore

the possibilities of the rapidly developing telecommunications system and its impact on society as well as the extension of the human body. Oliver Grau, a new-media art historian at Humboldt-University of Berlin, claims, "Telepresence unites three themes with deep roots in intellectual history: automation and the search for artificial life, illusion in art, and the rejection of the body in favor of a spiritual or mentalistic conception of the human self."[4] Kac's experiment addresses all three of these themes. Automation and artificial life are represented in the one-eyed robot itself, the camera mounted in the robot gives the illusory feeling that one is actually present in the robot's environment, and the concept of the expression of the controller's will through the remotely located robot illustrates what Grau calls the "mentalistic conception"[5] of self as opposed to a physical conception.

Specifically addressing Grau's second theme, illusion's role in telepresence, Judith Donath, Director of the Sociable Media Group at MIT, states, "As the virtual world grows to encompass all aspects of our lives and on-line interactions shape our communities, influence our politics and mediate our close relationships, the quality of being real, which is accepted and assumed with little thought in the physical world, becomes one of the central questions of society."[6] Communication over long distance is fraught with a much increased possibility of deceit compared to face-to-face interactions. Online chatroom impostors, misleading online message board postings, and webcameras falsely labeled as "live" have become commonplace.[7] This fact implies that we must enter into telepresence experiences with a degree of skepticism that is not necessary in our everyday interactions. This new skepticism, this new concern with the definition of what is real, pushes us not only to redefine our online lives, but also rethink our physical lives.

Kac also deals with Grau's third theme, the mentalistic conception of self. He writes, "The question is not how do these technologies mediate our exploration of the world, local or remote, but how they *actually* shape the very world we inhabit." [emphasis added][8] Both Grau and Kac believe that telepresence experiences, although not real in the physical sense, can have *actual* or real impacts on our sense of self and the world around us. This presents us with what seems to be a contradiction: Can remote experiences be as rich and effectual as physical experiences? This question causes us to rethink some of our most common activities, such as remote communication, which tends to be either non-interactive, like television, or one-dimensional, like a phone conversation. In his essay "Telepresence Art," Kac comments:

> *I see telepresence art as a means for questioning the unidirectional communication structures that mark both high art (painting, sculpture) and mass media (television, radio)....To me telepresence art creates a unique context in which participants are invited to experience invented remote worlds from perspectives and scale different than human, as perceived through the sensorial apparatus of telerobots.*[9]

In this statement, Kac also raises the notion of perception from the viewpoint of the robot. One would normally not attribute a human characteristic, such as possessing a viewpoint, to a robot, but Kac is very much concerned with the perspective of the other, which may be a robot, animal, computer, or anything else. Kac bestows the distinction of artificial life upon the robot, even though it has no true life without the presence of the human controlling it.

Kac engaged the idea of giving life through robots more directly in his 1996 exhibit Teleporting An Unknown State. The work hit upon the concept of biotelematics, or "art in which a biological process is intrinsically connected to computer-based telecommunications work."[10] Teleporting An Unknown State is perhaps more aptly described by the classic definition of experiment rather than that of art. It weaves together computing, telecommunications, biology, and humanity. A plant was placed in a box without any source of light, except for a projector which only functioned as long as light was transmitted to it from a series of remote webcameras operated by independent participants. The plant was literally dependent on the Internet and on collective human support for its life, a truly global affair. Paravathi Narayan from *The Singapore Business Times* exclaimed, "The Internet, a virtual and non-real world, here became one that was quite literally life supporting!"[11] Where Ornitorrinco explored the boundary of communication and artificial life, Teleporting An Unknown State raised the stakes to real life, albeit plant life. The experiment placed the plant's life at risk, but in doing so, actually raised human awareness of the importance of that particular

plant's survival. Teleporting made it clear that all life is becoming increasingly both interdependent on mutual cooperation and dependent on telecommunications.

Associate Professor Machiko Kusahara of Kobe University Graduate School of Science and Technology in Japan was particularly intrigued by Kac's and others' experiments with "telegardens." Ken Goldberg produced the first telegarden in 1994. Plants were arranged under a growth lamp and around a robotic arm capable of dispensing food and water. The arm was then remotely controlled by a human at a computer. Comparing Ken Goldberg's experiment to Tamagotchi, toy digital pocket pets, Kusahara comments, "The problem with Tamagotchi is that it has nothing to do with real life, and it was a simple and poor simulation of life's complexities. Telegarden [by Ken Goldberg] is based on life in a real (but remote) physical space."[12] Kusahara's point is clear: telegardens present more of a challenge to our concept of what is real as opposed to artificial life than even objects, such as Tamagotchi, which were intended as A-Life (the practical challenge of producing artificial life, especially through computer programs) itself. For Teleporting, this implies that the experience of the garden conveyed by the Internet and computers is an accurate form of A-Life. The plant was actually coming alive on-screen for the individuals controlling the light projector. However, some might argue that the medium of a computer screen severely limits the range of interactions possible, making the entire experience seem less than genuine.

Kac decided to make the interaction as real as possible in 1997 with A-Positive. The exhibit brought an entirely new meaning to human-machine interaction. A-Positive links a human and robot through an intravenous needle [Figure 1]. The needle draws blood from the human and transfers it to the robot (or "biobot" as Kac calls it) and the robot extracts oxygen from this blood which it uses to maintain a small flame (the symbolic flame of life), while the robot donates dextrose back into the human. Kac is conspicuously making a provocative statement about the ties between humanity and our creations. Describing A-Positive in his own words, he states:

A-Positive does away with the metaphor of robotic slavery and suggests a new ecosystem that takes into account the new creatures and organic devices that populate our postorganic pantheon, be they biological (cloning), biosynthetic (genetic engineering), inorganic (android epistemology), algorithmic (a-life), or biobotic (robotics). We have always asked what can machines do for us. Now might be the right time to ask what we can do together.[13]

Does A-Positive achieve its goals or is Kac alone in his interpretation of his art? Narayan reflects, "A-Positive also shows a symbiotic relationship between human and machine, which is very different from the popular notion of a master-slave relationship between man and robot."[14] A-Positive forces us to reconsider our assumptions concerning humans and robots. No, hooking a human up to a machine intravenously was not a novel idea. In fact, it happens every day in hospitals across the world. However, making the human-machine relationship unambiguously synergistic and then asking what it means to our culture is creative genius. Will all human-machine interactions in the future be the unidirectional experiences we normally assume them to be? No, the line in the future between man and machine will be blurred more than ever before. In order to be prepared, we must envision the likely future, when machines will be physically inside of almost everyone and human tissue will be used in machines.

Finally, before moving onto Kac's transgenic art, is his 1999 Darker Than Night interactive exhibit, which is a culmination of the works examined thus far. It brings computers, robots, animals, and humans together and asks them all to communicate with each other. Kac placed a robotic bat ("batbot") in a cave with over three hundred Egyptian Fruit Bats in a zoo. The robotic bat was equipped with the ability to convert real bats' high-frequency calls to within the audible range of humans and also rotate its head, where the sonar microphone was located. Human listeners could then remotely, via a virtual reality headset, turn their head to control the batbot's microphone and immerse themselves in the world of the bat. Darker Than Night asks the human species to experience, to the best of our ability, the world of another species. Our vehicle for understanding the bat is a robot aided by a computer, suggesting a tie not merely between humans and animals, but among humans, animals, robots, and computers

While Darker Than Night asks questions about the boundaries between humans, animals, computers, and robots, Kac's transgenic art crosses them, blurring the human-animal-robot-computer distinction. Through the use of genetic engineering, Kac has recently produced two pieces of art that have excited a good deal of controversy. Kac's first transgenic work, Genesis [Figure 2], was initially exhibited in 1999.

Kac translated a sentence into Morse Code from the Bible's book of Genesis: "Let man have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moves upon the earth." Then, using a special computer program created for the event, the Morse Code was translated into genetic base pairs. This message was inserted as an artificially created segment of DNA into a group of bacteria that were colored to make them easily identifiable. As the bacteria propagated, the message was transcribed and copied but also sometimes mutated. In addition, both local and remote users (via the Web) had the ability to control a UV lamp that would increase the rate of genetic mutation. Every click changed the message more and more. The original sentence grants man power over the animal kingdom, but Kac's twist grants man power over the Bible itself. Kac claims that the ability to alter the Bible's word implies that we do not have to be bound to its original meaning, and that we must continually reinterpret it.[15] He uses the Bible, which many consider the ultimate source of tradition, and transforms it in order to elicit a response from his viewers. He wants members of his audience to think for themselves about the issues he raises, rather than passively receive the art. The dialectic nature of Kac's work is vital to understanding this purpose and message.

Kac's seminal transgenic artwork is GFP Bunny [Figures 3, 4]. In 2000, Kac incorporated a fluorescent jellyfish gene (green fluorescent protein or GFP) into the genes of an albino rabbit. With the ability to glow green under UV light, Alba became the world's first glowing bunny [Figure 4]. As a living piece of art, the work explicitly integrates the notion of dialogue into its form. Kac states, "GFP Bunny comprises the creation of a green fluorescent rabbit, the public dialogue generated by the project, and the social integration of the rabbit."[16] He presents us with a challenging concept. The art is not simply the object, but also includes the public reaction and the future life and socialization of the rabbit. Kac insists, "Transgenic art is not about the crafting of genetic objets d'art, either inert or imbued with vitality. Such an approach would suggest a conflation of the operational sphere of life sciences with a traditional aesthetics that privileges formal concerns, material stability, and hermeneutical isolation."[17] Kac wants to make it clear that GFP Bunny is not like a traditional piece of art such as a painting; it is about much more than a fluorescent rabbit. He did not create Alba because he thought a glowing bunny would please the eye. Kac could have painted a rabbit if he had wanted to do that. Kac wanted to both make a statement and raise questions about genetic engineering. He argues, "Contrary to popular notions of the alleged monstrosity of genetically engineered organisms, her body shape and coloration are exactly of the same kind we ordinarily find in albino rabbits. Unaware that Alba is a glowing bunny, it is impossible for anyone to notice anything unusual about her. Therefore Alba undermines an ascription of alterity. It is precisely this productive ambiguity that sets her apart: being at once same and different."[18] Alba presents the viewer with a paradox. She is a genetically altered "creature," yet she is no Frankenstein. She is a cuddly white bunny! Kac deliberately chose an animal that would not seem grotesque, but rather something that the audience could relate to. Thus, Kac suggests to us that we cannot categorically reject genetic engineering, we must look at it on a case-by-case basis. In a world in which there are sharply contrasting viewpoints on genetic engineering, a subtle approach is a welcome remedy. Surely Kac realized the humor in the notion of shaking up the scientific, political, and art worlds with a white bunny.

Kac views himself as an artist who "literally becomes a genetic programmer who can create life forms by writing or altering this code,"[19] not unlike a computer graphics artist. At first, this statement seems callous, arrogant, and even perverse, yet it is a statement of fact. Kac is presenting his scientific powers void of all euphemism. Many others do not see it as that clear-cut. For instance, Arthur Caplan, Director of the Center for Bioethics at the University of Pennsylvania, said, "'Ethically I don't think we should use genetics simply for artistic exhibitionism. I think that is an abuse.'"[20] Caplan's statement reflects the view that art is intended "simply" to please the eye. From this perspective, Kac's works are an abuse! However, not all art is purely decorative; that art is shallow is a sadly prevalent misconception. If one is willing to look at either of Kac's transgenic works presented here with open eyes, it is apparent that Kac is no whimsical designer. He is a scientist making an appeal through a creative and thought-provoking approach. He wants us to continually grapple with the difficult issues where science and ethics are irreversibly bound. Eduardo Kac's artwork in telepresence, biotelematics, robotics, and transgenics all cross boundaries. They confound the traditional meanings of human, animal, robot, communication,

and computer. Works such as A-Positive and GFP Bunny are unconventional, but were not designed merely for "shock value," but rather to jolt us into reevaluating our norms. Kac is asking important questions about genetic and cybernetic engineering that our society will need to face in the near future. In *NY Arts Magazine* Ulli Allmendinger wrote, "To ask questions, to pose the issues that are rumbling through culture right now, and doing it in a way that gives it a visual form, that gives it a way that people can talk about, that's part of what Kac is doing and that's what good artists do."[21] Although Kac's artwork challenges traditional values, it is not destructive of them because it constructs a framework for future conversation. Cloning and genetic engineering are progressing much faster than the public's ability to comprehend the moral and ethical implications of these technologies, especially since scientific research is usually done out of public view. Society will need more men like Kac who can make complex scientific issues sensible to the average person and can offer their opinions from as close to an objective perspective as possible. Otherwise, it will only be extremely biased groups, such as pharmaceutical companies and religious organizations, that challenge our points of view. A glowing green bunny might just prove to be one of our most valuable guiding lights into the future of genetic research.

Works Cited

1.Jennings S, Kirwan J, Zlotnick L. "Glowing Bunny Draws Big Response." *The San Francisco Chronicle*. Final Ed. (25 Sept. 2000) D4.

2 Jennings, Kirwan, Zlotnick. D4.

3 Steuer J. "Defining Virtual Reality: Dimensions Determining Tele-presence," *Journal of Communications* 42 (Autumn 1992). 75-78.

4 Grau O. "The History of Telepresence: Automata, Illusion, and the Rejection of the Body." *The Robot in the Garden*. Ed. Ken Goldberg. (Cambridge, Mass: MIT Press, 2000) 227.

5 Grau 227.

6 Donath J. "Being Real: Questions of Tele-Identity." *The Robot in the Garden*. Ed. Ken Goldberg. (Cambridge, Mass: MIT Press, 2000) 311.

7 Goldberg K. ed. "Introduction: The Unique Phenomenon of a Distance." *The Robot in the Garden*. (Cambridge, Mass: MIT Press, 2000) 13.

8 Kac E. "Dialogical Telepresence and Net Ecology." *The Robot in the Garden.* Ed. Ken Goldberg. (Cambridge, Mass: MIT Press, 2000) 181.

9 Kac E. *Kac Web*. <http://www.ekac.org> Accessed11 Nov. 2001. "Telepresence Art."

10 Goldberg xvi.

11 Narayan P. "Electronic Art: Pushing the Limits." *Singapore Business Times*. 22 Aug. 1998. 14

12 Kusahara, *The Robot in the Garden,* 206.

13 Kac E. *Kac Web*. "Art at the Biobotic Frontier."

14 Narayan 14.

15 Kac E. *Kac Web*. "Genesis."

16 Kac E. *Kac Web*. "Genesis."

17 Kac E. *Kac Web*. "Genesis."

18 Kac E. *Kac Web*. "Genesis."

19 Kac E. *Kac Web*. "Transgenic Art."

20 Allmendinger.

21 Allmendinger.

For more images, see http://www.ekac.org

Bayesian Belief Network Analysis of Legal Evidence

Fred Luminoso

A well-known and powerful tool in probabilistic inference is the Bayesian belief network. Also known as Bayesian networks, Bayes' nets, inference diagrams, and a host of other aliases, belief networks have been greeted with widespread application in diverse fields of medicine, engineering, and business. One academic arena, however, is conspicuously absent from this list—law. The purpose of this article is first to introduce its reader to Bayesian models and networks; second, to provide a demonstration of their potential in a legal analysis context with the aid of a case study; and finally, to evaluate the real-world applicability of Bayesian networks to criminal law and civil litigation.

"Essentially, the purpose of the Bayes' net is to update the user's uncertainty when given new information."

Bayesian networks rely on "Bayesianism," a probabilistic methodology which dictates that all uncertainties may be expressed with a probability estimate between zero and one. To provide an example, the probability of landing a six on the roll of a fair die is clearly 1 in 6. If the uncertainty is not measurable for one reason or another, we must rely on our best guesses. For instance, one might want to estimate the probability that he will like a new entrée at his favorite restaurant and guess at seven in ten.

What Bayes' nets do is compute complex interrelated probabilities with the aid of Bayes' rule, which is derived from two probabilistic axioms. In symbols:

P(A) = P(B) + P(AB)
P(AB) = P(A|B)P(B) = P(B|A)P(A)

The first of these dictates that for any two events A and B, the probability of A is equal to the sum of two individual probabilities: one, the probability that A is true and B is true, and two, the probability that A is true and B is *false*. The second axiom dictates that the "joint" probability of the occurrence of both A and B is equal to the probability of A, given that event B has occurred ("the conditional probability of A given B") times the "prior" probability of B, or, equivalently, the conditional probability of B given A times the prior probability of A. Solving for P(A|B), we have

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} = \frac{P(B|A)P(A)}{P(B|A)P(A) + P(B|\bar{A})P(\bar{A})}$$

Bayes' rule:

Quite frequently, events A and B are such that we have knowledge of B, but in fact care about A. (In a criminal trial, for example, we have knowledge of the evidence in the case but wish to evaluate the defendant's guilt. So event B would be the occurrence of the evidence and A would be the defendant's guilt.) In order to calculate the desired probability, a Bayes' net couples Bayes' rule—the underlying computational algorithm—with a graphical representation of the

relationship between these events. In this framework, a node represents each event, and arcs link related nodes in the direction of causality. (Very often, knowledge of one incident does not affect our degree of belief in another. In this case, the two events are *independent* of each other, and no arc links the two nodes in the network. Mathematically, the conditional probability is equal to the prior probability: $P(A|B)=P(A)$. Essentially, the purpose of the Bayes' net is to update the user's uncertainty when given new information.

The reader may still be somewhat puzzled, and hopefully the introduction of a case study will clarify any confusion. Before I detail the study, let me end with a few closing comments on Bayes' nets. First and foremost, the linking of the nodes in the direction of causality leads many novices to protest that Bayesian networks are drawn backwards. For example, the Bayes' net representations of criminal cases that follow depict arcs pointing *from* the node pertaining to the defendant's guilt *to* the nodes representing the evidence. It may seem as though they should point in the other direction, as knowing the evidence will influence our degree of belief in the defendant's guilt. This is true. But it is clear that it is guilt which will (at least in part) determine the evidence, and that the evidence will not influence whether he is in fact guilty.

Second, the reader may wonder why we should bother with a Bayes' net to combine subjective probabilities. Why not simply look at the aggregate evidence and generate a probability of the event of interest in one fell swoop? The answer to this logical question is forthcoming; the impatient reader may jump to Part III of this article at once. That being said, let us proceed to the case study.

Case Study of Sacco and Vanzetti

I now review the work of Joseph Kadane and David Schum, who in 1996 released a massive Bayes' net analysis of the 1921 trial *Commonwealth of Massachusetts v. Nicola Sacco and Bartolomeo Vanzetti*.[1] The defendants, both immutable anarchists, found themselves charged with—and convicted of—the armed robbery and first-degree murder of two payroll officers carrying some $16,000 in cash. Even more than 70 years after their execution in 1927, lingering doubt remains as to whether their conviction was motivated by the facts or by the defendants' political beliefs.

The Sacco and Vanzetti trial itself generated over 160 items of evidence, and extensive investigation since the trial's highly disputed outcome

Figure 1: Bayes' Net of "consciousness of guilt" evidence against Nicola Sacco.

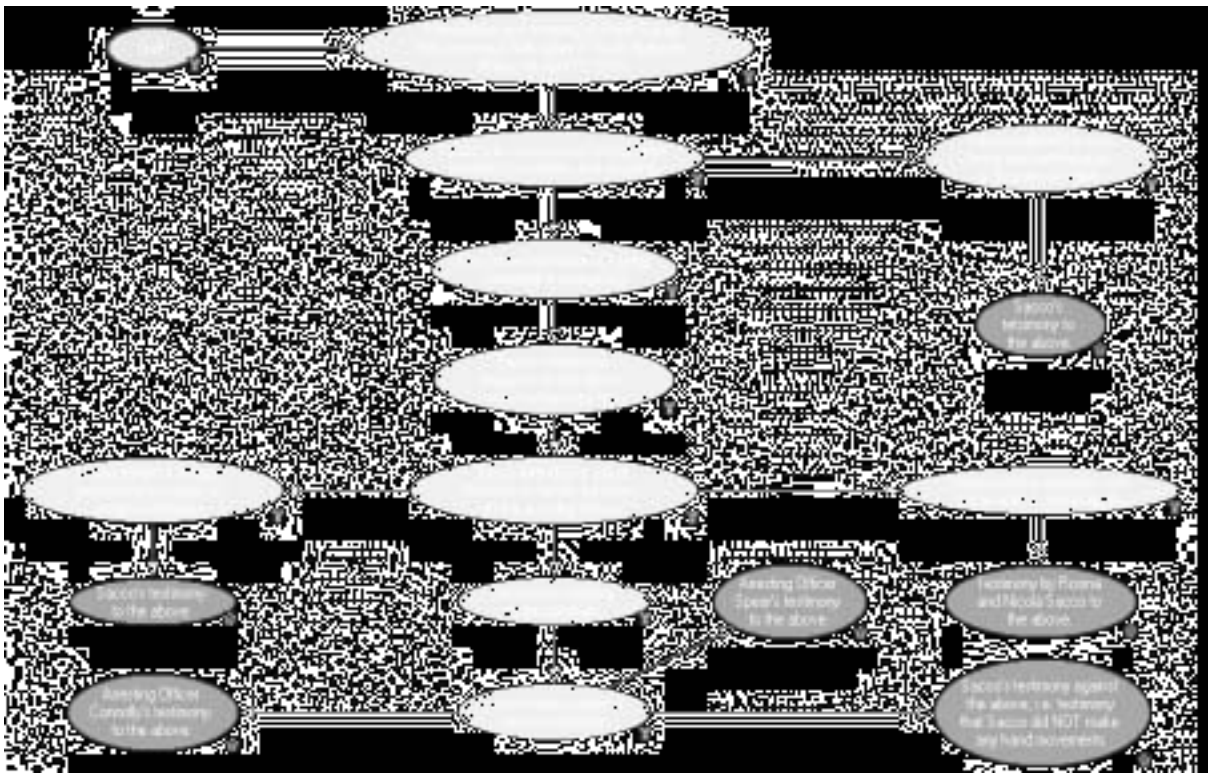

Figure 2: Bayes' net of firearms evidence against Nicola Sacco.

effectively brings the total to 395 items of evidence. For the sake of brevity, Kadane and Schum do not include all of this evidence in their Bayes' net analyses, but only a small subset: "consciousness of guilt," firearms, and identification evidence against Sacco. I include reproductions of two of these Bayes' nets in Figures 1 and 2.[2]

Note that the darker nodes represent observed phenomena, and that the Bayes' nets effectively revise our belief in guilt based on these observations. After the trial's conclusion, Judge Webster Thayer commented that some of the most incriminating evidence against the defendants was their alleged "consciousness of guilt;" that is, their behavior at the time of their arrest, which suggested they knew they had done something wrong. As the Bayes' net shows graphically, some eight degrees of freedom separate the proposition of guilt from that of the evidence. In fact, even assuming perfectly credible arresting officers (whose testimony would imply that Sacco *definitely* made suspicious hand movements), under certain other assumptions the probability of Sacco's guilt is a meager twelve percent. Similarly, probabilistic analysis of the firearms evidence against Sacco reveals that, given the highly suspect testimony of prosecution witness Pelser (whose statements appear to have been the result of "coaching" on the part of theprosecution), the odds of Sacco's guilt hover around 200:1 in favor of innocence. It may be likely that Sacco had the revolver Exhibit 28 on him when he was arrested, that shell W came from Exhibit 28, and that Exhibit 18 was fired through Exhibit 28. Given the suspect testimony and the distinct possibility that Exhibit 18 was *not* the bullet extracted from one of the guards' bodies, however, it is almost impossible that Sacco was guilty.

Real-World Application

This concludes my thought experiment. The question now becomes whether, and if so how, this research can be extended from thought experiment to real-world application. Clearly using them as a tool to aid in the evaluation of guilt is fraught with potential for abuse. Where Bayesian networks could make themselves useful is as a supplement to decision analysis (DA), already a popular mechanism in litigation.

In a method very similar to that of a Bayes' net, DA combines numerical methods with a graphical model (called a decision tree) of a sequence of events, with the purpose of optimizing decision-making under uncertainty. The tree represents each event with a node and assigns to it a probability distribution conditional upon the preceding events. The decision analyst attaches a specific monetary outcome to each "elemental possibility" (the most specific outcomes depicted on the furthest right of the tree), and then multiplies the product of the conditional probabilities together with the monetary outcomes to arrive at the "expected value" of each elemental possibility. To make the best decision in theory, the analyst only has to choose the option with the highest expected value. On the following page is a a lawsuit and its sample decision tree (Fig. 3).

If the client chooses to accept an out-of-court settlement, he stands a 100% chance of winning $600,000. If he does not, he stands about an 80% chance of being awarded $400,000 and a 20% chance of being awarded $1 million, for an expected value of $520,000. Thus, he should opt to settle. This example is slightly oversimplified, but the methodology is plainly extendable to highly complex lawsuits.

Decision analysis has already established a foothold in the field of civil law, having been employed by attorneys for Sega, Boeing, and General Electric, and drawing the exuberant declaration that "It will, one day, be malpractice not to apply this kind of analysis."[3] Bayesian networks could contribute to this area in several ways.

First, Bayesian networks could be utilized to compute more accurate conditional probabilities. In a widespread phenomenon known as conservatism, a subject produces subjective estimates that are more extreme (i.e., closer to zero or one) when asked to specify several conditional and prior probabilities (and compute the overall "joint" probability from Bayes' rule) than when asked to specify a "holistic" probability for the aggregate events up front.[1,2] Obviously, the question arises as to which is "better," or a more accurate estimate of the subject's uncertainty—the holistic probability, or the computed joint probability? I contend that it is the latter. Studies of two versions of Pathfinder, a Bayes' net system used for the diagnosis of lymph node disease, reveal that the newer version is substantially more accurate. This, in turn, is largely due to the fact that in the newer version, the expert "provided better probability assessments for a feature when he was allowed to condition the assessments on the observation of other features."[3] Also, psychological studies observe a conservative bias against new information—even in "expert" decision-makers. In other words, people are overly reliant on first impressions, and give undue credence to the initial view when presented with contradictory evidence.[4,5] A Bayes' net could thus serve as a psychological safeguard against this conservative bias. While this evidence may not be overwhelming or conclusive, it is certainly indicative that a Bayesian network has the potential to generate more accurate representations of an attorney's uncertainty and, as a result, produce more desirable results in a decision analysis.

Second, Bayesian networks could be an invaluable supplement to sensitivity analysis, an indispensable part of many mathematical analyses and especially decision analysis. Sensitivity analysis varies initial probabilities, one at a time, and observes the effect on the expected outcome, with the intention of finding the probability to which the expected outcome is most responsive. Having identified this probability, an attorney equipped with a Bayes' net might be able to perform sensitivity analysis on the network itself to determine which piece of evidence would be most important in maximizing (or minimizing) that probability.

As already mentioned, I anticipate these advantages of Bayes' nets to be applied, if at all in legal analysis, to litigation (which regularly utilizes decision analysis) and not criminal law (which does not). Decision analysis has yet to make a debut in criminal law due to the constraint it places on time, money, and other resources, and as such it only makes sense that criminal attorneys will not take advantage of the more complicated and as-yet undiscovered tool of Bayesian networks. However, though I have thus far suggested using Bayes' nets as a supplement to decision analysis, I would like to emphasize that Bayesian networks could play a powerful role independent of DA. We have already seen this with the Sacco and Vanzetti trial. A Bayes' net would allow attorneys, civil and criminal alike, to diagram and analyze evidence, and force them

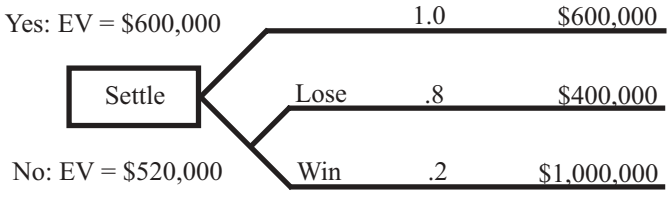

Figure 3: Sample decision tree for a lawsuit.

to consider the aggregate of the evidence in a way few other instruments could. This, after all, is the chief advantage of the already-popular decision analysis, as stated by Marc B. Victor, founder and president of Litigation Risk Analysis:

...[the] focus on computations is misplaced. In a good decision analysis of a lawsuit, only a small fraction of the effort (perhaps ten percent) is spent performing the necessary calculations, and only a part of the benefits of conducting the analysis is the quantitative results. Most lawyers who are familiar with how to perform a good decision analysis will attest to the fact that its real benefit is in forcing—and assisting—an attorney to understand his or her case better...[9]

Conclusions

The purpose of this article, to reiterate, has been to introduce the reader to Bayesian networks, their underlying mechanisms, and their potential applications in the field of law. By no means do I suggest that Bayesian networks can or should take the place of rigorous analysis; I only recommend that they be incorporated as a supplement to current practices. As Mr. Victor warns, "one of the main purposes for performing a good decision tree analysis [is] to impose rigor on an attorney so that he or she will think as carefully as possible about a case and each of its underlying elements…although computers allow all sorts of computations to be performed quickly, they should not become a substitute for hard thinking about complicated problems."[10]

Works Cited

1 Kadane J, Schum D. Probabilistic Analyses: Judgments and Stories. In: A Probabilistic Analysis of the Sacco and Vanzetti Evidence. New York: John Wiley, 1996.

2 The software program I used was GeNIe, available from the University of Pittsburgh at http://www2.sis.pitt.edu/~genie. Other useful programs include Microsoft Belief Networks, available at http://research.microsoft.com/adapt/MSBNx/, and HUGIN, available at http://www.hugin.com.

3 Hirshman HC. Sonnenschein Nath & Rosenthal. http://www.litigationrisk.com/m-tr-reviews.htm. Accessed 5 Sept. 2001.

4 Phillips L, Edwards W. Conservatism in a simple probability inference task. *J Experimental Psychology* 1966; 72:346-354.

5 Phillips L, Hays W, Edwards W. Conservatism in complex probabilistic inference. *IEEE Trans Human Factors Electronics* 1966; 7:7-18.

6 Heckerman D, Nathwani B. An evaluation of the diagnostic accuracy of Pathfinder. *Comput Biomed Res* 1992; 25:56-74.

7 Nisbett R, Ross L. Human Inference: Strategies and Shortcomings of Social Judgment. Englewood Cliffs, NJ: Prentice-Hall, 1980.

8 Tetlock PE. Theory-driven reasoning about plausible pasts and probable futures in world politics: Are we prisoners of our preconceptions? *Am J Pol Sci* 1999; 43:335-366.

9 Victor MB. The proper use of decision analysis to assist litigation strategy. *Business Lawyer* 1985; 40:618.

10 Victor MB. The proper use of decision analysis to assist litigation strategy. *Business Lawyer* 1985; 40:626-627.

Suggested Reading

Bergman P, Moore A. Mistrial by likelihood ratio: Bayesian analysis meets the F-word. *Cardozo Law Rev* 1991; 13:589-619.

Cohen LJ. The Probable and the Provable**.** Oxford: Clarendon Press, 1977.

Edwards, W. Influence diagrams, Bayesian imperialism, and the Collins case: An appeal to reason. *Cardozo Law Rev* 1991; 13:1025-1074.

Finkelstein M, Fairley W. A Bayesian approach to identification evidence. *Harvard Law Rev* 1970; 83:489-517.

Jensen, FV. An Introduction to Bayesian Networks. London: UCL Press, 1996.

Kadane J, Schum D. Probabilistic Analyses: Judgments and Stories. In: A Probabilistic Analysis of the Sacco and Vanzetti Evidence. New York: John Wiley, 1996.

Kaplan, J. Decision theory and the fact-finding process. *Stanford Law Rev* 1968; 20:1065-1092.

McDiarmid, M. Lawyer decision making: The problem of prediction. *Wisconsin Law Rev* 1992; 6:1847-1929.

Simon R. Beyond reasonable doubt: An experimental approach at quantification. *J Applied Behavioral Science* 1970; 6:203-209.

Simon R, Mahan L. Quantifying burdens of proof: A view from the bench, the jury, and the classroom. *Law and Society Rev* 1971; 5:319-330.

Tribe L. Trial by mathematics: precision and ritual in the legal process. *Harvard Law Rev* 1971; 84:1329-1393.

The Psychological Experience of Security Officers Who Work With Executions

Michael Osofsky

The Louisiana and Alabama "Execution Teams" were interviewed in order to understand the roles, experiences, and effects of carrying out the death penalty. One hundred twenty out of a possible one hundred twenty-four correctional officers were interviewed. Of those questioned, one hundred fifteen completed mental health inventories. The subjects were grouped based on their roles in order to gain a broader picture of the steps and their impact in carrying out the death penalty. Our results show that participants in the execution process stress "caring professionalism." There is an overwhelming emphasis on carrying out one's job at a high level. At the same time, officers are neither dehumanized nor callous, describing acting with respect and decency toward all involved. While their job is their prima facie duty, they experience stress and emotional reactions, frequently having a hard time carrying out society's "ultimate punishment."

". . . little knowledge exists about the actual nature of how executions are carried out."

The topic of state ordered executions invokes strong emotions from many people throughout the United States and around the world. In the past decade alone, dozens of countries have either placed a moratorium on executions or abolished the death penalty altogether.[1] Simultaneously, ambivalence is the term that best describes the overall attitude towards the death penalty.[2] On the one hand, the majority of the American public believes that serious offenders should be punished to the extent that they inflicted pain and suffering, namely retributive justice or the biblical concept of "an eye for an eye."[3]

Alternatively, a growing minority is horrified by the idea of state-ordered killing, regardless of the heinous nature of the crimes committed. In fact, an ABC Poll conducted in early 2001 found that public support for the death penalty had declined to 63%, a drop from 77% in 1996.[4] Many question whether the death penalty has any positive deterrent effect, citing evidence comparing states with and without capital punishment.[5] Others worry about the economic discrimination against the poor and even racist tendencies associated with the death penalty.[6] Additional opponents of capital punishment feel the punishment to be appalling arguing that innocent individuals can be put to death.[7] Finally, many individuals question the lengthy appeals process that allows inmates to be executed years after their convictions. Over the course of ten, fifteen, or even twenty years on death row, inmates can be rehabilitated, the family of the victim(s) receive no closure, and prison guards can form a relationship with the inmate.[8-9]

A great deal of intrigue surrounds the members of an execution team. From stereotypes of a hooded executioner to the notion of multiple executioners with only one possessing the deadly bullet, little knowledge exists

about the actual nature of how executions are carried out.[10-11]

Our interviews of execution team members at the Louisiana State Penitentiary at Angola and Holman State Prison in Alabama utilize an unprecedented number of subjects through full and uninhibited access to the staff involved. The current study was undertaken in order to gain more understanding about the unusual responsibilities and experiences of those who are directly involved with the legal termination of the lives of others.

One hundred and twenty correctional officers at the Louisiana State Penitentiary at Angola and Holman State Prison in Alabama were interviewed anonymously in order to understand broad areas of the execution process. The one to two hour interviews were conducted over the summers of 2000 and 2001. During 2000, interviews were conducted of fifty of fifty-two members of the Louisiana execution team. During 2001, fifty interviews were conducted of security officers who either work on Death Row or are a part of the execution process in Louisiana. An additional twenty interviews were carried out involving correctional officers who have worked with executions in Alabama. In addition to gathering demographic and background information, a number of questions were asked about the following topics: 1) The execution experience, including roles, reactions, preparation, emotions experienced, and changes over time; 2) Stresses related to their job and methods to cope with stress; 3) Support network and influence of work on relationships; 4) Aftermath of execution experience for the officer. Based on our interviews, we were able to recreate the step-by-step process of carrying out an execution. The process was largely similar in the two states, but differed due to both situational factors with the two facilities as well as the mode of execution employed in each state (Louisiana uses lethal injection while Alabama is one of two remaining states still employing the electric chair as its sole means of execution).

The security officers were asked to complete three separate measures. During 2000, subjects completed the Beck Depression Inventory (BDI) and the first page of a Clinician Administered Post Traumatic Stress Disorder Scale (CAPS 1) for the DSM-IV, a life events checklist. The reported results from these two measures are primarily descriptive due to our desire to understand the execution process and psychological impacts of carrying out the death penalty. During 2001, we asked the officers to complete a questionnaire pertaining to issues of moral disengagement employed throughout the process. Interviews were tape recorded (without their names on the tapes) in order to guarantee that quotes, reactions, and attributed material were accurate.

After completing the interviews, we classified subjects into one of twelve roles: Wardens, classifications personnel death row guards, death house/front gate security, liaisons to the press, mental health professionals, spiritual advisors, officers who sit with the victim's family, officers who sit with the inmate's family, the strapdown team, emergency medical technicians, and the Executioner.

Interview responses conveyed an interesting perspective on the death penalty relative to the existing literature on the subject. Consistent with current national polls, approximately two-thirds of officers indicate general support for the death penalty, stressing the heinous nature of the inmates' crimes and the impact on the victims and their families.

All but three do not believe the death penalty is racially motivated. However, an equal number raised concerns that social class and poverty play major roles in determining who is executed.

"I've never seen a rich man executed," Death Row guard Willie W. asserted. The inmates on Death Row tend to come from poor, underprivileged backgrounds in which they had little access to basic necessities. Sarah S., the deputy warden pointed out, "If they had educational opportunities, they wouldn't be here."

The execution team also noted that certain districts within the state are more likely to hand down a death sentence. This variation by district is a function of the District Attorneys, judges, and juries — standards that vary by city and state. A considerable number of the officers discussed their concern that many "lifers" have committed crimes that are as horrific as those committed by the inmates on Death Row. For this reason alone, several members of the execution team argued that either the sentences of those on Death Row should be commuted to life in prison or others should be on Death Row.

Further, we repeatedly heard that the death penalty simply takes too long to be carried out. Some described their identification with the inmates' pain in living and awaiting execution. Others discussed the high monetary cost to the state of the lengthy appeals process. Some worried that the victims cannot receive closure until the inmate is dead.

Ultimately, nearly every person we interviewed echoed two

main components of the execution process. On the one hand, and most importantly, the security officers stressed their professionalism. Their duty is to carry out the laws of the United States, whatever those may be. They believe in their jobs, and try to do them as well as they possibly can. On the other hand, they act with decency and humanity toward the inmates. In their efforts to adjust and function successfully, they struggle internally. Although most attempt to suppress painful feelings, they state that if it ever becomes easy to participate in an execution, they would worry about themselves and their loss of humanity. Some deal with their stress by disassociative mechanisms. Some overtly exhibit their distress through transient or persistent stress, guilt, and even depression. Although many officers view Death Row inmates as the "worst of the worst," all describe treating the inmates with decency. Death Row guard Charles S. said, "I treat them as I would want to be treated. I help them when I can and when my job permits." Strapdown team member Robert A. concurred, "They are people and deserve to be treated as such." While some prisoners do not repent or do so only superficially, the officers describe how many change, becoming cooperative in the process.

Certainly there are exceptions to the almost universal decency of the officers in this study; wrongful emotional and physical abuse can occur in a maximum-security penitentiary. Some guards have inappropriate motives for working at a prison. From our discussions it appears that most voluntarily leave or are weeded out over time. However, the officers we interviewed did not display hostility toward the inmates, but were concerned with maximizing humanity and dignity. Within the constraints needed to maintain security, they describe being kind to the inmates. Some describe feeling good about a number of inmates who shortly before their execution thank them for their compassion. If anything, after being involved on the death team, correctional officers become more reflective and take their job more seriously than ever.

Works Cited

1. Prokosch E. Human Rights v. The Death Penalty: Abolition and Restriction in Law and Practice. Amnesty International, 1998.
2. Finckenauer JO. Public Support for the Death Penalty: Retribution as Just Deserts or Retribution as Revenge? *Justice Quarterly* 1988; 5:81-100.
3. Gale ME. Retribution, Punishment and Death. *UC Davis Law Review* 1985; 18:973-1035.
4. Ellsworth P, Ross L. Public Opinion and Capital Punishment: A Close Examination of theViews of Abolitionists and Retentionists. *Crime and Delinquency* 1983; 29:116-169.
5. Reiman JH. The Rich Get Richer and the Poor Get Prison, 4th ed. Boston: Allyn and Bacon, 1985.
6. Jackson J. Legal Lynching: Racism, Injustice and the Death Penalty. New York: Marlowe, 1996.
7. Radelet ML, Bedau HA, Putnam CE. In Spite of Innocence: Erroneous Convictions in Capital Cases. Boston: Northeastern University Press, 1992.
8. Radelet ML, Vandiver M, Berardo F. Families, Prisons, and Men with Death Sentences: The Human Impact of Structured Uncertainty. *J of Family Issues* 1983; 4:595-596.
9. Goldhammer GE. Dead End. Brunswick: Biddle Publishing Company, 1994.
10. Mailer N. The Executioner's Song. Boston: Little, Brown, 1979.
11. Elliot RG. Agent of Death: The Memoirs of an Executioner. New York: Dutton, 1940.

Further Reading

Cabana, D. (1996). Death At Midnight: The Confession of an Executioner. Northeastern University Press.

Johnson, R. (1998). Death Work: A Study of the Modern Execution Process. Wadsworth Publishing Company.

Trombley, S. (1992). The Execution Protocol: Inside America's Capital Punishment Industry. Crown Publishers, Inc.

The Computerized, Three-Dimensional Reconstruction of Human Teeth for Pedagogical Purposes

Amrit K. Rao

An emerging area in the field of computer science is that of biocomputation, a discipline that encompasses a variety of medical applications ranging from telemedicine to surgical planning. This article describes a promising method of reconstructing three-dimensional images of dental anatomy to serve as teaching models in dental schools. The process is analogous to calculus—a series of measurements and photographs were taken of cross sections of human teeth. The three-dimensional tooth was consequently constructed by "integrating" each slice in order to form a whole tooth. The importance of such technology has been demonstrated in previous studies; indeed, accurate 3-D medical imagery can mean the difference between success and failure in a clinical setting.

"It is possible to virtually fly around the tooth or down the root canal while the tooth is opaque, or with various degrees of transparency."

Introduction

The nascent field of biocomputation promises to yield great dividends in the future. Modern computing power is improving exponentially and with this rise come new ways of applying such knowledge to other scientific realms. Already, computers have enhanced our understanding of nature at the atomic level, but as we push forward, we find that computer science has the potential to supplement the medical sciences in many ways as well. For example, refined collision detection models promise to give physicians and dentists a new way to practice their surgical technique before operating on patients. Furthermore, telemedicine, a branch of medicine that involves treating patients thousands of miles away, is also making its debut thanks to improved software and hardware. For telemedicine and computerized surgical planning to become a reality, however, more fundamental issues must be addressed, namely those of how a patient's data can be incorporated into a surgical/medical model. For instance, without a 3-D model of a patient's body, virtual reality surgical planning could never take place realistically. Clearly, the need for three-dimensional simulation technology is great, as numerous medical applications are predicated on its existence. The pedagogical tool we created represents an application of this baseline technology from which better things are expected to come.

Methods

In dental schools, tooth morphology is currently taught using x-rays, photographs, drawings, and extracted human teeth.[1] Even dental educators admit that these methods all have significant disadvantages and limitations.[2] For one, drawings, photographs, and radiographs are inherently two-dimensional; learning complex three-dimensional biological systems through the use of two-dimensional representations indeed proves to be a formidable task (Fig. 1). In addition, some of the

The images in Fig. 1-6 are surface-rendered models. There are several other viewing protocols that have been developed but have not been demonstrated. The same viewing protocols are available with volume-rendered and full color voxel models.

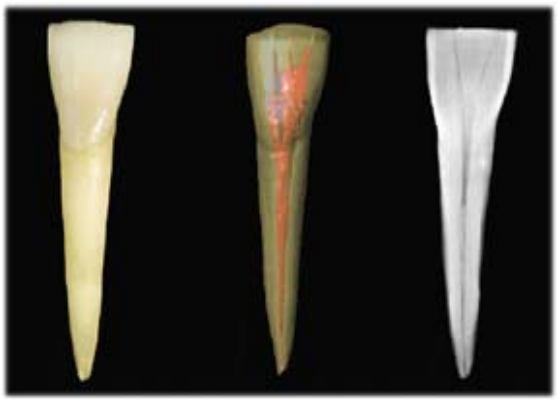

Fig 1. This labial view shows 3 images of the same tooth. On the left is a photograph, in the center a colorized micro-CT scan and on the right an x-ray.

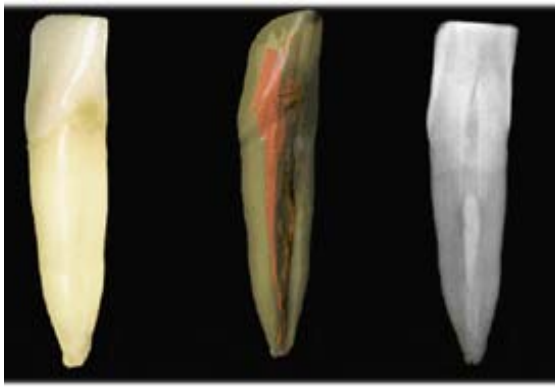

Fig 2. By rotating all of the images together on the computer, the complexities of the root system becomes apparent.

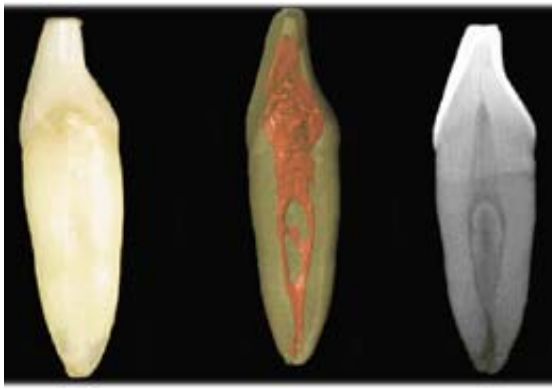

Fig 3. Further rotation of the images reveals a complex internal anatomy. This tooth has a single canal in the chamber, changes to 2 mid-root, becomes 1 again toward the apical third and then splits into 2 again at the apex.

drawings that dental students use are many decades old (*Pathways of the Pulp*, the best selling endodontic textbook in the world, uses fifty year old figures).[3] For years it has been held that dental schools would ideally be able to teach their dental students with the aid of full sets of extracted teeth in their educational courses, but the difficulty of obtaining such sets severely limits its use. Furthermore, even the use of actual human teeth has its own set of problems. Although they are the "real thing," the study of many important exterior features of teeth requires heavy magnification; sometimes even an ordinary magnifying glass does not suffice (Fig. 4). Also, if a student wishes to examine the interior of the tooth, the tooth must be permanently destroyed. This makes the use of teeth especially limited, as dental schools must constantly replenish their supply of human teeth in order to educate future dentists.

The purpose of this paper is to showcase a radically different approach to the teaching of human dental anatomy than has currently been employed. To achieve this objective, three-dimensional models of human teeth were made using a method of acquiring and storing precise volume data using high-resolution X-ray computed micro-tomography. With the latest high-tech imaging techniques and equipment, researchers at the Stanford-NASA National Biocomputation Center have developed a program that produced interactive, stereo, 3D models based on real teeth. The ability to produce virtual 3D models of teeth is a substantial improvement from the past. Such models allow for multiple viewing options. It is possible to virtually fly around the tooth or down the root canal while the tooth is opaque, or with various degrees of transparency. It is also possible to cut and view from any desired rotation (Fig.e 2).

The process of making computerized, three-dimensional models of patient data is a long one that includes steps that are not intuitively obvious. There are several basic tasks that must be accomplished. First, a complete set of human teeth must be acquired. After the teeth are obtained, they must be photographed in such a way that the full contour is present; this will ultimately be the "cover" of the computerized tooth. To take these pictures, individual teeth are mounted on a turntable and are simultaneously photographed and x-rayed in five degree increments for 72 times (giving a complete, 360 degree picture). A sophisticated method of contour mapping is required if high-resolution

virtual reality teeth are desired. To this end, a micro-CT scan is used (all teeth for this study were scanned by Michael Flynn, Ph.D. and the Department of Diagnostic Radiology at Detroit's Henry Ford Health Systems). A total of 58 teeth were mounted on a granite optical bench and subsequently scanned using a microfocus x-ray source and digital x-ray detection apparatus.

Steps must be taken to reduce experimental error associated with these techniques. The tooth, for example, can unexpectedly move while it is being x-rayed. To minimize movement, the data acquisition was performed in a rotate only mode and on a sturdy platform. In addition, much of the x-raying process entails error in and of itself. For instance, the x-ray source that was used suffers from geometric distortion that arises when the x-rays deflect off curvaceous surfaces (i.e. teeth) and onto the flat ones (the detector). This problem is solved through several instrument calibration techniques and mathematical analysis (piecewise linear method).

After the micro-CT scanning, the 16 core teeth are individually embedded in methyl methyacryralate blocks that are mounted on a micromilling machine. These blocks are milled in the occlusal-apical ("bottom to top") axis of the tooth at an average of 40 to 50 microns; roughly 350 to 500 "slices" were made per tooth. Images of each slice are taken such that each figure can serve as a kind of cross section. It is important to note that the images of each cross section not only contain the general "outline" of each slice but also the outlines of the interior substructure. This allows the computerized image to not only contain an accurate representation of the exterior of the tooth but the internal anatomy as well. The next step is to integrate all of the cross sections into a computerized, 3-D wireframe onto which the micro-CT contour can be superimposed.

During this phase, a National Biocomputation Center software package was employed to segment the

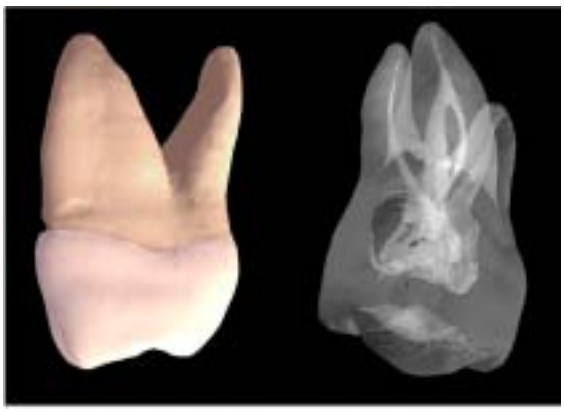

Fig 4. Two images of the same tooth. The computer program allows the user to alter the transparency to any degree for the study of internal and external relationships. The above image can also be rotated to any desired position.

Fig 5. Having the ability to freely rotate a tooth and alter the transparency of the outer surface reveals the corresponding association of a lingual pit to the pulp chamber. It is also an aid to assist in understanding restorative limitations and endodontic access. Such views may also aid in determining apical foramen location.

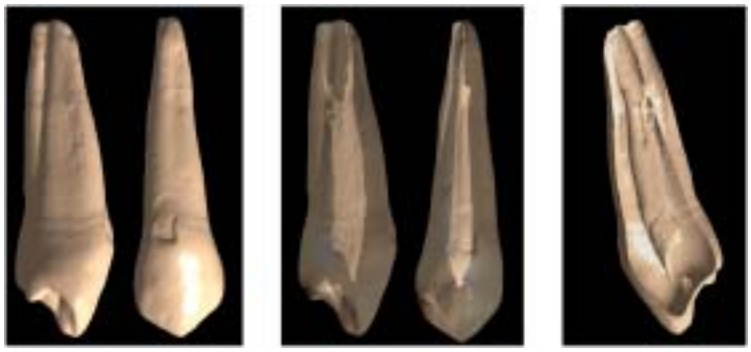

Fig 6. Multiple images of the same tooth demonstrate the range of computer imaging possibilities. The left view is opaque, the central introduces the transparency and the view on the right has a cutting plain introduced to view the internal anatomy. Such cutting planes can be used to view the tooth complexities in all possible orientations and opacities.

data (separating each "slice" and ordering it) and construct a mesh that was made using a modified Marching Cubes algorithm.[4] Next, many of the artifacts, or useless parts of the anatomy (such as bubbles and cavities), must be removed. Once the data is artifact-free, it is now ready for the visualization phase, which includes the coloring of the teeth in order to set apart the various anatomy.

At first, visualizing the reconstructions as they were produced proved to be too difficult for public viewing, as it took too long for the computer to display the reconstructions. To solve this problem, the number of polygons that was used to reconstruct the teeth was dramatically reduced (from roughly 8 million) using a Quadratic Slimming approach.[5] This maximized the resolution but at the same time minimized the rendering time. After a computer program named Meshview was produced and implemented, the reconstruction could then be displayed on a PC with ordinary computing power.

Discussion

In dentistry, an intimate knowledge of tooth anatomy, both internal and external, is essential for diagnosis, treatment planning, and clinical success. Many procedural errors made in clinical practice can be traced back to an inexact knowledge of this anatomy. Computerized 3-D teaching tools such as the one described in this paper have the potential to curb the incidence of this kind of clinical error.[6]

All dental procedures—restorative, periodontal, pedodontic, surgical and endodontic—require intimate familiarity with dental anatomy. Endodontics, for example, deals primarily with internal anatomy, but requires a complete understanding of all spatial relationships. An ideal endodontic procedure involves a three-dimensional cleaning and shaping followed by a perfect obturation of pulpal space. Accessing the pulp chamber requires a clinician to extrapolate the tooth's internal anatomy from its external shape. This extrapolation is difficult because the internal anatomy is not necessarily correlated with the external shape. Procedural errors would be minimized if clinicians were able to construct accurate mental models of the internal and external anatomy of the tooth. Radiographs have limited usefulness as a guide during these procedural steps because they are two-dimensional and only a few views are available. 3-D models, on the other hand, greatly facilitate a student or dentist's ability to learn general anatomy, anatomical relationships, and anatomical variations in order to maximize clinical success.

Learning anatomy in three dimensions, after all, allows students to recognize patterns and concepts (such as the convergent nature of tooth canals) that are not readily apparent in the study of 2-D schematics. Furthermore, 3-D models can be manipulated in ways that textbook pictures and physical teeth cannot. Computers, for example, give dental students the ability to take a kind of trip down a tooth, examining each cross section individually. Also, the wall of the tooth can be made transparent in order to reveal pulp pathways in a way that has never been displayed before.
Forensic science, which often relies on dental records to identify dead bodies, is another area of science that will benefit from variations on this technology. Using these models, forensic students will be better able to understand such subjects as measurement references and forensic classifications.

Forensic science, which often relies on dental records to identify dead bodies, is another area of science that will benefit from variations on this technology. Using these models, forensic students will be better able to understand such subjects as measurement references and forensic classifications.

The application of such technology is immense. Surgeons, for example, can use 3-D models of patient data in order to plan operations. Furthermore, as computing power and technique improve, the surgical planning phase can turn into surgical *practicing*, in which computerized simulations of surgical procedures can be done pre-operatively and in an interactive fashion. This will likely increase patient survival and satisfaction.

Aside from the implication of these new technologies in the practice of medicine, what is particularly interesting about this brand of experimentation is that it is truly a multidisciplinary effort, involving computer science, biology/physiology, math, and physics. The potential for interdisciplinary collaboration on such efforts is exciting, and it is arguable that only in a university environment can one find the resources for such work.

Works Cited

1 Wallen ES, Schulein TM, Johnson LA, "A Computer Program to Aid in Visual Concept Development in Dentistry." Comput Methods Program Biomed, 1997 Feb; 52[2]:105-15.

2 Dowker SE, Davis GR, Elliot JC Royal ., "X-ray microtomography: nondestructive three-dimensional Imaging for Invitro Endodontic Studies." Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 1997 Apr; 83[4]:510-6.

3 Pathways of the Pulp, Cohen and Burns 1998, 7th Ed., Mosby St. Louis, MO.

4 Lorenson WE, Cline HE, "Marching Cubes: a High Resolution 3D Surface Reconstruction Algorithm." Computer Graphics, Vol. 21, No. 4, pp 163-169 (Proc. Of SIGGRAPH), 1987.

5 Garland M, Heckbert P, "Surface Simplification Using Quadratic Error Metrics." Computer Graphics, (Proc. Of SIGGRAPH), 1997.

6 Ackerman MJ, "The Visible Human Project: a resource for education." Medinfo, 1998;9 Pt 2: 1030-2.

The Status of the Mechanical in the Writings and Works of Two Artists: Cézanne and Matisse - The Artist as a Dysfunctional Machine

Marina Kassianidou

This paper looks at the work of Henri Matisse and Paul Cézanne in the context of the technological developments that were taking place during these artists' lifetimes. In particular, the paper focuses on the parallels between the mechanical process and mass production and the works of the two artists. Both Cézanne and Matisse seem to perceive art as a form of mechanical process. Also, both artists adopt a form of mass production by their insistence on depicting the same subject matter over and over again. Interestingly, however, the parallel between mechanical developments and the work of the two artists eventually breaks down. Both artists face difficulties in trying to carry out their processes, and in the end they seem unable to achieve any finished product. The paper argues that Cézanne and Matisse use the mechanical framework as means of expression, but at the same time, they reveal the inadequacy of that framework when dealing with art.

"Cezanne and Matisse use the mechanical frameworks as means of expression, but they also reveal the inadequecy of that framwork when dealing with art."

In his "Notes of a Painter," Henri Matisse states that "[a]ll artists bear the imprint of their time, but the great artists are those in whom this is most profoundly marked." [1] In the late 19th and early 20th centuries, the time of Paul Cézanne and Henri Matisse, industrial and scientific developments transformed the world into a system that could be analyzed and understood through science. [2] The development of factories and the use of industrial processes in manufacturing goods led to the mass production of everyday consumer items. It seemed as if anything could be made available via a mechanical process. In light of Matisse's claim that "all artists bear the imprint of their time," one would expect to find this new mechanical process and mass production in the works of Cézanne and Matisse. Indeed, an interesting parallel can be drawn between the technological developments and the works of the two artists. Both Cézanne and Matisse seem to perceive art as a process in itself – as something they have to work their way through just like any mechanical process. Both artists adopt a form of mass production by their insistence on depicting the same subject matter over and over again. However, at some point, the parallel between mechanical developments and the work of the two artists breaks down. Both artists face difficulties in trying to carry out their processes; in the end they seem unable to achieve a finished product. They are rarely pleased with the result, so they keep returning to the same subject matter in an attempt to complete their processes and achieve the perfect artwork. Even their mass production is an illusion given that they depict the same subject matter in slightly different ways as opposed to creating exact replicas of their work. They become like dysfunctional machines that get stuck and keep executing the same thing over and over again, slightly varied each time, in an effort to get it right. Thus, Cézanne and Matisse bear the imprint of their time in that they use the mechanical framework as means of expression but more interestingly in that they reveal the

inadequacy of that framework when dealing with art – there is in fact no mechanical process that will make everything work.

For Cézanne, painting becomes a process of understanding and expressing one's perception of nature. [3] Cézanne sees the artist as someone capable of reconstructing nature in its true form. [4] For him the artist becomes a builder. In fact, in one of his letters, he calls Michelangelo a "builder."[5] In most of his letters, Cézanne refers to his paintings as "experiments," "studies" or as a "process." [6] These words suggest a scientific or mechanical process that he has to go through before he can yield what he considers to be a perfect product. In fact, Cézanne does not depict an object as he knows it but rather as it reveals itself to him through careful observation. [7] Before painting a landscape, he breaks it down and studies its geological structure. In one of his letters he states, "Deal with nature as cylinders, spheres, cones, all placed in perspective so that each aspect of an object or a plane goes toward a central point." [8] He breaks down the landscape into simple forms and then strives to recapture it as an emerging organism. [9] Thus, Cézanne is looking for a logical process through which he can realize nature on a canvas. He defines the role of the artist as someone that penetrates what is before him and perseveres in expressing himself "as logically as possible." [10] He sees art as a slow process, noting in one letter, "The reading of a model and its realization are sometimes very slow in coming." [11]

The process, or construction, that Cézanne goes through appears in his work. According to Schapiro, in Cézanne's work one can "see the object in the painting as formed by strokes" where each stroke corresponds to a unique action. [12] In a painting of Mont Sainte-Victoire (Fig. 1), Cézanne constructs the landscape out of brushstrokes and lines. He uses patches of colors to depict the various forms and planes. Every single brushstroke seems to assist the process of seeing. Cézanne would sometimes ponder for hours before putting down a certain stroke because, as Bernard said, each stroke must "contain the air, the light, the object, the composition, the character, the outline, and the style." [13] These careful brushstrokes organize themselves before the viewer's eyes. [14] In the painting, the sense of depth is created through the use of broad interlocked layers of color. [15] In another painting of Mont Sainte-Victoire (Fig. 2), the slow transition from the vertical lines of the trees to the horizontal lines of the mountain, through many intermediate diagonal lines, creates a complex whole. [16] The play of color contrasts is a delicate means of evoking a sense of depth. The contrast of warm and cool colors changes gradually from lively combinations of green, yellow and orange in the foreground to a distant and more harmonious combination of blue and pink. The complexity of the brushwork, with its countless directional changes, depicts the modeling of the objects in all their complexity. Cézanne is putting pieces together – putting perspective and color together to create a whole. He takes a complex nature scene and tries to find a process by which to realize it on the canvas.

Cézanne painted Mont Sainte-Victoire over sixty times from different angles and using different materials (Fig. 3, 4, 5). He kept producing images of the mountain repeatedly like mass-produced items. At the time, the advancement of engineering and factories allowed useful items to be widely produced. The availability enabled more people to share in the comfort of owning things and it led to the development of a consumer society whose main characteristic was the possession of material goods. Cézanne, in a way, is mass-producing his own work. He keeps returning to the same subject matter, maybe as an attempt to possess it – to recognize and understand all of its features and to get to know it intimately.

Like Cézanne, Matisse also understands painting as a process and as a construction. Matisse's instructions to his students reveal his insistence on construction. He sees the human body as a form where every part is equally important. He asks his students to build the model "as a carpenter builds a house." [17] Interestingly enough, he uses the word "builder" to define an artist, just like Cézanne. He insists on the mechanics of construction and he gives different rules for dealing with drawing, sculpture and painting. [18] In his "Notes of a Painter," Matisse emphasizes that he needs to have a clear vision of the whole from the beginning. [19] He sees art as a process, stating that he prefers to rework his paintings. [20] He also describes a process of drawing a woman's body by first giving it grace and charm and then by emphasizing the essential lines until he arrives at a more fully human meaning. [21] Just like Cézanne, Matisse feels the need to define a process as he works through his painting. Art is not the work of an instant; instead it is a process that involves work and construction.

The construction in Matisse's work is seen through an actual transformation of motifs. The central reclining nude in Joy of Life (Fig. 6), with her arm over her head, reappears in The Blue

Nude (Fig. 7) and in his sculpture Reclining Nude (Fig. 8). He wants to take the figure out of the picture plane and perfect it in a way that only he can imagine. He converts it from a part of a group, as depicted in Joy of Life, to a single detailed figure occupying the whole canvas in The Blue Nude. Then he proceeds to turn it from a two-dimensional painting to a three-dimensional statue. It is almost as if he is going through an industrial process – first he comes up with an abstract conception of the product, as shown in Joy of Life. Then, he chooses a focus and sketches it in more detail, as in The Blue Nude. Finally, he creates the tangible, three-dimensional model. He takes the subject matter and transforms it through different materials. The transformation from sculpture to painting and vice versa is reminiscent of a mechanical process where the engineer moves from a paper sketch to a three dimensional implementation of the object. Thus, Matisse is working almost like an engineer.

Matisse also shares in Cézanne's repetitive nature. The same nude figure from Joy of Life, in addition to being transformed into a statue, appears in about nine other paintings as a still life ornament. We see it in Still Life with Pewter Jug and Pink Statuette (Fig. 9) as a little ornamental statuette. Then it reappears in Goldfish and Sculpture (Fig. 10). Also, this same figure appears in Large Reclining Nude (Fig. 11) in a slightly different position. Matisse, like Cézanne, cannot escape his subject matter. He is trapped in the need of producing more of it and in the need of capturing it and understanding it. The fact that he depicts the same figure repeatedly reveals a special connection with the figure – it reveals an obsession with his subject matter and a need to see it transformed into something more than a mere image. Matisse seems to be visualizing his subject matter from all angles and all sides.

However, there is a problem with Cézanne and Matisse's mechanical processes. In an ideal mechanical process, the goal is realized and the process eventually ends. In mass-productions, the products are identical – replicas of the one perfect end result. This is not the case with Cézanne and Matisse, as there is never an end to their processes. Both artists are dissatisfied with the end result of each of their processes. They keep working on their creations, hoping that this time they will get it right.

Cézanne notes in one of his letters, "The painting proceeds willy-nilly. Sometimes I am quite carried away, and more often I am sadly disappointed." [22] In yet another occasion he puts off sending a painting to the Salon because he is unhappy with the final result. [23] In his letters, Cézanne repeatedly mentions how difficult and painful the process of painting is. He constantly reminds his readers how slowly he is progressing in his studies. He is often dissatisfied and frustrated, which could explain the many times he paints the same subject. It is all part of a process to realize the perfect end result. However, that day never seems to come, and in his letters we see a constant dissatisfaction with his work and a need to continue working on his process. Like Cézanne, Matisse states that even though he might be satisfied with work completed in a single sitting, he will soon tire of it. It will no longer please him so that he will have to rework it. [24]

Both Cézanne and Matisse seem unable to complete their processes. It is understood that in an industrial process, the end result will be a finished product ready for use. In the case of the artists, the finished product would be a painting ready for exhibition. For Cézanne, the notion of the unfinished is literal in that he does not finish all of his paintings and he sometimes leaves white unpainted spaces on the canvas. In one of his watercolors of Mont Sainte-Victoire (Fig. 4), most of the canvas is left untouched so that the image appears transparent. There are missing parts and holes in the painting that qualify it as an unfinished product in a world of finished goods. For Matisse, the fact that he keeps going back to the same subject matter, the reclining nude, and depicting it in different ways suggests that he is dissatisfied with the original. He is dissatisfied with every attempt at making that figure, thus, every one of those figures can be considered unfinished. Every new depiction of the reclining nude seems to suggest that the previous depiction was a preparatory step, an unfinished composition leading to the new painting.

Every time the artists go back to their motifs, they represent those motifs differently. Each time Cézanne represents the mountain differently in an attempt to capture its completeness and its three dimensional nature. He paints the mountain from nearby (Fig. 3), and then he paints it from a point further away (Fig. 1, 2, 4, 5). He paints it using thick, dark oil paints (Fig. 3, 5), and then using light watercolor (Fig. 4). The various paintings seem to complement each other. Mass-production means producing the same thing over and over again for wide use. Cézanne, however, is not producing the same thing. He depicts the same object in a slightly different manner, suggesting his inability to actually achieve a finished product. Cézanne's mass-production is a production of fragments of the same product. All the paintings

taken together give a more complete picture of the subject matter.

The same is true for Matisse's work. His depictions of the nude complement each other in that they all appear as parts of the same object. In The Blue Nude the viewer sees the figure on her side and in Large Reclining Nude she sees her on her other side (Fig. 7, 11). In Reclining Nude the viewer sees her from all sides as a three-dimensional object (Fig. 8). Because these figures are only slightly different, they come across as the exact same object interpreted in different ways. They are not mere replicas of the original, but they are parts of the original. They reveal new aspects of the original figure. The construction is an ongoing one and the figure keeps developing through Matisse's work.

The relationship of the artists with the mechanical process is an ambivalent one. They seem to be willing, whether it is consciously or unconsciously, to use the mechanical as means of expression. They use it as a framework for structuring their views on art and their artistic techniques. However, the artists are not perfect machines and the process does not work as planned. The record gets stuck and we keep hearing the same tune. Only it is not the exact same tune. The artists' will to achieve their goals, despite their limited means, enables them to create different images of the same thing. Their will enables them to interpret their subject matter in a unique way. By appearing to be dysfunctional machines they demonstrate that notions like the perfect finished product may, in fact, not exist – in the world of art, everything may be an experiment that can be studied and developed but never completed.

Works Cited

1 Henri Matisse, "Notes of a Painter," Theories of Modern Art (Berkeley, University of California Press, 1968) 136.

2 Georg Simmel, "Metropolis and Mental Life," Georg Simmel: On Individuality and Social Forms. Selected Writings (Chicago – London: The University of Chicago Press, 1971) 327.

3 Judith Wechsler, The Interpretation of Cézanne (Michigan: UMI Research Press, 1972/1981) 1.

4 John Rewald, ed. Paul Cézanne: Letters (New York: Hacker Art Books, Inc. New York, 1984) 297.

5 Rewald 304.

6 Rewald all.

7 Wechsler 62.

8 Rewald 296.

9 Maurice Merleau-Ponty, "Cézanne's Doubt," Sense and Non-Sense (Evanston, IL: Northwestern University Press, 1964) 17.

10 Rewald 298.

11 Rewald 255.

12 Meyer Schapiro, Paul Cézanne (New York: Harry N. Abrams, INC, 1952) 19.

13 Merleau-Ponty 15.

14 Merleau-Ponty 14.

15 Schapiro 74.

16 Schapiro 66.

17 Alfred H.Barr, Matisse: His Art and His Public (USA: The Museum of Modern Art, NY, 1951) 550.

18 Barr 550.

19 Matisse 134.

20 Matisse 132.

21 Matisse 132.

22 Rewald 279.

23 Rewald 282.

24 Matisse 132.

The images mentioned in this paper may be found in the following sources:

1: Cézanne, Paul. Mont Sainte-Victoire. Courtauld Institute of Art, London. Arthistory.cc. Cézanne, Paul: The Mont Sainte-Victoire and Bibemus Saga. http://www.arthistory.cc/auth/cezanne/st-victoire/. 15 November 2000.

2: Cézanne, Paul. Mont Sainte-Victoire. The Metropolitan Museum of Art, New York. Arthistory.cc. Cézanne, Paul: The Mont Sainte-Victoire and Bibemus Saga. http://www.arthistory.cc/auth/cezanne/st-victoire/. 15 November 2000.

3: Cézanne, Paul. Mont Sainte-Victoire seen from the Bibemus Quarry. The Baltimore Museum of Art. Arthistory.cc. Cézanne, Paul: The Mont Sainte-Victoire and Bibemus Saga. http://www.arthistory.cc/auth/cezanne/st-victoire. 15 November 2000.

4: Cézanne, Paul. Mont Sainte-Victoire. The Museum of Modern Art, New York. Arthistory.cc. Cézanne, Paul: The Mont Sainte-Victoire and Bibemus Saga. http://www.arthistory.cc/auth/cezanne/st-victoire/. 15 November 2000.

5: Cézanne, Paul. Mont Sainte-Victoire Seen from Les Lauves. Kunstmuseum, Basel. Arthistory.cc. Cézanne, Paul: The Mont Sainte-Victoire and Bibemus Saga. http://www.arthistory.cc/auth/cezanne/st-victoire/. 15 November 2000.

6: Matisse, Henri. Joy of Life. Barnes Foundation, Merion. Arthistory.cc. Matisse, Henri. http://www.arthistory.cc/auth/matisse/. 18 November 2000.

7: Matisse, Henri. The Blue Nude. The Baltimore Museum of Art. William M. Brinton's Online History Books. Index of Plates. http://www.european-history.com/matisse.html#blueNude. 18 November 2000.

8: Matisse, Henri. Reclining Nude. The Baltimore Museum of Art. Alfred H. Barr, Matisse: His Art and His Public (USA: The Museum of Modern Art, NY, 1951) 337.

9: Matisse, Henri. Still Life with Pewter Jug and Pink Statuette. Henri Matisse Galerie d'Arte. http://victorian.fortunecity.com/pollock/146/s18.htm. 19 November 2000.

10: Matisse, Henri. Goldfish and Sculpture. Private collection. Henri Matisse Galerie d'Arte. http://victorian.fortunecity.com/pollock/146/g4.htm. 19 November 2000.

11: Matisse, Henri. Large Reclining Nude. The Baltimore Museum of Art. The Cone Collection. http://www.artbma.org/collection/cone/cone_html.html. 20 November 2000.

Note: The general historical context for the paper was provided by Professor Leah Dickerman's class Art 145 – Making the Modern, Fall 2000 - 01. Rebecca Gertmenian and Gabriela Muller read and offered suggestions for the paper.

Asymptotic Quantization: A Method for Determining Zador's Constant

Joyce Shih

Because of the finite capacity of modern communication systems, better methods of encoding data are required. Quantization refers to the methods by which analog signals are converted into digital representations and compressed, thereby making them suitable for storage. The asymptotic optimal performance of vector quantizers of fixed dimension and large rate was first developed in a rigorous fashion by Paul Zador. This paper describes a Lagrangian formulation of Zador's quantization results and applies it to estimate Zador's constant. Knowledge of Zador's constant may improve current quantizer design techniques by providing theoretical performance bounds.

"By applying the Lloyd clustering algorithm to a Lagrangian formulation of Zador's result, it is possible to obtain numerical estimates of Zador's constant."

Introduction

With the growth of the internet and digital media, data compression is becoming increasingly important due to the overwhelming abundance of information that computer users wish to transmit and store. Quantization refers to the methods by which analog signals, such as speech, music, and images, are converted into digital representations and compressed, thereby making them suitable for storage. One of the primary approaches currently employed in analyzing fundamental limits of quantizer performance is Paul Zador's high-rate quantization theory, which characterizes the optimal achievable performance of systems with fixed dimension and large rate in terms of a constant, $b_{2,k}$.[1]

By applying the Lloyd clustering algorithm to a Lagrangian formulation of Zador's result[2], it is possible to obtain numerical estimates of Zador's constant.[3] Knowledge of this constant may improve current quantizer design techniques by providing theoretical performance bounds. This paper presents the results of numerical simulations employed to obtain estimates for the value of Zador's constant in the first through fourth dimensions. In addition, the calculated value of Zador's constant for an infinite dimension system is given.

Quantization

Because of the finite capacity of modern communication systems and digital storage, better methods of encoding data are required. The goal of quantization is to characterize the input data using as few bits as possible in such a way that reproduction may be recovered from the bits with as high quality as possible. One of the earliest examples of quantization is "rounding off"; any real number can be rounded off to the nearest integer and coded as that integer. This example of scalar quantization can effectively take an infinite set of real values and approximate, or "compress," them by mapping that set onto a finite set of discrete values.

Vector quantization (VQ) is an extension of scalar quantization to multiple dimensions; it is a compression method that works by mapping each k-dimensional input vector onto one of a finite number of k-dimensional reproduction vectors. A 2x2 pixel set or image would be an example of a 4-dimensional input vector.

A vector quantizer system, q, is comprised of two functions, an encoder and a decoder, which are designed using the Lloyd Algorithm.[4] The encoder α_k examines the input source X, blocks it into vectors of length k, and maps each vector onto a codeword in the codebook, C. The codeword is then sent through the channel, after which the decoder β_k maps the codeword onto its corresponding reproduction vector.

The encoder α_k can be decomposed into two parts, $\alpha_\kappa = \gamma \circ \alpha$. In the first step, α maps the signal input onto the reproduction vector in the codebook that best matches it. In the second step, γ converts the reproduction vector into a codeword. Similarly, the decoder can be broken down into $\beta_\kappa = \beta \circ \gamma^{-1}$, where γ^{-1} associates the codeword with its corresponding vector in the codebook, and β outputs the reproduction vector. The coder $(\alpha_\kappa, \beta_\kappa)$ can thus be rewritten as (α, γ, β). This is represented pictorially in Figure 1.

The quality of a k-dimensional vector quantizer q can be measured in terms of its distortion, which quantifies the loss of information resulting from approximating X, the input source, as Y_i, the code (reproduction) vector. For the sake of simplicity, we take the distortion to be the mean-squared difference,

$$d(X, Y_i) = \| X - Y_i \|^2 = \sum_{l=0}^{k-1} | X_l - Y_{i,l} |^2, \quad \textbf{(1)}$$

between the input source X and the reproduction vector Y_i, where the subscript i refers to the i^{th} reproduction vector in the codebook, l is the number of bits used to represent each source vector, and k is the dimension. Typically we are interested in the performance of an algorithm given a variety of input signals. We thus define an average distortion:

$$D_f(q) = \sum_i \int_{S_i} f(x) \| X - Y_i \|^2 dx, \quad \textbf{(2)}$$

where $f(x)$ is the probability distribution function that describes the likelihood that the source X will correspond to a given reproduction vector x, and S_i is the i^{th} codeword (i.e., the codeword that corresponds to the reproduction vector x).

While distortion measures the fidelity of a quantizer, rate measures its "cost:" the number of bits required to express the codeword for transmission to the decoder via the channel. The average rate of a quantizer is given by

$$R_f(q) = \sum_i p_f(S_i) l(i), \quad \textbf{(3)}$$

where $p_f(S_i)$ is the probability of using the i^{th} codeword S_i, and $l(i)$ is the "cost" (i.e., length in bits) of the i^{th} codeword.

The optimality of a quantizer q is determined by both its distortion and rate (i.e., its quality and cost), which can be expressed as

$$\rho(f, \lambda, q) = D_f(q) = \lambda R_f(q), \quad \textbf{(4)}$$

where f is the probability distribution function (p.d.f) which characterizes the input source and λ is a Lagrange multiplier which quantifies the importance of rate relative to distortion for a given application. If λ is small, it allows a large rate (i.e., high cost or long codeword length), so a larger codebook can be used and the distortion introduced by compression will be minimal. Conversely, if λ is large, the rate must be small, because cost is critical. In this case, a high degree of compression is key, and quality of the reproduction (i.e., information loss or distortion) is less important. For the purposes of this paper, we will limit ourselves to considering systems in the large rate limit (i.e., small values of λ and little distortion).

The classic approach to describing optimal performance is in terms of the distortion-rate function. For rate greater than zero (i.e., $R > 0$), the operational distortion-rate function is defined as $\delta_f(R) = \inf_{q: R_f(q) \le R} D_f(q)$. Zador proved that under certain conditions on the p.d.f. f,

$$\lim_{R \to \infty} 2^{\frac{2}{k}R} \delta_f(R) = b_{2,k} 2^{\frac{2}{k}h(f)}, \quad \textbf{(5)}$$

where $b_{2,k}$ is Zador's constant, which depends only on k and not on f, and $h(f) = -\int f(x) \log f(x) dx$ is the differential entropy[3] of f. While the exact value of $b_{2,k}$ is known for $k = 1$, only upper and lower bounds are known for higher dimensions (although it is known that it converges as $k \to \infty$). Therefore, the goal of this project was to compute values for Zador's constant (i.e., $b_{2,k}$) for dimensions greater than one by writing a computer program to perform entropy-constrained vector quantization (ECVQ) simulations. A summary of the quantizer terms is presented in Table 1.

The ECVQ Algorithm

The ECVQ algorithm[5] employed in this research uses the Lloyd algorithm mentioned earlier to design vector quantizers with the least possible distortion subject to a constraint on rate or entropy. Unlike other quantization algorithms, ECVQ jointly optimizes both the rate R and distortion D rather than optimizing each quantity separately. ECVQ works by minimizing the Lagrangian functional,

$$\rho_\lambda(\alpha, \beta) = E\left[d(X, \beta(\alpha(x))) + \lambda | R(\alpha(X)) | \right], \quad \textbf{(6)}$$

where $\beta(\alpha(X))$ is the overall

quantization operation on the input source X, to find the optimal coder. At the cost of higher complexity, ECVQ generally outperforms other entropy-coded quantization schemes, including the scalar uniform threshold, lattice, and constrained number-of-indexes vector quantization schemes.

The ECVQ algorithm consists of four main steps. In the first step, the algorithm obtains an initial reproduction codebook or input source. Since Zador's constant is independent of the distribution, simulations were first performed using the simplest possible nontrivial distribution, a uniform distribution on the k-dimensional unit cube, which puts equal weight on integers between 0 and 1. Later simulations were also performed using a Gaussian distribution,

$$f = e^{-(x-\mu)^2/2\sigma^2},$$

where μ is the mean and σ is the standard deviation, in order to verify that the results were in fact independent of the distribution used. The second step in the ECVQ algorithm involves training the codebook for each value of λ. For decreasing values of λ, the algorithm was run until it met a stopping criterion,

$$\left(\frac{\rho_{old}-\rho}{\rho} > 0.005\right), \textbf{(7)}$$

In the third step, the encoder maps each input vector onto the nearest codeword in the codebook by finding the codeword that minimizes ρ (and hence the distortion):

$$\alpha(X) = \arg\min_{i\in I}\begin{bmatrix} d(X,\beta(i)) \\ +\lambda \mid R(i) \mid \end{bmatrix}, \textbf{(8)}$$

Equation **(8)** is analogous to nearest neighbor encoding in standard vector quantization (VQ). However, in ECVQ the rate for the particular codeword chosen is updated by

$$\| R(i) \| = \log_2(1/p(i)), \textbf{(9)}$$

where $p(i) = P\{\alpha(X) = i\}$. The final step requires the decoder given by

$$\beta(i) = \arg\min_{Y\in v} E\begin{bmatrix} d(X,Y_i) \\ \mid \alpha(X) = i \end{bmatrix}, \textbf{(10)}$$

to compute the conditional expectation of the distortion between the output and the input, given that the encoder produced index *i*. It effectively computes an average or centroid of all the vectors mapped to a particular cell (i.e., codeword) thus far. This centroid will continue to evolve as more data is mapped to each of the cells. The ECVQ algorithm is summarized in Table 2.

Computing Zador's Constant

We say that a probability distribution function *f* exhibits the *Lagrange-Zador property* if the following limit exists:

$$\lim_{\lambda\to 0}\left(\frac{\rho(f,\lambda)}{\lambda} + \frac{k}{2}\ln\lambda\right) - h(f) = \theta_k, \textbf{(11)}$$

where θ_k depends only on the dimension, not on the p.d.f. The Zador constant, $b_{2,k}$, and θ_k are related by

$$\theta_k = \frac{k}{2}\ln\frac{2e}{k}b_{2,k}, \textbf{(12)}$$

Therefore,

$$\theta_k = \frac{k}{2}\ln\frac{2e}{k}b_{2,k} = \frac{\rho(f,\lambda,q)}{\lambda} + \frac{k}{2}\ln\lambda - h(f)$$
$$= \frac{D_f(q)}{\lambda} + R_f(q) - h(f) + \frac{k}{2}\ln\lambda \quad , \textbf{(13)}$$

For the special case of a uniform distribution function, $h(f) = 0$. Examining Equation **(13)**, it can be seen that it is possible to calculate $b_{2,k}$ if the values of D_f and R_f are first obtained via computer simulations running the ECVQ algorithm.

Results

Estimates of Zador's constant obtained from computer simulations are reported in Table 3 for k = 1 through 4. For comparison purposes, the upper and lower bounds for dimensions two through four, along with the exact value of Zador's constant for a one-dimensional system, are also given. Because Zador's constant is independent of the probability distribution function, the simulations were run using a uniform distribution for simplicity. In performing the simulations, both the codebook size and the number of training vectors were varied as detailed below.

For dimensions 1, 2, and 3, the codebook size was held constant at 1024. For dimension 1, the test was run five times with 50,000 training vectors, once with 100,000 training vectors, and three times with 250,000 training vectors. The average value obtained for $b_{2,1}$ from these simulations was 0.08323, which deviates from the actual value by 0.1%. Because algorithm performance improves as codebook size increases, we focused on 250,000 training vectors for the second dimension. The test was run seven times with 250,000 training vectors and once each with 50,000, 100,000, and 500,000 training vectors. The tests gave an average value of 0.07918 for $b_{2,2}$, which differs from Zador's constant for fixed rate coding by 1.3%. Although it is not known whether the values of $b_{2,2}$ for the fixed rate and variable rate cases are identical, it has been conjectured that the two constants are the same. For k = 3, eight simulations using 250,000 training vectors and two simulations using 500,000 training vectors were run. The results gave an average value of 0.079 for $b_{2,3}$, which falls within the known upper and lower bounds.[5]

For dimension 4, seven simulations using 250,000 training vectors and another three simulations using 500,000 training vectors were run with a codebook size of 1024. In addition, a single simulation was run utilizing 500,000 training vectors and 2048 codewords. The average value of $b_{2,4}$ obtained from these simulations was 0.07776, which again falls within the known upper and lower bounds.[5]

As mentioned earlier, Zador's constant is independent of the probability distribution function. However, to check that the simulation results were in fact independent of the probability distribution function used, simulations were also performed for the first dimension using a Gaussian distribution function. Ten tests were run using 250,000 training vectors and 1024 codewords. The value obtained for $b_{2,1}$ from these simulations was 0.0835, which agrees well with both the actual value of 0.0833 and the value of 0.08323 obtained from the simulations performed using a uniform distribution function. Thus, it appears that the choice of a uniform distribution did not bias the results.

For the infinite case $b_{2,\infty}$, can be calculated by using Zador's result,[4]

$$\frac{1}{1+\beta} V_k^{-\beta} \le k b_{2,k} \le \Gamma(1+\beta) V_k^{-\beta}, \quad \textbf{(14)}$$

where $\beta = \frac{r}{k}$ and $r = 2$ for mean squared error; $\Gamma(x)$ is the gamma function, and V_k is the volume of a unit sphere in k dimensions. The infinite case shows $b_{2,k}$ converges upon the value 0.05854.

Discussion

As stated above, the goal of quantization is to convert continuous signals into bits in a way that optimally trades off distortion or signal to noise ratio (SNR) with bits. Quantization theory provides quantitative relations between distortion and bit rate under certain assumptions. For example, the famous "6-dB-per-bit-rule" describes how the SNR for a uniform scalar quantizer with high rate and low distortion increases 6dB for each one bit increase of rate. Ideally, we would like to minimize both distortion and bit rate, but each can be decreased only at the expense of increasing the other and hence it is the tradeoff that matters. Zador characterized the tradeoff under quite general conditions for the "high rate" case where the bit rate is high and the distortion small, the situation arising in most modern analog-to-digital converters.

Zador's constant can be viewed as a fundamental constant of nature. It describes the relationship between distortion and rate in a manner similar to the way pi describes the relationship between the circumference and radius of a circle. However, unlike pi, the exact value of Zador's constant is only known in the first dimension. Estimating the constant in higher dimensions is of interest because it allows the application of theoretical results to predict the performance of vector quantizers on real world signals.

Conclusion

Quantization is in essence analog to digital conversion for the purpose of storage in a digital channel. Quantization is becoming increasingly essential as digitization and the internet require improved methods of conserving memory and storage space. Starting with the Lagrangian formulation of Zador's results, the generalized Lloyd ECVQ algorithm has been employed to estimate Zador's constant for k = 1 through 4 in hopes that knowledge of Zador's constant may lead to improved quantizer design techniques.

Works Cited

[1] Zador, PL. Topics in the Asymptotic Quantization of Continuous Random Variables. Bell Lab Tech Memo 1966.

[2] Gray, RM, Linder, T, Li, J. A Lagrangian Formulation of Zador's Entropy-Constrained Quantization Theorem. IEEE Trans Inform Theory 2002; (in press).

[3] Shih, J, Aiyer, A, Gray, RM. A Lagrangian Formulation of High Rate Quantization. IEEE Int Conf Acoustics Speech and Signal Processing 2001;1-4.

[4] Gersho, A, Gray, RM. Vector Quantization and Signal Compression. Norwell: Kluwer Academic Publishers, 1992: 9-13.

[5] Gersho, A. Asymptotically Optimal Block Quantization. IEEE Trans Inform Theory 1979; 25: 373-380.

[6] Chou, PA, Lookabaugh, TD, Gray, RM. Entropy-Constrained Vector Quantization. IEEE Int Conf Acoustics Speech and Signal Processing 1989; 37:31-41.

Figure 1: A Communication System

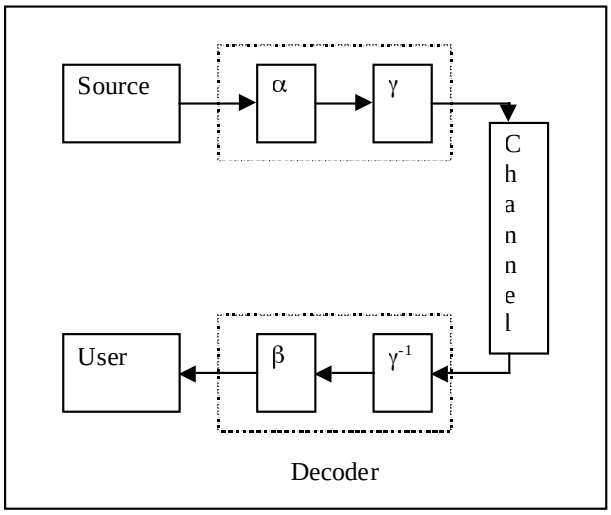

Table 1. Summary of Quantizer Terms

Term	Definition
Distortion	Quantifies the difference between the input source and the reproduction vector. Distortion measures the fidelity of the quantizer.
Rate	Rate measures the cost or number of bits required to express a codeword.
Optimality	The optimality of a quantizer depends on its distortion and rate. This value can be expressed as $\rho(f,\lambda,q) = D_f(q) + \lambda R_f(q)$, where λ quantifies the importance of rate relative to distortion.

Table 2. ECVQ Algorithm

Steps	Description	Formula
(1)	Obtain an initial reproduction codebook.	
(2)	Train the codebook for each λ.	
(3)	The encoder maps each input vector onto the nearest codeword in the codebook that minimizes the cost.	$\alpha(X) = \arg\min_{i \in I}\left[d(X,\beta(i)) + \lambda \mid R(i) \mid\right]$
(4)	The decoder computes the centroid for each codeword or cell based upon all the input vectors mapped onto that codeword or cell.	$\beta(i) = \arg\min_{Y \in v} E\left[d(X,Y_i) \mid \alpha(X) = i\right]$
(5)	Repeat steps 1-4 until stopping criterion has been reached.	$\left(\frac{\rho_{old} - \rho}{\rho} > 0.005\right)$

Table 3. Values and Bounds for Quantization Coefficients $b_{2,k}$

K	Sphere Lower Bound	Actual Value	Simulation Value	Cube Upper Bound	Zador Upper Bound
1	0.08333	0.08333	0.08323	0.08333	0.5
2	0.07958		0.07918	0.08333	0.5
3	0.07697		0.07900	0.08333	0.1157
4	0.07503		0.07776	0.08333	0.09974
∞	0.05854	0.05854			

Author Biographies

Ulrike Buschbacher

Ulrike Buschbacher was born in Berlin, Germany and moved to the US in 1991, with her parents and older brother. She is a senior graduating from the English department and receiving Honors from the Interdisciplinary Studies in Humanites Department. She is currently pursuing a coterm in English as well, but is taking a year off to accept a teaching fellowship in London. Her academic interests are in American modern literature and American cultural studies. Since the summer of 2001, and with the aid of an URO grant, Ulrike has been working on her honors thesis, which studies the manifestation of the American Dream ideology in fiction and in film in the last two decades. She would like to thank Prof. Gigante for all of her invaluable help and guidance.

Mentor: Professor Denise Gigante

Susan Cameron

Susan Cameron is a junior double majoring in Art History and English because she loves the symbiotic relationship of art and literature. She grew up in Abilene, Texas and attended high school at Phillip's Exeter Academy in New Hampshire. Susan has been President of Stanford Environmental Representative for two years. She has coordinated the campus-wide Earth Week celebration each year, thereby learning the importance of patience and perseverance. She engages her creative side by being the Poetry Editor of *The Mind's Eye* literary magazine. Next year she takes the reins as Editor in Chief of this lively publication of Stanford's best poetry, prose, and art. During the summers she loves volunteering as head cabin counselor at Camp Sanguinity, a camp in Texas for children with cancer and blood disorders. She studied abroad in Florence this autumn, where she fell head over heels in love with Italian art, literature, food, and general *moda di stare*. She hopes to one-day work as a legal representative for a major museum, gallery, or auction house. Above all, she hopes her way is long to Ithaca, as Cavafy once said. Special thanks to Jody Maxmin, Alex Nemerov, and Wanda Corn for their guidance and inspirational teaching, and to my family and friends for too many things to name.

Mentors: Professor Jody Maxmin; Professor Wanda Corn; Alex Nemerov

Sara Ferry

Sara Ferry graduated salutatorian from Chaffey High School of Ontario, California in 2000, and since has been admitted to Stanford University. Currently in her sophomore year at Stanford, Sara is pursuing a B.A. in Religious Studies with honors along with a minor in Jewish Studies. Sara specializes in the study of both Classical Judaism and Early Christianity, with particular interests in biblical languages and the Dead Sea Scrolls. Since coming to Stanford, Sara has been the recipient of several research grants that have supported her continued study of the Dead Sea Scrolls. Sara has also had the opportunity to work as a Research Assistant for Professor Arnold Eisen within the Religious Studies department at Stanford, and act as a writing tutor for the Undergraduate Advising Center on campus. Next fall, Sara plans to pursue an intensive analysis of the language of purity within various scrolls found at Qumran through a tutorial at Oxford University. Additionally, she will begin preliminary work on her honors thesis that will examine the connection between purity and eschatology at Qumran.

Mentor: Professor Robert Gregg

Michael Fyall

Michael Fyall is a senior set to graduate in June with a degree in Management Science and Engineering. He has been a member of the Stanford Rugby team for four years and was a starter on this years Division II National Championship squad. During his sophomore and junior years, Michael played keyboard for the jazz and funk group En Fuego. He is also an active member of the Sigma Chi Fraternity and held the leadership positions of Alumni Chair and Financial Manager. Michael's research with the Virtual Design Team at Stanford started with the sophomore seminar "Discovering Micro-Organization Theory for Fast-Paced Project Teams." He has worked with Professor Levitt as a research assistant for the past three years and was the teacher's assistant to the seminar his junior year.

Mentor: Professor Raymond Levitt, CEE

Brenna Hearn

Brenna Hearn, originally from Aiken, South Carolina, is currently a junior at Stanford University and majoring in mechanical engineering. Brenna's interest in engineering began with a love of physics at the South Carolina Governor's School for Science and Mathematics and was increased through her participation in the Stanford Summer Engineering Academy in 1999. Participating in biomechanics research at the Stanford Biomotion Research Laboratory through the Summer Undergraduate Research Institute this past summer, Brenna has become interested in investigating injury prevention using mechanical engineering concepts. For the past year, Brenna has been working in the Stanford Biomotion Research Laboratory, conducting biomechanics research under Professor Thomas Andriacchi. Brenna has focused in two areas: sports injury prevention (specifically ACL injury and stress fractures) and an investigation of the biomechanics of the knee during cycling. Her work on dynamic changes in translation and rotation of the knee during bicycling was presented this past fall at the 2001 American Society of Biomechanics meeting by co-author Chris Dyrby. Her most recent research involves developing a process that would allow characterization of patterns in running and cutting styles using conventional digital video cameras. Outside of academia, this year Brenna is the president of the Stanford Engineering Association, the Social Manager at Synergy, a Writing Tutor Peer Academic Advisor through the Undergraduate Advising Center, and is active in the Society of Women Engineers (SWE), having recently been elected Co-President of SWE for the 2002-2003 year. Brenna wishes to express her gratitude to Dr. Thomas Andriacchi, Dr. Gene Alexander, Chris Dyrby, Ajit Chaudri, Rich Bragg, and the entire Biomotion Lab Group for the opportunity to work with them and her family and friends for their continual support.

Mentors: Chris O. Dyrby, Eng.; Thomas P. Andriacchi, Ph.D.

Alison Kamhi

Alison Kamhi was raised in Memphis, Tennessee by her parents, Dr.'s Alan and Beth Kamhi. She has a sister, Franne, and two cats, Clio and Mendelsohn. Alison is now a junior at Stanford University, majoring in Modern European History with a double minor in Linguistics and German Studies. Her academic interests include European colonial relations, the concept of national identity, and the perspective of written vs. oral histories. She used a Presidential Scholar's Grant to support her research in Madagascar during the summer of 2001. The following semester, she enrolled in the Vassar-Wesleyan Program in Paris and continued her study of French colonial relations at the Sorbonne and the Dénis Diderot Université in Paris. After returning to Stanford winter quarter to synthesize her research in Madagascar and France, Alison is currently enrolled in the Stanford in Berlin Spring Program in Germany and beginning work on her Senior Honors Thesis on East German perceptions of Western history.

Mentors: Dr. Richard Roberts; Dr. Susan Kus; Dr. Pier Larson; Dr. Erik Smith; Dr. Lesley Sharp; Dr. Gerry Berg

Marina Kassianidou

Marina Kassianidou was born and raised in Cyprus, a beautiful island in the Mediterranean. In 1998, she was awarded a CASP/AMIDEAST (Cyprus American Scholarship Program) scholarship to study in the United States. She first came to Stanford in September 1998 and received the 1999 President's Award for Academic Excellence in the freshman year. After two years and many classes, she has decided to major in Computer Science and Studio Art and will graduate in June of 2002. Marina has taken painting and art history classes both at Stanford and at the London Institute of Art and Design in the UK. Her paintings and drawings have appeared in several student exhibitions in Cyprus and in Stanford student publications. Within the field of Computer Science, she is interested in Human Computer Interaction and the reasons why there are so few women in Computer Science. This year, she co-authored an article with Professor Eric Roberts and Stanford senior Lilly Irani discussing ways in which Computer Science departments can increase recruitment and retention of female students. This article will appear in a special issue of *Inroads*, the ACM SIGCSE (Special Interest Group in Computer Science Education) bulletin this summer. Next year Marina will pursue a Master of Science degree in Computer Science at Stanford.

Mentors: Professor Leah Dickerman; Rebecca Gertmenian; Gabriela Muller

Thomas Loverro

Thomas Loverro is a junior from East Hampton, NY. He is a Political Science major with a focus in International Relations and a History minor. Currently he is studying abroad at Oxford where he has been since the start of the winter quarter. He is very interested in government social policy, especially relating to education and genetic engineering. In his free time, Tom is usually either windsurfing or attending a Stanford sports event.

Fred Luminoso

Fred Luminoso is a senior majoring in economics and mathematical and computational science. He has competed on the varsity wrestling and crew teams and next year will pursue a co-terminal master's degree in management science and engineering. His career goals include becoming a military officer and writer. Funding for this research was made possible through the Summer Undergraduate Research Fellowship program in the School of Engineering at Stanford University. The author wishes to extend special thanks to Professor Ross Shachter of the Department of Management Science and Engineering and Professor John Donohue of the School of Law, both of whom provided substantial assistance in the production of this work.

Mentors: Professor Ross Shachter; Professor John Donohue

Michael Osofsky

Michael Osofsky is currently a junior majoring in psychology with a minor in cultural and social anthropology. While at Stanford, Michael has received several awards including the Dean's Award for Academic Achievement and has been a student speaker for the Campaign for Undergraduate Education. Michael is currently the Deputy Chair of the ASSU Undergraduate Senate, and has been in an ASSU leadership role since his freshman year. Within the psychology department, Michael is a member of Psi Chi, the national psychology honors society, is President of the Stanford Undergraduate Psychology Association, and has been a Director for the first-ever Stanford Undergraduate Psychology Conference. Michael has conducted research under Professors Philip Zimbardo, Albert Bandura, Claude Steele, and Andrew Walder. Michael has presented his research to the American Psychiatric Association and at a global symposium in Switzerland. His findings will be featured in *Psychology Today* this year with a companion piece from Professor Zimbardo.

Mentor: Dr. Philip Zimbardo

Amrit Rao

Amrit Rao is currently a freshman who will most likely major in Biological Sciences. His career in college-level research began when he was a sophomore in high school, when he joined Dr. Kevin Montgomery and Dr. Michael Stephanides at the Stanford/NASA National Biocomputation Center in the summer of 1999. Since then, he has assisted in or worked independently on a variety of projects including a study on the mechanical properties of microvessels, computerized cleft lip reconstruction, and the three-dimensional visualization of patient CT data for surgical planning purposes. He is currently studying temporomandibular disorders under Dr. Sabine Girod. Aside from doing research, Amrit is involved in the Hindu Students Council and Project Redistribute. He lives in Saratoga, CA, with his parents, sister, and cat (Cleo).

Mentors: W. Paul Brown, DDS.; Kevin Montgomery, Ph.D.; Michael Flynn, Ph.D.; Eric Herbranson

Ashwini Sagar

Ashwini Sagar will be graduating from Stanford University in June, 2002 with Honors in Psychology and a minor in Feminist Studies. Next year, she will be completing her masters thesis at Columbia University, receiving an M.S. in Human Nutrition. Ashwini will be attending medical school following that, working towards a career in OB/GYN or Psychiatry. Her undergraduate research and course work have focused on women's health and issues of mind/body wellness. She has also been a staff member at the Stanford Women's Center for 3 years focusing on women's health outreach. Ashwini is a researcher in the lab of Dr. Hans Steiner, in the Department of Psychiatry at Stanford Medical Center. Their work focuses on the interface of psychosocial and medical problems, with an emphasis on juvenile wellness and adolescent health. Her particular research is on eating disorders, and she is currently completing a chapter on "Bulimia Nervosa" for a textbook on child and adolescent psychiatry. At Stanford, she has received the Stanford Dean's Award for Academic Achievement, the Asian American Woman's Award, the Stanford in Government Civic Award, the James Lyons' Award for Service Excellence, and was recently named one of the top 15 college women of 2001 by Glamour Magazine. Ashwini loves hanging out with her friends, teaching aerobics, and shopping!

Joyce Shih

Joyce Shih is currently a senior majoring in Electrical Engineering with an emphasis in signal processing. She first became interested in Electrical Engineering because of an interesting introductory course on the subject taught by Professor Robert Gray, who challenged his students to use their analytical skills to solve practical problems. He later became Joyce's mentor in the Stanford Research Experience for Undergraduates (REU). Under his mentorship, she studied the theoretical performance bounds of current quantizer design techniques through calculating Zador's constant, a fundamental constant of nature. She presented her research findings in a coauthored paper titled, "A Lagrangian Formulation of High Rate Quantization" for IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2001. She has also been a poster presenter at the Stanford Electrical Engineering Research Fair and 1st runner up at the Society of Women Engineer's (SWE) National Technical Paper Presentation Competition 2001. Besides her research interests, she has traveled to Bolivia with her church group, runs regularly with friends, and will compete in the Miss California pageant in July.

Mentors: Professor Robert M. Gray; Anuradha Aiyer, Ph.D.