NDSU

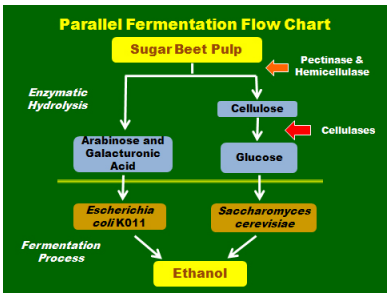
North Dakota State University
College of Engineering and Architecture

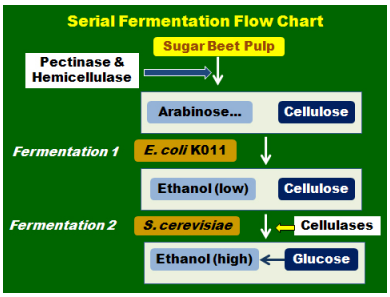
2010 Faculty Research Interests

Contents

This document was compiled in January 2011 by the CEA Research and Graduate Committee, Mike Christenson, chair (mike.christenson@ndsu.edu)

Agricultural and Biosystems Engineering





Enzymatic Pretreatment of Sugar Beet Pulp for Ethanol Production

Investigators: Scott Pryor

Department: Agricultural and Biosystems Engineering

Funding Source: American Crystal Sugar Company, SBARE, Sugarbeet Research and Education Board of MN and ND

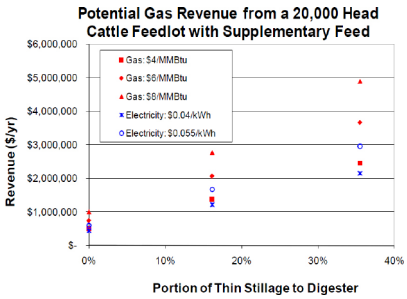
Research Areas: Cellulosic ethanol, byproduct utilization

Research Statement: The majority of cellulosic ethanol studies have focused on the use of feedstocks such as corn stover, wheat straw, switchgrass, or hybrid poplar wood chips. In comparison with sugar beets, these feedstocks may have greater potential for ethanol production on a national scale but beet pulp has potential economic advantages that have yet to be fully explored. Because of the unique composition of beet pulp, it does not require the expensive thermochemical pretreatment common for other feedstocks. In addition, the resource is available at sugar processing plants and requires no additional harvest, storage, or transportation. These benefits may make beet pulp ethanol production both feasible and important on a regional basis.

Research Methods: Sugarbeet pulp hydrolyzes to a complex mixture of sugars including glucose, arabinose, and galacturonic acid. We are using a recombinant bacterium, E. coli KO11, and a conventional yeast, Saccharomyces cerevisiae, to ferment this mixture of sugars to maximize ethanol yields and titers. Pulp is hydrolyzed with conventional pectinase and cellulase enzymes and fermented sequentially with the two organisms or in parallel after partial hydrolysis. Maximizing solids loading rates will be a key factor in maximizing ethanol concentrations.

Major Results: We have been able to effectively convert all sugars present in beet pulp hydrolyzate to ethanol. Maximum sugar yields (g sugar/g pulp) occur with solid loading rates of 10% while sugar concentrations (g/L) continue to increase with loading rates as high as 16%. We are using rates of 12% which have give a slightly lower yield but significantly higher sugar, and therefore ethanol, concentrations.

Contact: scott.pryor@ndsu.edu



Feasibility of a Cattle Feedlot/Large Dairy Co-located with the Blue Flint Ethanol Plant

Investigators: Greg Lardy, Scott Pryor, Eric DeVuyst, Ron Wiederholt, Wally Eide, J.W. Schroeder

Department: Agricultural and Biosystems Engineering, Animal Science, Agribusiness and Applied Economics

Funding Source: Great River Energy, APUC

Research Areas: Anaerobic digestion, economic feasibility, ethanol coproducts

Research Statement: This study looked at the economic and technical feasibility of co-locating a dairy or beef cattle facility with Blue Flint Ethanol (50 MGY) near Falkirk, ND. Co-location of a dairy or cattle feedlot on site would have multiple potential benefits. On-site use would allow for DDGS utilization without drying or long transportation. Markets would be ensured for both the ethanol plant and the animal feeding operation. Cattle manure could be processed in an anaerobic digester to produce biogas that could be used for electricity production or thermal energy at the feedlot or ethanol plant. The facility would then help Great River Energy to meet Minnesota's renewable energy mandate.

Research Methods: We developed a spreadsheet model of an anaerobic digestion system to predict reactor sizes and biogas production based on herd size and supplementary substrates from the ethanol plant. These results were integrated into an economic model to determine overall feasibility. As the business plan is developed, it would be possible to operate the feedlot and digester facility as separate businesses requiring some economic exchange for manure. However, they are distinctly intertwined. The dairy/cattle facility was developed specifically for collection of manure to feed the digester while the digester requires manure in order to produce biogas.

Major Results: Based on the valuation assumptions for items including energy, milk, feed, construction materials, etc, the dairy project was determined not to be economically feasible. Challenges include: high capital construction costs, uncertainty of feed and milk prices, high milk hauling and marketing costs, the lack of a large scale milk processing company within a reasonable distance of the proposed dairy.

The integration of an existing ethanol facility with a cattle feedlot and an anaerobic digestion facility may be technically feasible, provided the cattle feedlot facility is designed to facilitate collection of manure which is largely free from soil contamination (e.g. a confinement facility built with slatted floors). Economic feasibility of this system is heavily dependent on construction costs for such a facility and financing details.

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Use of Mixed Perennial Feedstocks for Ethanol Production

Investigators: Scott Pryor, Mario Biondini, Paul Nyren

Department: Agricultural and Biosystems Engineering, Range Science, Plant Science

Funding Source: USDA-CSREES

Research Areas: biomass utilization, biomass production, cellulosic ethanol

Research Statement: Much work has been completed on using various biomass crops as a feedstock for cellulosic ethanol production. Use of mixed feedstocks has many potential advantages. With the ability to utilize a wider variety of substrates, a processing plant would have more feedstock available within an economically feasible transportation radius. By growing mixed feedstocks, average yields should remain high over a range of weather conditions and the yearly variation will be lower. This will ensure a processing plant sufficient feedstock on a yearly basis. Mixed species fields will also require lower inputs of fertilizers and have fewer pest and disease problems than would perennial or annual monocultures.

Research Methods: We are gathering biomass feedstocks from around ND that have been planted individually and in mixtures. The highest yielding varieties along with the high-yielding weed species are being tested for carbohydrate composition and potential ethanol yield. Additional analysis will include pretreatment and fermentation to ethanol individually and in combinations to test for processing consistency.

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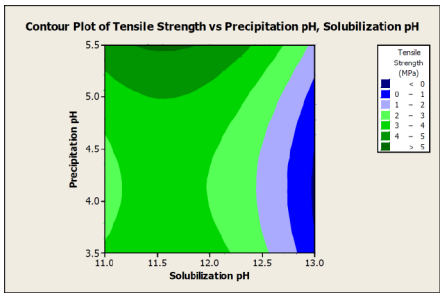

Biodiesel Co-product Development: Utilization of Canola Meal and Canola Proteins for Industrial Bioproducts

Investigators: Scott Pryor, Chad Ulven (ME), Dennis Wiesenborn(ABEN), Sam K.C. Chang (CFS)

Department: Agricultural and Biosystems Engineering

Funding Source: USDA NRI

Research Areas: Biodiesel coproducts, biobased materials and products

Research Statement: High-value products from oilseed meal must be developed to ensure economically viable biodiesel production from canola. Although significant work has been done on the utilization of soy proteins for industrial applications, literature reports on the use of canola proteins for such products are sparse. While most protein-based bioproducts research relies on commercial protein products, we believe advances in bioproduct development will require process control at all stages – protein extraction, protein modification, and product formulation.

Research Methods: We are exploring the impact of protein processing conditions on the quality of protein isolates and the biobased plastics made with them. We are looking at removing certain fractions of the canola protein that may have more potential uses in the food industry but detrimental properties for other industrial applications. We are also examining the impact of solubilization and precipitation pH on the properties of resulting protein isolates and the plastics from which they are made.

Major Results: We have found that the processing conditions that maximize yields of canola protein isolates are not the same as those that maximize various mechanical properties of resulting biobased plastics. By modifying the isolation procedures, we can produce an improved protein isolate with better characteristics in terms of strength, water resistance, and thermal stability.

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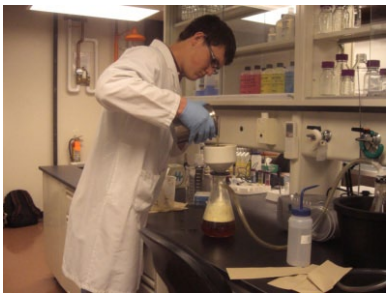

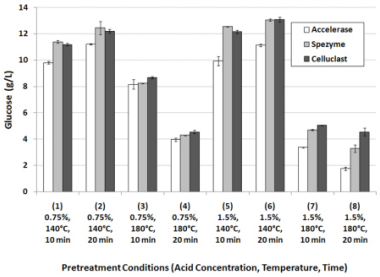

Consistency of Cellulase Activity Assays with Pretreated Biomass Hydrolysis

Investigators: Scott Pryor

Department: Agricultural and Biosystems Engineering

Funding Source:

Research Areas: Cellulase enzymes, cellulosic ethanol, bioconversion

Research Statement: Cellulase enzymes used for biomass hydrolysis and ethanol production are not measured or valued by volume or weight, but rather by their activity. Cellulase activity is a quantifiable assessment of how effective a given quantity of enzyme is at hydrolyzing its substrate. This assessment is done under a very standard and controlled set of conditions with a well-defined standard substrate. This is necessary for different researchers to compare their results. Although activity is measured with a standard substrate under standard conditions, and enzymes are loaded based on this activity measurement, real conditions and real substrates may be very different.

Research Methods: We have used 4 different commercial cellulase products and tested them all with equal loadings (based on standard activity measurements) using pretreated switchgrass as a model substrate. Dilute Acid and Soaking in Aqueous Ammonia pretreatments were used to test the impact of acidic and alkaline pretreatments, respectively. Enzymes are being tested for sugar yields during hydrolysis alone and with a simultaneous saccharification and fermentation process.

Major Results: We have found that commercial cellulase products do not yield the same concentrations of sugars despite identical loadings on an activity basis. One product consistently showed 10% lower sugar yields under nearly all conditions. These results have been confirmed with both acidic and alkaline pretreatments under a range of pretreatment parameters. Discrepancy in the efficacy of hydrolysis is therefore not likely due to the presence of hemicellulose or lignin alone as the two pretreatments act on different fractions of the biomass. Differences based on enzyme product inhibition will be assessed with the simultaneous saccharification and fermentation testing.

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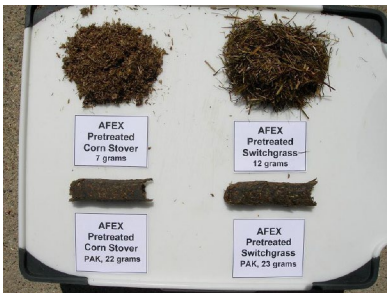

Transforming and Densifying Biomass in Regional Biomass Processing Centers (RBPC)

Investigators: SDSU (K. Muthukumarappan, W. Gibbons, J. Julson, J. Gonzalez, M. Twedt), NDSU (S. Pryor), MSU (B. Dale, C. Saffron), SDSMT (L. Christopher), Federal Machine (J. Flaherty Sr.)

Department: Agricultural and Biosystems Engineering

Funding Source: North Central Sun Grant

Research Areas: Cellulosic ethanol, densification, feedstock logistics

Research Statement: The goal of this proposal is to develop and validate the performance of an integrated biomass pretreatment and densification process that will reduce the logistical hurdles facing second generation biofuels. This process will link Ammonia Fiber Expansion (AFEX) pretreatment with a novel compaction process to produce densified biomass particles that: 1) retain their original composition, 2) have a density approximately 10 times that of baled biomass, and 3) eliminate the need for further pretreatment at the processing plant. This will minimize the distance that low density feedstock bales will be transported.

Research Methods: NDSU will be responsible for testing simultaneous saccharification and fermentation of the various feedstocks before and after pretreatment and densification to confirm that densification does not have an adverse impact on downstream processing for ethanol production.

Additional objectives include 1) optimizing AFEX pretreatment to enhance both densification and hydrolysis, 2) optimizing densification operating parameters, 3) evaluating the effects of storage on physical characteristics, 4) determining the effects of densification on rates and yields of hydrolysis and fermentation, and 5) conducting economic and energy analyses of process to determine optimal and minimal scale.

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Photo of an irrigation system near Leeds, ND, courtesy of Duane Anderson.

Devils Lake Basin Water Utilization Test Project

Investigators: Dean Steele and David Hopkins

Departments: Agricultural & Biosystems Engineering, Soil Science

Funding Source: USDA-NRCS, ND State Water Commission, and Local Sources

Research Areas: irrigation, flood mitigation, soil science

Research Statement: Excessive precipitation since 1993 has led to rising water levels in Devils Lake and the surrounding basin, causing flooding and extensive property damage and loss. Solutions to mitigate flooding have included a proposal to use irrigation to divert water to the atmosphere via crop water use or evapotranspiration (ET). The Devils Lake Basin Water Utilization Test Project was conducted to determine whether irrigation can be used as a flood mitigation tool while providing an economic benefit. The primary objectives of the Test Project are to: 1) determine how much additional water from Devils Lake and associated water bodies can be utilized via sprinkler irrigation, 2) evaluate the effects of irrigation on representative soil map units within the basin, and 3) extrapolate the results from the test project to the broader basin.

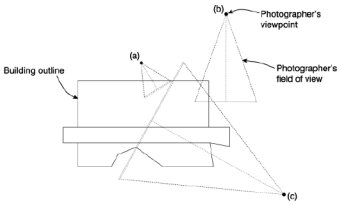
Research Methods: The Test Project was conducted on ten irrigated sites for 2006 through 2008. A remote sensing approach was used to estimate ET on a pixel-by-pixel basis for over one-half of the Devils Lake basin. Seasonal estimates of ET were determined for various crops for a best-case year (2006) with high evaporative demand and low rainfall to compare ET for irrigated crops on the Test Project sites with ET for largely nonirrigated crops in the remainder of the basin. Similar overlays of ET were used to compare ET for spring wheat and corn on selected soils. Spring wheat was selected for these simulations because of its predominance in cropped area in the basin, while corn was chosen as a contrast to spring wheat because of corn's longer growing season and higher expected seasonal ET.

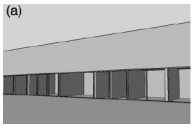
Major Results: The project indicated that, at best, ET for irrigated corn was approximately 1.4 to 1.7 inches greater for irrigated corn compared with ET for all corn in the study area for 2006. This gain in ET is considerably less than a previous study's estimate that an average of about 5.4 inches of additional crop water use could be attained via irrigation in the Devils Lake basin compared with average values of water use for nonirrigated crops. The project's ET modeling results lead us to believe that a pilot-scale project (expansion of the Test Project to include more irrigated area) should not proceed on the basis of using irrigation as a flood mitigation tool in the Devils Lake basin. Soils interpretations are ongoing.

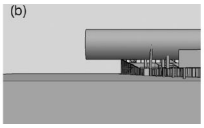
Narrative adapted from: Steele, D.D., and D.G. Hopkins. 2009. Devils Lake Basin Water Utilization Test Project. Report submitted to the Devils Lake Basin Joint Water Resource Board, 9 June. Fargo: N. Dak. St. Univ. ABEN Dept.

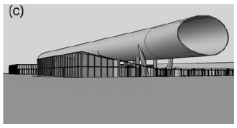
Contact: Dean.Steele@ndsu.edu. (701) 231-7268. http://www.ndsu.edu/aben/department/personnel/dean_d_steele/

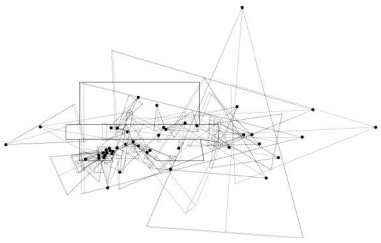
Architecture and Landscape Architecture











On the Architectural Structure of Photographic Space

Investigators: Mike Christenson, AIA, NCARB

Departments: Architecture and Landscape Architecture

Funding Source: None

Research Areas: Photography, visualization

Research Statement: The ambiguous relationship between photography and architecture is one of constructed and re-constructed identity. As a specific exploration into this relationship, this research considers the construct of point-of-vew/field-of-view maps (or POV/FOV maps), that is, diagrams which register photographers' positions, fields of view, and directions of view corresponding to a set of photographs of an existing work of architecture. A POV/FOV map can be expected to differ according to whether the set of photographs under consideration is (a) sampled from a image-sharing site such as Flickr; (b) published in an academic monograph; or (c) published in the popular press. This research tests the extent and significance of these differences through a comparative study of Mies van der Rohe's Crown Hall and Rem Koolhaas's McCormick Tribune Campus Center, both at the Illinois Institute of Technology in Chicago, USA. In both cases, POV/FOV maps are used to compare sets of professional or academic photographs to sets of touristic and popular-press ones. Reflecting the tenuous nature of architectural identity as constructed through photography, the comparison both confirms and denies assumptions concerning differences between professional and amateur approaches. The paper concludes with the speculation that tools like Google Street View are likely to further erode traditional distinctions between modes of identity-construction, in particular, those distinctions which a POV/FOV map can register.

Research Methods: Digital modeling, POV/FOV map construction

Major Results: Presented and published in *Proceedings, 2010 Conference of the Australia and New Zealand Architectural Science Association, Auckland, New Zealand.*

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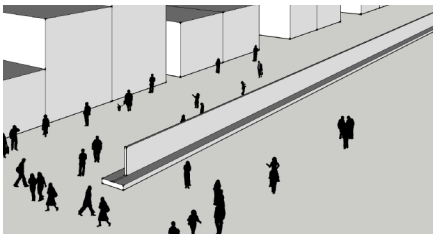
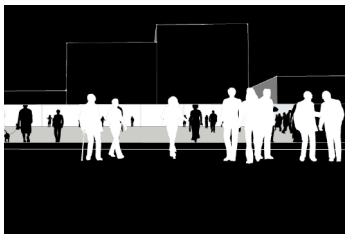

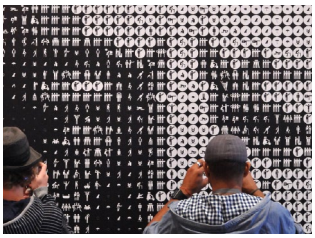

Photography and the vicarious experience: implications on urban safety?

Investigators: Mike Christenson, AIA, NCARB

Departments: Architecture and Landscape Architecture

Funding Source: None

Research Areas: Photography, urban safety

Research Statement: The relationship between on one hand, physical factors in the built environment affecting one's visibility, and on the other hand, one's perception of personal safety within that environment, is well-demonstrated.Arthur Stamps has proposed *permeability theory:* "[T]hat enclosure can be conceived as properties of a three-dimensional region of space which affects safety by the degree to which it permits or limits locomotion or perception through itself." Related to permeability theory is Oscar Newman's theory of *defensible space.* In particular, Newman's notion of *natural surveillance* suggests that if a place is understood by its inhabitants to be watched, it will be perceived as more safe than one which is understood to be unwatched. Given the demonstrated relationship between the perception of safety and the physical characteristics of the environment, coupled with Newman's theory of defensible space as it relates to natural surveillance, a question arises which is whether the performance of tourists is itself structured by an apparent need to insert a device between themselves and an environment which is perceived as unsafe. Suppose that in each of two cities, a raised platform is constructed along the median of a public road in a busy commercial area. Each platform is publicly accessible to citizens. Along the center of each platform, a 2-meter-high wall is constructed, the surface of which on both sides is a flat video/sound display. Recording devices for video and sound are embedded within the wall. Thus, the wall functions as a two-way perceptual device effectively creating a visible and audible portal between the two cities (i. e., "telepresence"). Definitions having been established, we can now ask: *How does the architecture of the device affect the perception of safety in its environment?*

Research Methods: Digital modeling, isovist mapping

Major Results: Presented and published in *Proceedings, 2010 Young Architects Forum, Indian Institute of Architects, Jaipur, India*.

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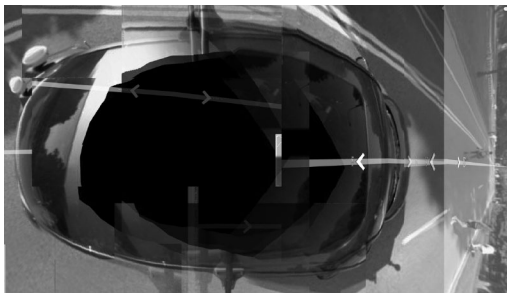

Google Street View and the transition from the unknown to the known

Investigators: Mike Christenson, AIA, NCARB

Departments: Architecture and Landscape Architecture

Funding Source: None

Research Areas: Photography, Google Street View

Research Statement: Using traditional media and tools, it can be very difficult to find existing photographs of buildings belonging to the so-called "everyday landscape." These are buildings which have traditionally escaped attention, whether scholarly or touristic: the fact of a building being inadequately photographed in a historical sense can be used to define it as being part of the everyday landscape. But this historically dependable property of photographs is rapidly eroding, in large part because of tools like Google Street View, which hosts publicly available, place-specific photography of many of the world's public streets. The worldwide reach of Google Street View is coupled with its failure to discriminate in traditionally meaningful ways between buildings. As tools like Google Street View promise to make it just as easy to find photographs of the corner gas station as of Lincoln Cathedral, do we need to redefine what we mean by the "everyday landscape?" Does the term lose its value when confronted with ubiquitous photography? Or do Google Street View and tools like it in fact reinforce historical distinctions between ordinary buildings and extraordinary ones? This research develops these questions through the comparative analysis of traditional (pre-Google Street View) and contemporary modes of photographing a particular American urban landscape; in so doing, each mode's potentials are highlighted and their respective limitations are established.

Research Methods: Photographic panorama construction

Major Results: Presented and published in *Chang[e]ing Identities: Design, Culture, Technology (Proceedings of the 2009 ACSA Southwest Fall Conference)*

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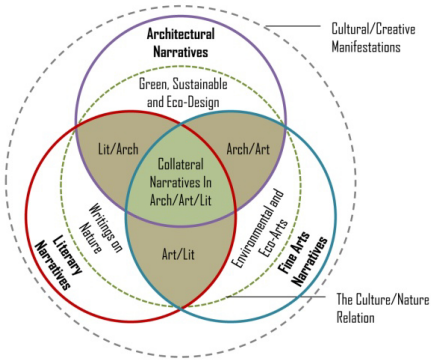

4. The Course Diagram for 'The Green Aesthetic": The 'Collateral Model' in section: (temporal dimension is the 'Z' axis)

The Green Aesthetic: Nature, Culture, and Architecture

Investigator: Assistant Professor David Crutchfield, AIA NCARB

Department: Architecture and Landscape Architecture

Funding Source: None

Research Areas: Hermeneutic inquiry into green/sustainable design

Research Statement: Framed within a social-constructivist perspective, the intent of this research is to postulate potential trajectories in contemporary sustainable and 'green' architecture by examining the historic development of the relation of western culture and nature as reflected not only in architecture but also within other creative cultural manifestations.

Research Methods: Methods employed include identifying prevailing social attitudes toward the natural world over time and utilizing interpretive analysis to identify manifestations of these social ethics within various contemporary creative/aesthetic works.

Tactics include the review of historical Euro-American literary references, the investigation of fine arts from the same timeframes, as well as the analysis of collateral architectural work.

Major Results: Results of this investigation include insights gained into the formative social trends and drivers influencing design and architecture.

The nature/culture relation is indeed reflected in each of these manifestations, although at varying rates relating to the media/methods. Therefore a review of the nature/culture discourse within today's literature and fine art may offer insight into the future of architecture's response to this relation.

Much of today's discourse in these other two fields relates to a questioning of the reliance on technological innovation (alone?) to resolve the environmental issues of our time. Many promote the need to (simultaneously?) instill an aesthetic, internalized, and intuitive appreciation for the natural world.

Contact: Assistant Professor David A. Crutchfield AIA, NCARB

	Product	Cost Per sq. foot	3rd Party verification	Leed Points Available	Percent Recycled Content per Panel	Distance to Production Location	Production Plant Energy Efficiency	Production Plant Water Efficiency	Material Properties	Lifecycle	Variability of uses	Companies Environmental Commitment
		$40-$90	none at this time	up to 5 points	85% recycled glass, 7% portland cement, 8% proprietary materials	1,800 miles Richmond CA to Fargo ND, old Ford Plant	Daylite building, completely solar powered by the end of 2008	Recycle all water, use more in restrooms then in production	As hard as granit, Stronger than regual concrete	Product only been around for 10 years.	counter tops, bar tops, hearths, tube decks, tables, flooring, wall cladding	"We are committed to making everyone aware that there are other alternative resources that can benefit the earth and can be equally beautiful as natural stone without the devastation. "
IceStone		1.25" thick $45-$50	MBDC's (C2C)	up to 6 points	75% recycled glass used, 25% portland cement mix	1,400 miles Brooklyn Navy Yard, NY to Fargo, ND	Strive tob ecome carbon-neutral, purchase renewable energy credits, reduce energy use per square foot of production	Hannover Principles of Design for Sustainability, Water Principles of the Wcsd Buisness Council for Sustainable Development	twice the strength of marble	down cycled into tiles, landscaping materials, roadbed aggregate	kitchen countertops, shower walls, window sills, fireplae surrounds	At IceStone we are committed to creating surfaces for your home and office space that are both beautiful and sustainable.
PaperStone		1.25" thick $60-$65	FSC Certified, Smartwood and The Rainforest Alliance	up to 5 points	55% recycled paper, 45% petroleum-free resin from cashew nut shell liquid	1,500 miles Hoquiam, WA to Fargo, ND	EPA energy use/savings calculator 1 slab saves 2.03 million BTU's of energy	EPA energy use/savings calculator 1 slab saves 1233 gallons of water	structurally ridgid and sound in vertical and horizontal aplications	no information avealbe	kitchencounters, window sills, door thresholds, landscape furniture, rainscreens	PaperStone® is committed to innovative green products that contribute to a wholistic lifestyle that is smart, elegant, and responsible.
Squak Mountian Stone		1.5" thick $70-$95	none at this time	up to 6 points	Post-Consumer % = 2.5% Post-industrial % = 49%	1,400 miles Woodinville, WA to Fargo, ND	Material is hand-cast into "slabs" as an alternative to natural or quarried stone.	no information available	Resembles soapstone or limestones.	no information avealbe	countertops,table s, tiles, backsplashes, vanities	"Since 2004, we have recycled more than 2,000 pounds of paper . . . 50,000 combined pounds of granite dust, fly ash and glass—materials that would otherwise end up in local landfills.Consumers can feel good using Squak Mountain Stone... knowing that they are supporting waste reduction efforts."
Teragren		starting at $25	Member of the US Green Building Council	up to 6 points	99% fast growing bamboo.	Zhenjiang, China to Fargo, ND	Carbon Neutral Offices	Finished Requier no Solvents	Dense fibers, bamboo grows to maturity in 5-6 years	no information avealbe	countertops, flooring, veneers, panels,stairs	A core component of the Teragren mission is to measure our company's environmental footprint and work toward mitigating—and ultimately neutralizing—its environmental impact.

Derived from the research methods, this student generated matrix is a preliminary example of a comparative analysis for 'solid surface' finish materials.

Greenwash in Architecture

Investigator: Assistant Professor David Crutchfield, AIA NCARB

Department: Architecture and Landscape Architecture

Funding Source: None

Research Areas: Hermeneutic inquiry into Green/Sustainable Design, Critical Analysis

Research Statement: This research seeks to develop effective critical analytical tools and techniques to aide in critical decision making throughout the entire eco/social ('Green/Sustainable') design process.

The motivation for this research stems from the inherent conflict between the socio-environmental ethic of 'Green' Design and the marketplace ethic of 'Caveat Emptor' (buyer beware). With the growing market (and advertising) for all things 'Green', the ability for today's designer (as market savvy consumer) to effectively distinguish and compare products, systems, and designs is increasingly important in making appropriate and informed design decisions.

Research Methods: The methods of research include an investigation into the societal origins, meanings, and interpretations of the terms 'green' and 'sustainable', an examination of the ethics and tactics of the 'green consumer/economy', and an analysis of the trends and determinants of 'green/sustainable' design.

Major Results: The goal of this investigation is the development of a pragmatic model framework for use in the critical analysis of products, systems, and/or designs to determine their 'green-ness' as defined and measured by the interpretations and determinants derived in the course of the research.

Contact: Assistant Professor David A. Crutchfield AIA, NCARB

Digitally Enabled Remote Design Collaboration

Investigators: Mark Lindquist

Department: Architecture and Landscape Architecture

Funding Source: None to date

Research Areas: Visualization, Design collaboration, Presence

Research Statement: The research evaluates existing methods and techniques for online design communication and collaboration that will inform the adaptation and creation of new software for web-based design collaboration.

Research Methods: Student projects presented to remote audiences using static and interactive 2d and 3d visualization; bespoke software design & evaluation; adaptation of existing 3d modeling tools for remote design collaboration

Major Results: Research is ongoing; existing software adaptation is promising yet to date unsuccessful; bespoke software development holds equal value and a successful prototype is near. Interim results have been published in conference proceedings.

Contact: mark.lindquist@ndsu.edu

Design Communication & Knowledge Creation from Immersive Visualization

Investigators: Mark Lindquist

Department: Architecture and Landscape Architecture

Funding Source: Department of Architecture and Landscape Architecture

Research Areas: Visualization, Design collaboration, Public participation

Research Statement: The research is an ongoing investigation into opportunities for using immersive visualization and immersive environments for design communication, evaluation and knowledge creation. The overarching project has morphed into a variety of offshoots: assessing the success of immersive environments for public participation in urban design and planning; studying the impact of audio on design understanding by different publics; knowledge creation capabilities afforded by immersive media.

Research Methods: Public workshops have been conducted for urban design evaluation; student projects presented to remote audiences using static and interactive 2d and 3d visualization; feedback and evaluation has employed primarily ethnographic methods

Major Results: Immersive environments have proven to offer many advantages for design evaluation and communication, particularly when combined with real-time digital models. Immersive visualization using panoramic imagery has proven to be very effective at conveying material and spatial qualities of a remote or virtual location at a design level. Preliminary findings have been presented at numerous conferences and published in peer-reviewed journals. Research is ongoing.

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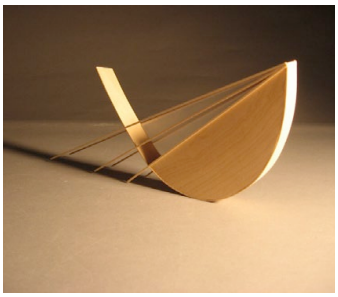

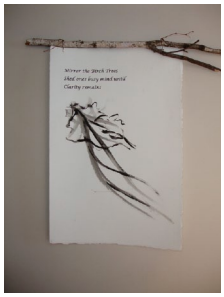
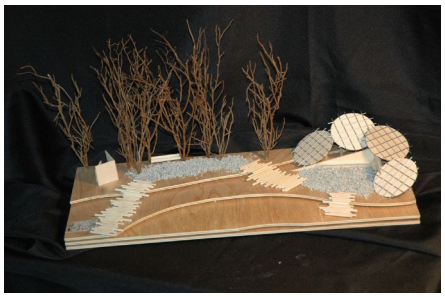

Development of creative potential

Investigators: Joan Vorderbruggen, Assistant Professor, Darryl Booker, Associate Professor

Department: Architecture & Landscape Architecture

Funding Source: Self

Research Statement: The teaching of design in architecture is both a revealing of the creative design potential of the student and a synthesis of knowledge/experience gained over time. With out the former the synthesis of knowledge ends up being a repetition of mostly historical precedents. If architecture is about the solving contemporary built environment problems then finding ways for students to identify and reveal creative potential remains the primary outcome of the beginning design studio. The work so far involves the "making" of things as a way of revealing that potential.

Project 1. MAKING through Knowledge-building, Intention & Creation: Spending time alone to sketch, write and document both quantifiable and qualitative impressions of the place. Discussions and exercises in studio further the interpretation and understanding of the knowledge they've gained from the reading and the site impressions.

Intention becomes a link between knowledge and making, through poetry and painting. The traditional making of Haiku poetry & Sumi paintings focuses the student to think in terms of essence. The embodiment of essence is translated into the creation of a teacup, inspired by earlier work. The teacup serves as a metaphor, the generative concept that translates essence and knowledge into the design of spaces, forms, and order that includes teahouse and garden. In teaching beginning design students, it is imperative to assist them in developing an understanding of the knowledge-building, creation process. Knowledge as gained through the making of things allows for students to see the interrelationship between knowledge and intention, knowledge and creation, and intention and creation. The act of making can serve as the liquid medium that allows knowledge, intention, and creation to flow and mix together fluidly, as opposed to a linear progression that stacks one upon the other.

Interpretation and translation of a Japanese Tea Ceremony by students located at conjoined border cities in Minnesota and North Dakota has been a successful means of introducing the act of making to a beginning architecture studio. The making process assists and simultaneously relies on the understanding of another culture's ceremony/ritual. Making also leads to and comes from a greater knowing of place. The making of a project is explored and expressed through several means: knowledge (reading), intention (writing & painting) and creation (drawing & modeling). Knowledge-building is an initial component of the teahouse project, where students are asked to establish an understanding of the ritual and history of Teaism through the readings of the Book of Tea by Kakuzo Okakura. Students make visits to the site (a park like setting), and Creation is the realization of knowledge and intention, culminating in the designing of a teahouse itself. Creation can also instill knowledge and intention. Sketches, architectural drawings, and models demonstrate the student's accumulated experiences of making into something real and perceived - a final project that embodies the

interpretation of the tea ceremony, the selected site into a teahouse and garden project.
The final act of making is the presentation itself, where knowledge is gained through designing and making the presentation. Critiques of the student work by outside reviewers provide the students the critical feedback as to the intention/creation/making of the project itself; thus providing for more knowledge-building to be gained from the process.

Research Methods: Empirical through project testing in studio

Major Results: Inconclusive

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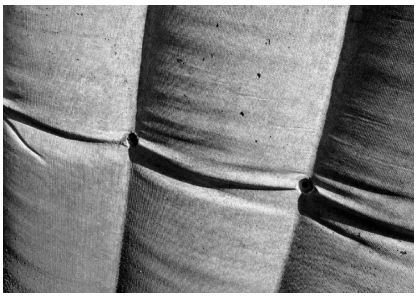

Billowing wall (concrete cast in fabric form)

Investigator: Regin Schwaen

Department: Architecture and Landscape Architecture

Funding Source: Self-funded

Research Areas: Fabric form technology, sustainable construction methods, domestic flood protection

Research Statement: Fabric form is a cutting edge technology that is very likely to open unknown dimensions within today's casting methods in concrete. Almost all cast concrete structures are limited to space within rigid molds made of wood or metal. When casting in fabric form new dimensions for shapes made in concrete can unfold. Traditional casting methods are static by nature. Wood and metal has limited flexibility, and in most cases it is never intended for the mold to flex when casting. Fabric form, on the other hand, acknowledges the fact that concrete is liquid, and this way create a dynamic entity for casting. The property of the liquid concrete in part dictates the shape to the fabric. If architects were to explore fabric form, a new chapter in the typology of cast buildings can open dimensions of more aesthetically pleasing and sustainable construction methods.

Research Methods: To explore the properties of fabric form a cast was done by pouring concrete into a mold made of an open lattice system to where a fabric was attached, such as a simple geotextile woven of a synthetic but sustainable polypropylene plastic, in this case using GEOTEX 315ST produced by Propex. The elongation can reach up to 12% in this product before failure. The size of the cast is equal to a wall about 70 feet long, 8 feet tall, and 8 inches thick. Furthermore a wall about 40 feet long, 8 feet tall, and 8 inches thick was cast with the help of a rigid and traditional steel-plymold interlocking the cast in fabric form. This made it possible on site to compare the new and old method of constructing a mold in the very same research objective and by doing so it is possible for the profession as well as the public to instantly compare the properties of traditional casting technology as well as fabric form technology when casting concrete.

Major Results: So far traditional formwork has dictated and defined concrete primarily by the surface of rigid molds in wood, steel, or plywood; however, if concrete is allowed to flex, move, and wrinkle the surface in the very first moments it cures, substance, such as the fluid properties within concrete, will be and are better defined. Fabric form is ideal for future in depth explorations of concrete where surface and mass merge. When casting concrete in fabric form the mass is not limited to a flat surface, instead the short window of the liquid properties of concrete is celebrated in the random flexing of the mold. A more organic, fluid, flexible, economical, and sustainable casting technology that relies on membranes or woven fabric can revolutionize the way architects and engineers cast concrete in the future. Such explorations can set new standards for the aesthetics of concrete and hold the potential to unfold new spatial principles and dimensions in architecture.

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Embodiment and Transgression:
Crossings of Anselm Kiefer's Art andthe Post-War Reconstruction in Berlin

Investigator: Assistant Professor, Stephen Alexander Wischer

Department: Architecture and Landscape Architecture

Funding Source: The Provost Graduate Fellowship (McGill University 2010-11) and The Principal's Graduate Fellowship (McGill University 2010-11)

Research Areas: History/Theory of Architecture (Hermeneutics, Phenomenology, Art and Architecture)

Research Statement: Inspired by the relationship between artistic creation and architectural inquiry my research examines the mnemonic palimpsest of Anselm Kiefer's work as it relates to specific architectural creations/sites/memories in the context of postwar Berlin. Both the convergence and the inherent differences (distance) between these artefacts reveal the potential for poetic translation in the post-cosmological context. My research opens questions as to the interwoven relationship between historical consciousness, narrative and embodiment in our active engagement with the world.

Research Methods: My method of investigation involves the hermeneutic translation of historical texts, architectural and artistic creations in order to contextualize the specific interrelationship between these artefacts in cultural-historical grounds. This research will continue to develop through the related course sequence in the Ph.D. (architectural history/theory) program at McGill University in Montreal, Quebec, Canada under the supervision of Dr. Alberto Perez-Gomez. Continued development of this research will be tested over the next three years through mandatory progress reports and presentations leading to the comprehensive oral examination, dissertation examination and the doctoral oral examination.

Major Results: This research will elucidate the grounds of translation between art and architecture, contributing to the discussion of architectural representation and inquiry. I anticipate this research will open to very practical potentials for architectural investigation in my pedagogy and will contribute to my ongoing focus on peer-reviewed publications, installations and/or presentations via exhibition and symposia.

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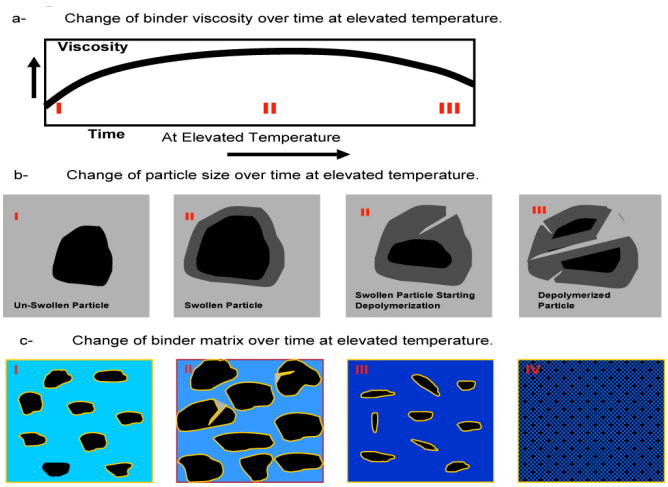
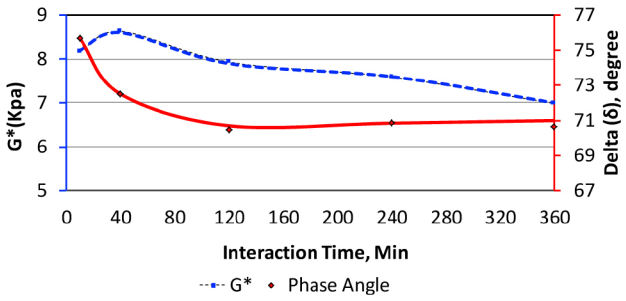
Civil Engineering





Use of Recycled Tire Rubber as Asphalt Modifier

Investigators: Magdy Abdelrahman

Department: Civil Engineering

Research Areas: Infrastructure, Pavement, Recycled Materials

Research Statement: This project will focus on using recycled materials, like tire rubber, to enhance the performance of pavement as an aspect of the civil infrastructure sustainability. The broad goal of the research program is to fundamentally characterize the materials and process variables responsible for property development in asphalt-rubber interaction. Recycled tires, also known as crumb rubber modifier (CRM), and recycled asphalt pavement (RAP) for example, can be engineered and used successfully in asphalt pavement applications. The proposed research will synthesize asphalt-CRM binders through interactions, will characterize the physical and chemical properties of asphalt-CRM and recycled asphalt materials, and will model the impact of chemical releases from recycled asphalt materials containing additives and polymers on soil and groundwater.

Research Methods: Research on asphalt-rubber matrix confirmed earlier findings by the PI and by other researchers and established the initial experimental considerations of the asphalt-rubber interactions. TGA testing can explain the thermal changes in the rubber during the interaction process, which will help to study the changes to the liquid phase, due to possible devulcanization and that can help optimize the interaction process to control binder properties.

Major Results: Preliminary testing has been completed to finalize the experimental considerations. Tested physical and thermal properties of the interacted binders.

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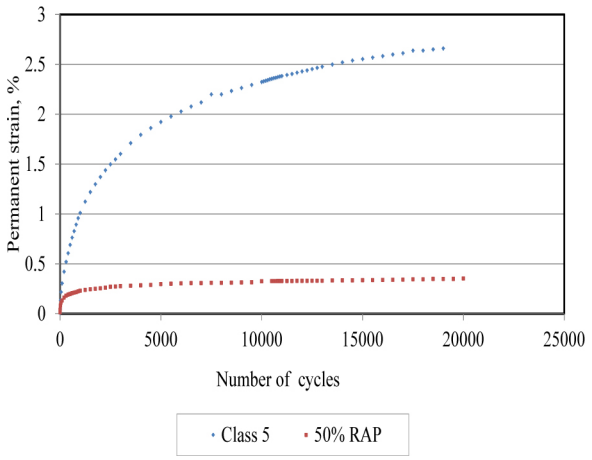

Use of Recycled Asphalt Pavement as Base layer

Investigators: Magdy Abdelrahman

Department: Civil Engineering

Research Areas: Infrastructure, Pavement, Recycled Materials

Research Statement: This project will focus on using recycled materials, like tire rubber, to enhance the performance of pavement as an aspect of the civil infrastructure sustainability. The broad goal of the research program is to fundamentally characterize the materials and process variables responsible for property development in asphalt-rubber interaction. Recycled tires, also known as crumb rubber modifier (CRM), and recycled asphalt pavement (RAP) for example, can be engineered and used successfully in asphalt pavement applications. The proposed research will synthesize asphalt-CRM binders through interactions, will characterize the physical and chemical properties of asphalt-CRM and recycled asphalt materials, and will model the impact of chemical releases from recycled asphalt materials containing additives and polymers on soil and groundwater.

Major Results: Extended the current effort on the use of RAP as base layer in the following areas:

Effect of state of stress on the resilient modulus of base layer containing reclaimed asphalt pavement.

Modeling the effect of moisture on the resilient modulus of base layer containing reclaimed asphalt pavement.

Variability of RAP resilient modulus as a base layer and its impact on the performance of flexible pavement.

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VIABILITY RELATIVE TO CONTROL: FREE CELLS VS. ENTRAPPED CELLS

Long CNTs			Short CNTs		
C CNTs (µg/mL)	Entrap. cells	Free cells	C CNTs (µg/mL)	Entrap. cells	Free cells
5	86.43	61.71	5	91.87	92.18
10	78.68	56.79	10	87.56	87.61
20	66.13	54.79	20	85.51	87.81
50	77.53	53.57	50	78.31	66.94
100	68.96	46.41	100	70.59	62.45
200	72.39	45.75	200	65.79	55.96
500	64.46	15.36	500	60.13	28.9
1000	55.35	9.18	1000	56.27	22.8

Mitigating Effect of Carbon Nanotubes on Bacterial Cells by Polymeric Entrapment

Investigators: Eakalak Khan and John McEvoy (Veterinary and Microbiological Sciences Department)

Department: Civil Engineering

Funding Source: National Science Foundation

Research Areas: Nanotechnology and Sustainability

Research Statement: Carbon nanotubes (CNTs) are extensively commercialized and widely used nanomaterials. However, research on the environmental impact of CNTs has been limited and there is growing concern that CNTs may negatively affect a number of key environmental processes. Early research in this area has shown that CNTs can reduce the viability of Gram negative bacteria by puncturing the cell wall and membrane, and may therefore impact the beneficial bacteria used in wastewater treatment and bioremediation. Cell entrapment is a technology for embedding bacteria in a porous polymeric medium that allows the free diffusion of substrates while preventing cell loss and protecting the bacteria from environmental fluctuations. The goal of our research is to study the protective effect of entrapment on bacteria that are exposed to CNTs and to identify the mechanisms of protection.

Research Methods: Effects of CNTs on free and entrapped bacterial cells were investigated by incubating the cells with different concentrations of short and long single wall CNTs. Escherichia coli was used a model bacterium and polyvinyl alcohol (PVA) was an entrapment matrix studied. Initial concentration of E. coli was also an experimental variable. The standard plate count and β-D-galactosidase assay were used to determine the viability of E. coli cells incubated with and without CNTs.

Major Results: Both short and long CNTs have a negative effect on free and entrapped E. coli cell viability. The effect increases with concentration of CNTs. Short CNTs are less harmful to the viability of E. coli cells compared to long CNTs. Entrapped E. coli cells are less negatively affected by CNTs compared to the free (non-entrapped) cells. It is possible to protect bacterial cells from the adverse effect from CNTs by entrapping them in PVA.

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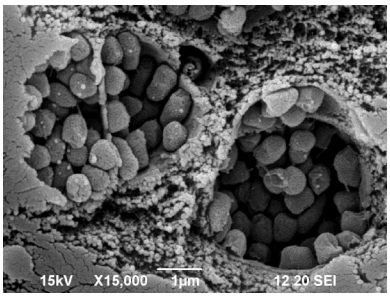

SEM image of Pseudomonas putida entrapped in alginate with unusual round shape

Fundamentals of Cell Entrapment for Water Pollution Control

Investigators: Eakalak Khan

Department: Civil Engineering

Funding Source: National Science Foundation

Research Areas: Nanotechnology and Sustainability

Research Statement: Microbial cells are beneficially used in several industries including wastewater treatment. They are sometimes entrapped in porous media to eliminate the need for their separation from liquid products. Some examples of the applications of entrapped cells include the production of alcohol and antibiotics. The use of entrapped cells for wastewater treatment has been empirical. There has been no clear understanding on the fundamentals of whether and how the entrapped cells function differently compared with free cells. The objective of this research was to investigate the effects of cell entrapment on physiological aspects of bacteria found in wastewater treatment systems.

Research Methods: The effects of entrapment on cell morphology, cell surface property, and stress of species that are representatives of different bacterial groups in biological wastewater treatment were investigated. Two different types of entrapment matrix [alginate and polyvinyl alcohol (PVA)] were examined. Free and entrapped cells were studied in parallel in sequential aerobic batch reactors fed with real municipal wastewater. The morphology of entrapped cells was observed using scanning electron microscopy (SEM) while cell surface property was determined by atomic force microscopy. A real-time polymerase chain reaction technique was used to quantify the expression of stress related genes of cells.

Major Results: The morphology and surface property of cells changed differently depending on the type of entrapment media but the changes were consistent among three species studied. The cell morphology of tightly packed alginate entrapped cells changed from bacilli (rod) to coccoidal (round). The PVA entrapped cells turned into a slim morphology compared to the free cells. The surface roughness increased in the alginate entrapped cells but decreased in the PVA entrapped cells. The formation of putative nanowires was observed in the PVA entrapped cells. The free cells did not express a stress gene associated with the limitation of oxygen while the alginate entrapped cells had higher expression of the gene than the PVA entrapped cells. These results reiterate the importance of media choice for the use of entrapped cells for wastewater treatment.

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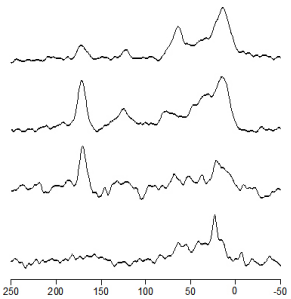

13C NMR solid state spectra of Red River NOM fractions.

Rapid Fractionation of Natural Organic Matter in Water Using a Novel Solid Phase Extraction Technique

Investigators: Eakalak Khan

Department: Civil Engineering

Funding Source: North Dakota Water Resources Research Institute

Research Areas: Sustainability

Research Statement: Natural organic matter (NOM) is a broad range of heterogeneous organic compounds derived from the decomposition of plants and animals and is commonly found in natural waters. It plays important roles in water quality and treatment. It not only creates aesthetic problems in water such as color, taste and odor but also forms carcinogenic disinfection byproducts, such as trihalomethanes and haloacetic acids, upon reacting with chlorine. Because of its heterogeneity, the behavior of bulk NOM is not well understood. As a result, the fractionation of NOM is often required to determine its composition. However, existing methods for separating NOM into different subgroups of compounds that have similar properties are time consuming. This research attempted to develop a more rapid NOM fractionation procedure.

Research Methods: A new fractionation procedure was developed using pre-packed solid phase extraction sorbents that can separate NOM into six fractions based on polarity and charge: hydrophobic base (HPOB), hydrophobic acid (HPOA), hydrophobic neutral (HPON), hydrophilic base (HPIB), hydrophilic acid (HPIA), and hydrophilic neutral (HPIN). The developed method was used to fractionate NOM from two raw water sources (Suwannee River, GA and Red River, MN). Fourier transform infrared spectroscopy (FTIR) and solid state 13C nuclear magnetic resonance (NMR) were used to characterize the functional group and carbon structural group of the isolated NOM fractions, respectively. In addition, the new method was also applied to water samples along the treatment train of the Moorhead Water Plant, MN to investigate the removal of each NOM fraction by different treatment units.

Major Results: This research introduced a novel rapid NOM fractionation technique. The new technique was capable of producing reliable results within 6 hours compared to 24 hours by existing methods. Based on FTIR and 13C NMR spectra, Suwannee River NOM primarily contained carboxylic content while Red River NOM was made up of carboxylic and primary amine groups. The 13C NMR spectra of NOM fractions provided quantitative information of carbon type and verified that this new technique can fractionate different classes of NOM. The NOM distribution along the treatment train of the Moorhead Water Treatment Plant revealed the treatability of NOM fractions by coagulation, ozonation, and filtration processes. The major NOM fractions remaining in finished water were HPIN and HPOA, HPIA.

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Infrastructure rehabilitation using advanced composite materials

Investigators: Dr. Jimmy Kim, P.Eng.

Department: Civil Engineering

Funding Source: TCU, NDSU, and NDEPSCoR

Research Areas: structural engineering, composites, modeling

Research Statement: The issue of infrastructure management and rehabilitation is one of the primary interests in civil engineering community. Constructed structural members deteriorate because of aging, corrosion, increased service loads and traffic volume, use of deicing salts, and collision of heavy trucks. Over $180 billion is required to address structurally deficient or functionally obsolete bridges in the United States. Sustainable and cost-effective rehabilitation methods are therefore necessary.

Research Methods: The research is based on a combined experimental and computational analysis.

Major Results: Various rehabilitation systems have been employed to improve the performance of deteriorated structural members. On-going research includes the repair of damaged steel girders and truss bridges using advanced composites, and the application of emerging materials.

Contact:

Electrical and Computer Engineering

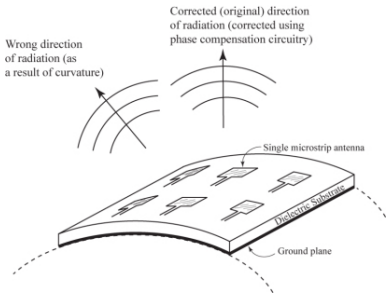

Fig.1. A printed microstrip array on a curved surface illustrating a change in radiation direction as a result of curvature and radiation correction using phase compensation circuitry.

A Small Wearable Conformal Phased Array Antenna for Wireless Communications

Investigators: Benjamin Braaten, Chao You, Micheal Reich and Aaron Reinholz

Department: Electrical and Computer Engineering

Funding Source: ND NASA EPSCoR and DMEA

Research Areas: Antennas and Flexible Sensors

Research Statement: It has been shown that by placing a printed microstrip array on a curved surface, the direction of radiation of the array changes by as much as 30 degrees. In previous work very specific arrays were designed to operate in a desired manner while attached to a surface of fixed curvature. In these cases, if the surface curvature changed for any reason, the array performance would be undesirable and a new array would need to be designed. This work is proposing an antenna array that dynamically adjusts to changes in surface curvature. This makes this array very useful for applications such as wearable antennas. For example, this array could be attached to a planetary space suit, satellite or vehicle for wireless communications. If the array is embedded into a space suit and the individual wearing the space suit moves around, the array can dynamically adjust to maximize communications while the material used to construct the suit and antenna changes shape.

Research Methods: The technical objectives of this research are:

1. Further study and characterize commercially available flexible sensors for measuring the curvature of the antenna.
2. Design, manufacture and test an appropriate phase compensation circuit.
3. Integrate the flexible sensors and phase compensation circuit into a prototype antenna array and test the performance.
4. Travel to the NASA Jet Propulsion Laboratory (JPL) in Pasadena California for a final presentation to the Spacecraft Antennas Group and Spacecraft Antenna Research Group.

Major Results: The antenna being proposed in this work could be applied to many different frequency bands of operation. Two particular bands of operation are the UHF band (300 MHz – 3 GHz) and the S-band (2-4 GHz). Both of these bands are of particular interest to the NASA community. Space – to – Space wireless communications system uses a center frequency of 414.1 MHz (1.4 MHz BW) for Extravehicular Mobility Unit – to Extravehicular Mobility Unit (EMU – EMU), EMU – to – Space Shuttle Orbiter (SSO), EMU – to – International Space Station (ISS), SSO – to – EMU, SSO – to – ISS, ISS – to – EMU and ISS – to – SSO communications.
All of these applications are of particular interest to this research. For example, EMU – to – EMU wireless communications involve space suites worn by astronauts. By embedding the antenna proposed in this work in a space suite, optimal wireless communications could be maintained as the astronaut is moving and deforming the antenna array.

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Prototype Hand-Held EIS Health Monitor

Improved Hand-Held Electrochemical Impedance Spectroscopy Health Monitor

Investigators: Dr. Roger Green, Dr. Victoria Johnson Gelling, Kai Johnson

Department: Electrical and Computer Engineering, Dept. Coatings and Polymeric Materials

Funding Source: U.S. Army

Research Areas: Real-time signal processing, spectral analysis, non-stationary systems

Research Statement: Electrochemical Impedance Spectroscopy (EIS) is used in corrosion, battery, and fuel cell research. These targets can have a wide range of impedance over a broad range of frequencies. This research focuses on the development of a hand-held electrochemical impedance spectroscopy heath monitor that provides improved measurement capabilities in the presence of the very high impedance, non-linear, and non-stationary characteristics typical of real-world targets.

Research Methods: Several facets of signal processing are involved in determining the characteristics of the targets. Digital signal processing accounts for the signal generation and measurement. Statistical signal analysis is utilized to improve measurement accuracy. Real-time signal processing, embedded system design, instrumentation and electronics, and printed circuit board design are necessary for device development. Electrochemical principles also factor into the design, the expertise for which is provided by the collaborating investigators from the Department of Coatings and Polymeric Materials.

Major Results: Previous research produced a portable device capable of qualitative health assessment. Current research efforts have produced a hand-held device capable of fully quantitative results. Additional research is ongoing to compensate for load-dependent transients and further improve output accuracy.

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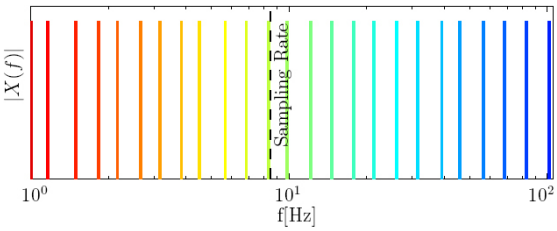
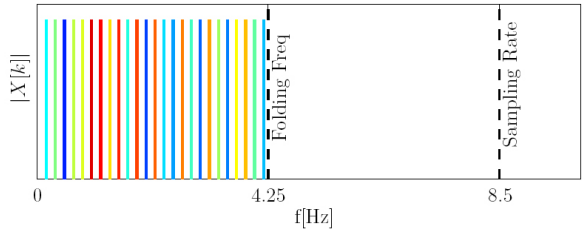


Excitation Frequency Distribution



Analysis Frequency Distribution after Undersampling

Design of Multisine Excitation Signals to Improve DFT Bin Utilization Without Distortion from Select Harmonics in an Undersampled Receiver

Investigators: Roger Green and Mike Schmitz

Department: Electrical and Computer Engineering

Funding Source: None

Research Areas: Spectral Analysis, Undersampling

Research Statement: An algorithm is being developed to increase the DFT bin utilization in the analysis of an undersampled multisine excitation signal while simultaneously preventing distortion of the excitation signal from select harmonics. The algorithm tunes each excitation frequency of the multisine signal such that the alias of every excitation frequency is coincident to a unique DFT frequency bin void of any select harmonics when undersampled at a specific sampling frequency. This improved frequency distribution enables the multisine receiver to operate with reduced power consumption, computational complexity, and harmonic distortion. The algorithm can be applied to any arbitrary or application-specific multisine excitation signal.

Research Methods: The primary electrical engineering methodologies include 1) signal processing, 2) system identification, 3) non-linear system analysis, 4) spectral analysis, 5) computer-aided simulation, and others.

Major Results: Earlier research focusing on optimization of multisine excitation signals for receiver undersampling without harmonic constraints shows that significant improvements in both sampling frequency and DFT bin utilization can be achieved. One example of an optimized 25-tone log-spaced multisine signal shows that the sampling frequency in the receiver can be reduced to only 4% of the Nyquist frequency. In addition, the computational complexity of calculating the DFT is reduced by a factor of 38.

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Variable to Fixed length codes for low-power wireless sensor networks

Investigators: Raj Katti

Department: Electrical and Computer Engineering

Funding Source: Department of ECE, NDSU

Research Areas: Data Compression

Research Statement: It is well known that data compression helps save energy in wireless sensor networks. This is because the execution of about 3000 instructions consumes the same amount of energy as the transmission of one bit over a distance of 100 m by radio. Although compression consumes energy, it saves more energy by reducing the number of bits transmitted by radio. Most compression methods are fixed-to-variable length (FV) coders that use Huffman coding or arithmetic coding. These suffer from synchronization problems because errors in the transmission of compressed data result in incorrect decoding. To solve this problem variable-to-fixed length (VF) coding has been proposed. In VF coding the input is parsed into variable length strings that form a dictionary and each variable length string is replaced by a fixed length codeword of N-bits. Errors in a codeword do not affect the correct decoding of other codewords. VF codes outperform FV codes when there are strong dependencies between source symbols.

Research Methods: Several VF codes have been proposed in the literature but they have not addressed the problems of security and low-power consumption which are present in today's wireless networks. In this work we consider what these problems mean for VF code design and propose solutions for them. We propose a new variable-to-fixed length (VF) coding scheme based on arithmetic coding that is useful for wireless applications like sensor networks. The novelty of the proposed scheme is the use of the Kullback-Leibler distance between probability distributions in order to perform splitting in arithmetic coding. This leads to compression algorithms that have low computational complexity with better compression. The compression algorithms can be made progressively simpler depending on the power consumption that is allowed. The proposed compression algorithm can be modified to perform encryption by choosing a map from the dictionary of the VF code to fixed length binary strings based on a key.

Major Results: The new VF coding method achieves upto 20% better compression than existing methods and consumes less-power than existing methods. The new compression method can be made progressively simpler resulting in a gradual decrease in power consumption.

Contact:

Compression based Encryption and Physical Layer Security

Investigators: Raj Katti

Department: Electrical and Computer Engineering

Funding Source: Department of ECE

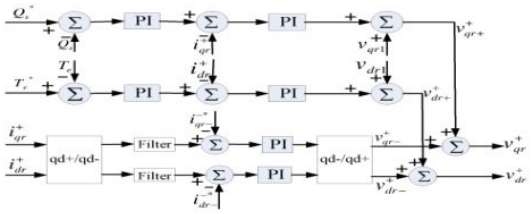
Research Areas: Cryptography

Research Statement: Many of the recently based encryption methods for multimedia are not based on sound cryptographic methods. Our goal is to prove using cryptography that these methods are insecure. A recent trend in implementing security at the physical layer has brought about key-less methods of encryption. However cryptography is based on computational complexity. We are probably the first to propose to combine cryptography and wireless communication techniques to derive low-power encryption algorithms.

Research Methods: We use distinguishable security to prove that encryption schemes based on arithmetic coding such as randomized arithmetic coding and arithmetic coding based on interval splitting are insecure under ciphertext-only attacks. We then consider modifying Trellis coded modulation and space-time codes such as Alamouti codes to obtain encryption algorithms that are fast and consume less power.

Major Results: Distinguishability is a powerful tool that can be used to prove/disprove security of encryption algorithms. Work on combining complexity based security and information theoretic security to obtain new physical layer encryption methods is on-going.

Contact:



Control of Wind Generation for Inter-Area Oscillation Damping

Investigators: Rajesh Kavasseri

Department: Electrical and Computer Engineering

Funding Source: National Science Foundation

Research Areas: Dynamics/Stability of grid interconnected wind generation systems

Research Statement: The objective of this research is to improve the damping of inter-area oscillations in power systems by integrating damping controllers in grid-connected doubly-fed induction-generator-based wind farms. The project will also help convey the benign effects of stability enhancements if grid interconnected systems are equipped with such controllers. The project will help reduce some of the barriers to grid integration of wind farms. If successful, the research will facilitate penetration of large scale wind power into the existing grid.

Research Methods: The approach is to employ two rotor control loops that allow independent modulation of active and reactive powers while providing damping benefits. This project addresses the problem of stability enhancements in power systems, given the increasing presence of and unique challenges in wind farms. The focus lies in developing robust damping controllers through a novel concept of real/reactive power modulation in wind farms to help mitigate instability concerns in the overall interconnected power system.

Major Results: With properly tuned controllers, DFIG based systems can have a benign effect of the damping of some of of the oscillatory modes. DFIG based systems can also be utilized for power quality mitigation problems in micro-grids by coordinated reactive power management techniques.

Contact:

Advanced Monte Carlo Methods applied to Optical Coherence Tomography

Investigators: Ivan T. Lima Jr.

Department: Electrical and Computer Engineering

Funding Source:

Research Areas: Photonics, biomedical engineering, optical coherence tomography.

Research Statement: The goal of this research is to develop new methods to model light transport in tissue using advanced Mote Carlo methods. The use of this method will speed up the calculation of the optical coherence tomography (OCT) signal by several orders of magnitude, which will enable the optimization of these systems.

Research Methods: Computer simulations and laboratory experiments.

Major Results: We showed how to speed up the calculation of the class I OCT signal in Monte Carlo simulations by three orders of magnitude.

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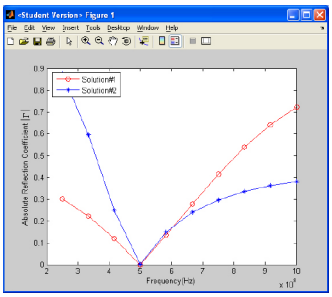

Reflection Coefficient versus Frequency for L-match.

Radio-frequency (RF) and Microwave Engineering Education

Investigators: D. A. Rogers

Department: Electrical and Computer Engineering

Funding Source:

Research Areas: radio-frequency (RF) and microwave engineering education

Research Statement: The project involves development of MATLAB-based computer routines for the design and analysis of radiofrequency (RF) and microwave devices to aid student learning in the classroom. Current results deal with the design of transmission-line and waveguide devices including stripline and microstrip geometries. Future work will include additional elements appropriate to the different areas of the discipline such as active devices, antennas, radiowave propagation, and lightwave propagation.

Research Methods: This involves original MATLAB computer algorithms and useful interfaces that allow the user to design and analyze microwave and similar devices and systems using the number-crunching power of modern person computers.

Major Results: Current results deal with the design of transmission line and waveguide devices including stripline and microstrip. Additional devices and systems will be included as the project progresses.

D. Bais and D. A. Rogers, " Developing a CAD Tool for Radio Frequency and Microwave Engineering Education." Proceedings, 2008 North Midwest Sectional Meeting of the American Society for Engineering Education, University of Wisconsin at Platteville, Oct. 17, 2008, Session 1B, Paper No. 3, 7 pp.

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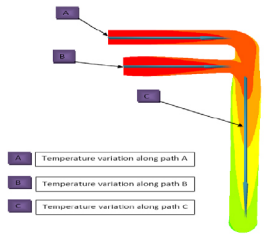
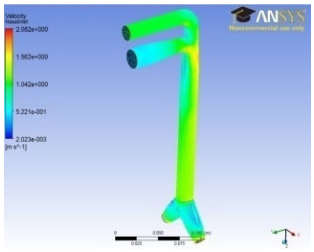
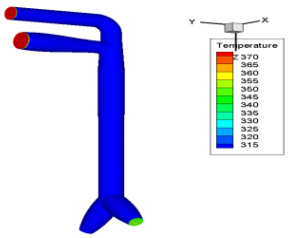
Industrial and Manufacturing Engineering







CFD heat transfer simulation for the Human upper Respiratory Tract for oronasal breathing condition

Investigators: Dr. Kambiz Farahmand

Department: Professor & Chair, Industrial and Manufacturing Engineering Department, NDSU

Funding Source:

Research Areas: Oronasal breathing, 3D heat transfer, Respiratory heat exchange

Research Statement: Injury caused due to accidents related to fire or smoke can be hazardous in nature. The degree of treatment also varies depending on the damage caused on the human respiratory tract. The injury due to inhalation of hot gas is commonly encountered (Enkhbaatar and Traber, 2004) hence the treatment to the injury also has to be developed effectively. A 3D heat transfer model helps study the injury and to develop engineering solutions or preventive measure along with effective treatment therapies. A study of the heat transfer mechanism of the human respiratory tract would help asses any heat, smoke and fire related injury affecting the human respiratory tract. The design of respirator systems used by people working in extreme environments like fire fighters exposed to forest fire, chemical and biological exposure or hazardous material exposure can be better improved by comprehensive study of the thermal profile. This can help in better occupational health and safety in case of firefighter's and emergency responders. These emergency responders are exposed to extreme temperatures and do have protection equipments like a respirator for oxygen supply, but still the inhaled air is heated because of the extreme temperature in the surrounding atmosphere.

Research Methods: A three dimensional heat transfer model of heated airflow through the upper human respiratory tract consisting of nasal, oral, trachea and the first two generations of bronchi is carried out here by using computational fluid dynamics simulation software. The model developed is for the simultaneous oronasal breathing during the inspiration phase with high volumetric flow rate of 90 liters/minute and the surrounding air temperature being 100 degrees centigrade. A simplied three dimensional geometry representing the upper human respiratory tract is developed here consisting of nasal cavity, oral cavity, nasopharynx, pharynx, oropharynx, trachea and first two generations of the bronchi. The respiratory tract is modeled circular in cross-section and varying diameter for various portions as identified in this study. The dimensions are referenced from the literature herein. Based on the dimesion a simplified 3D model represnting the upper human respiratory tract is generated.

Major Results: A heat transfer study along the Human Respiratory Tract (HRT) gives the temperature distribution and variation along the surface of the respiratory tract for the given length during oronasal breathing conditions. The temperatures obtained along the surface of the tissue walls help in assessing the internal burn injury caused. This study will assist in developing safe and effective preventive measures and treatments to the injuries caused in the respiratory tract. This model will be useful in studying the flow characteritics and could assist in treament of injuries of the human respiratory tract and to help determine drug delivery mechanism and dosages in comparison with nasal breathing or oral breathing treatment or applications. Also a methodology is proposed to measure the characteristic dimension of the human nasal and oral cavity at the inlet/outlet points which are classified as internal measurements.

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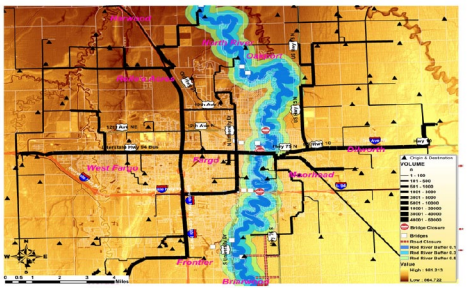

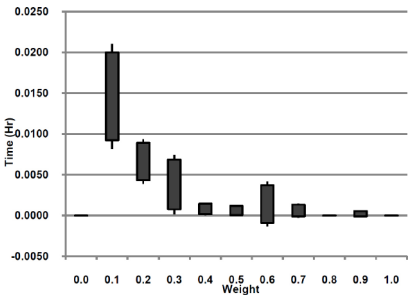

Application of Signal Detection Theory to Ascertain Driving Risk and Mitigation in a Flooded Urban Area

Investigators: Kambiz Farahmand, EunSu Lee & Peter G. Oduor

Department: Transportation and Logistics

Funding Source:

Research Areas: Urban transportation, Flood, Route

Research Statement: Historically, the Red River of the North (predominantly located between the US states of North Dakota and Minnesota) is prone to major flooding with the year 2009 as the most recent record level. The floodplain and surrounding areas has been repeatedly classified as a national emergency region by Federal Emergency Management Administration (FEMA) during the flood season. Significant damage and travel retardants resulted along major portions of the valley. Transportation systems play an important role in times of emergencies by providing evacuation gateways to stranded communities. In addition, road and bridge closures in a flooded area disrupt travel and freight movement. The Department of Transportation (DOT) and other transportation authorities are delegated with the mandate to determine detours and set alternate routes circumventing flooded areas. This information is critical to emergency responders and risk-mitigation planners. In many cases due to the dynamic characteristics of a flood, accurate and up-to-date information may not be readily available. The general public in most cases would collect information from private and other sources, such as media or rely on personal experiences.

Research Methods: Geographic Information Systems (GIS) with Digital Elevation Models (DEM) derived from remotely sensed stereoscopic data can be utilized to predict the high likelihood areas that would be flood prone and affected routes. Real-time geospatial information may also provide users and planners visual information and an unbiased rendition of dynamic and fast changing situations. The main objective of this study was to design a route choice approach with impedance, which takes into account both travel time and user perceptions. Each raster grid cell in the study area was weighted by multiple decision criteria such as environmental, man-made public features, dirt and rock, socioeconomic, and regulatory practices. They measured the priority by pair-wise comparison with linear scale each factors. Each element's raw impedance was calculated by the ratio of its value to an affinity value. The final analytic impedance was calculated by multiplying the element's raw impedance and the affinity's relative importance. In this regard, grid cells are used to represent the geographic space. To determine the least impedance path, the free flow travel time is calculated for each cell and added to the congestion travel time.

Major Results: We investigated the correlation between a risk−taking, risk−averse, or risk−neutral choice and selected routes in a flooding scenario within Fargo-Moorhead area. Remotely sensed data and flood prediction models were utilized as inputs. From this study, we found out that Signal Detection Theory (SDT) improves the choice/route selection analysis by integrating basic signal benchmarking information with Geographic Information Systems (GIS). The main reasons for using SDT were two-fold: (1) to identify programmatically flooded routes based on applied signals; and (2) to ascertain route selection process and performance applying absolute and relative impedances. Remarkable concepts introduced by this study includes methods to aid in segregating between

risk-takers' and risk-averse route selections using a multi−criteria route impedance approach for 50 randomly selected routes. The study shows sensitivity values for (a) $\omega = 0.0$ to 0.3 grouping (b) $\omega = 0.4$ to 0.5, and (iii) $\omega = 0.6$ to 1.0. Conservative risk−averse with a weighting $\omega = 1.0$, who practice safety conscience instead of quick response time, had longer travel times and slower speeds than average as expected. Route selection was executed using the classical shortest path algorithm to minimize distance, time, and general physical link impedance.

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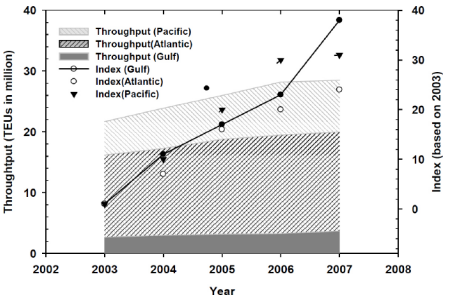

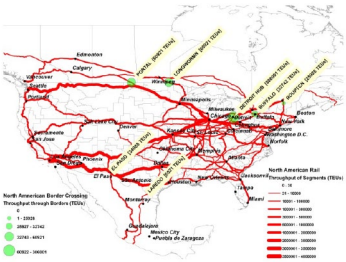

Temporal-Spatial Simulation Model for Containerized Freight in Global Supply Chain

Investigators: Kambiz Farahmand, EunSu Lee, Peter G. Oduor, Denver Tolliver, & Om Yadav

Department: Transportation and Logistics

Funding Source:

Research Areas: Transportation and Logistics, Geographic Information Systems, Simulation

Research Statement: The number of containerized freights steadily grows due to the prosperous international trade and globalization. In the U.S., the transportation infrastructure including highways, railways, and waterways struggles due to the constrained capacity and congestion in urban areas. To understand the movement of containerized freights through these infrastructures, the visualization of them helps to understand the current issues and the prospective visions. The transportation infrastructure of the U.S. for intermodal transportation systems is vulnerable by security, capacity, and social issues. Intermodal transportation for containerization seeks for the integration of facilities and networks by means of managerial efforts and advanced technologies. As an alternative, the U.S railway and highway systems can share the lines crossing borders in order to utilize the resources in Canada and Mexico to achieve the win-win strategy. By doing so, the neighbor countries may increase the productivity of the infrastructures by the U.S. market and the U.S. can decrease capacity investment and congestions. It is critical stage to develop a modeling tool and then to understand the current containerized freight flow through North America to analyze the supply chain and flow patterns. Flexible choice of modes and routes and traffic assignment implemented by segment level of informative GIS is the key component to estimate the current and patterns and supply chains with the new strategies of substitutions based on scenarios.

Research Methods: The input data are categorized by the resource, activity, and economic parameters. The transportation demand is derived by the economic activities of manufacturing, consuming, and moving the products and services between the different locations, where the economic activity occurred in. To estimate the activities, firstly the O-D matrices will be generated based on the public sources. In this study, Geographic Information Systems (GIS) are utilized to visualize the flow of containerized freight imported to and exported from the U.S. In addition, the discrete event simulation technique is adopted to emulate the infrastructure disruption to estimate the impact of the unexpected events and the alternative flows into the U.S. The main ides is (i) to utilize the limited transportation resources, (ii) to reduce the energy consumption, and (iii) the integrated transportation in the North America including Mexico and Canada.

Major Results: From this research, a high density of rail shipping can be seen between the Pacific coast and the Mississippi valley area including metropolitan areas like Minneapolis, Chicago, Kansas City, Memphis, Dallas, and Houston. In the eastern area, most container traffic can be seen for routes from New York/New Jersey and Norfolk to Chicago. The findings are expected that the integrated transportation resources can mitigate the impact of disruption from main channels and also can reduce the total travelling in the system's perspective.

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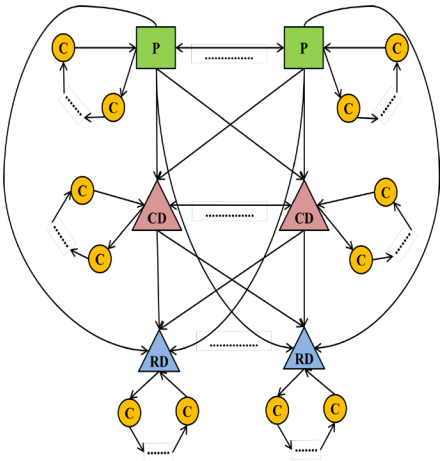

The graphic of the four-layer LRP: the distribution network consists of plants (P) in green, central depots (CD) in purple, regional depots (RD) in blue, and customers (C) in orange.

Developing heuristic solutions to solve a four-layer location routing problem

Investigators: Kambiz Farahmand, Mohsen Hamidi

Department: Industrial & Manufacturing Engineering

Funding Source: N/A

Research Areas: Location routing problem optimization, GRASP, Tabu search

Research Statement: Location-Routing Problem (LRP) which is known as an NP-hard problem simultaneously takes into consideration location, allocation, and vehicle routing decisions to design a distribution network. Multi-layer and multi-product LRP is even more complex as it deals with the decisions at multiple layers of a mutli-layer distribution network while multiple products are transported within and between layers of the network. Due to the complexity of LRP, exact methods can only tackle relatively small instances. For solving larger problems and real instances, the only helpful methods have been heuristics. In this research, heuristic solutions are being developed to solve a complex four-layer LRP.

Research Methods: A combination of GRASP (greedy randomized adaptive search procedure), tabu search, and path re-linking techniques are being used to solve the problem.

Major Results: The heuristic solutions will solve the complex problem in a reasonable amount of time and generate high-quality (optimal or near-optimal) solutions.

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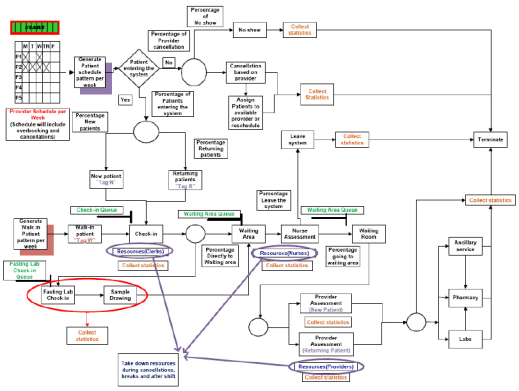

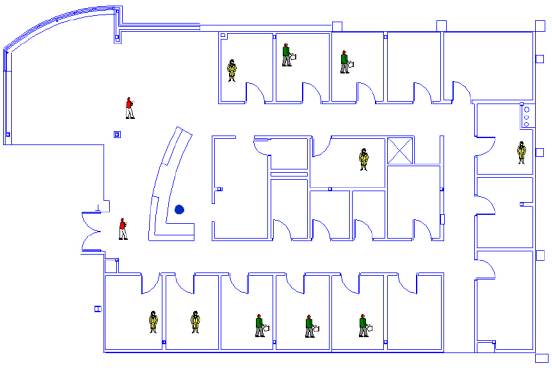

A systematic Approach to Layout Design for Clinic Space

Investigators: Kambiz Farahmand

Department: Industrial and Manufacturing Engineering Department

Funding Source: Veteran Engineering Resource Center

Research Areas: Clinic Space Layout, Utilization, Patient Flow

Research Statement: It is becoming an urgent and critical issue to improve the utilization of current capacity in healthcare facilities nationally. Improving the space utilization will involve increasing the utilization rate of exam rooms, nurse stations, procedure room, etc. in such a way that resources would be used in the most efficient way as possible. Optimizing the patient flow will improve the throughput of the system. The number of patients that are admitted and are cared for per unit of time would be increased, which would lead to increased system efficiency with the same resources. Another important aspect is increasing patient satisfaction by ensuring the smooth flow of patients, and identifying factors contributing to redundant flow or movement of patients and staff. Increasing user access would provide shorter waiting times for the patients overall. In addition, the time between the appointments would also decrease with the improved throughput. Not only the patients, but the staff would also benefit from increasing the user access with more balanced work schedules. Various proposals for the new clinical space layout plans are presented. Advantages and disadvantages along with the benefits of each option are discussed.

Research Methods: A Literature Analysis considering areas in Human Factors Engineering/ Ergonomics; Lean management; Time Study; Operations Research; Delphi Studies; Facilities Management.

The layout planning is performed by developing the activity relationship chart and relationship diagram based on the data collected from the stakeholders of the Clinic that serve as the key points in developing an optimal layout. The activity relationship charts and diagrams would help in understanding the interaction and relationship between different rooms in the clinic area.

Major Results: Some of the issues identified: Inefficient use of space; Poor layout; Non-value added activities; Waiting; Inefficient procedures; Understaffed clinics; Nurses' station is too small for clinic traffic; Only one printer for the entire team; Privacy issues; Storage Space

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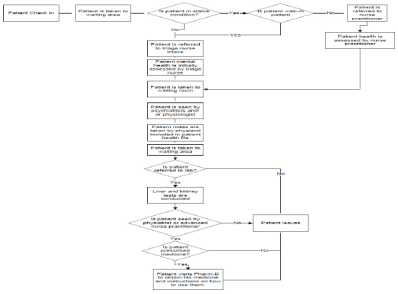

Specialty Clinics and Lab – Improved Flow, Layout and Efficiency

Investigators: Kambiz Farahmand

Department: Industrial and Manufacturing Engineering Department

Funding Source: Veteran Engineering Resource Center

Research Areas: Clinical Space Redesign, Efficient Flow, Space Utilization

Research Statement: The Mental Health clinic consists of several directorates including Psychology, Psychiatry, Substance abuse treatment program, Administration, Social work, Nursing, and Pharmacy. The mission of the clinic is Providing outpatient and inpatient neuropsychological consultation services for a Wide-range of referral sources, including neurology, psychiatry, physiatrist, primary care, social work, and various other entities throughout the system. Stress lab is located at the Radiology department. Patients are referred to the Stress lab mainly from cardiology or primary care clinics. Additional space is needed in both areas, but expansion is not an option, so how do you optimize the utilization of the current space. Several different layout options are prepared based on the analysis of the data for each area. The idea for presenting more than one alternative is to provide more flexibility to the staff members who will be in charge of deciding on the final layout and modifications recommended. One of the alternatives can be selected for implementation or a hybrid of several recommended options is considered. Advantages and disadvantages of each layout option recommended are presented. The proposed system helps increase the efficiency by improving the patient flow, and reducing the non-value adding activities such as walking and waiting.

Research Methods: The mission of MHSL is providing outpatient and inpatient neuropsychological consultation services for a wide-range of referral sources, including neurology, psychiatry, physiatrist, primary care, social work, and various other entities throughout the VA system. Interviews were conducted with the staff to know their work process. Later work flow was analyzed.The layout planning is performed by developing the activity relationship chart and relationship diagram based on the data collected from the stakeholders of the Clinic that serve as the key points in developing an optimal layout. The activity relationship charts and diagrams would help in understanding the interaction and relationship between different rooms in the clinic area.

Major Results: Issues related to the person interviewed were noted down, this basically comprised of the people from the administrative staff, providers (psychiatrist and psychologists, addiction therapists, social workers, advanced nurse practitioners) and staff at the reception. The other users of the system such as the counselors and nurses whose input will also be important for further analysis should be considered. The next week target will be to continue with the interview sessions for the nurses and triage nurses and gather more information with the current usage of the resources and how we can optimize it. A detailed and accurate layout study of the current clinic setup to clear the doubts related to existing study.

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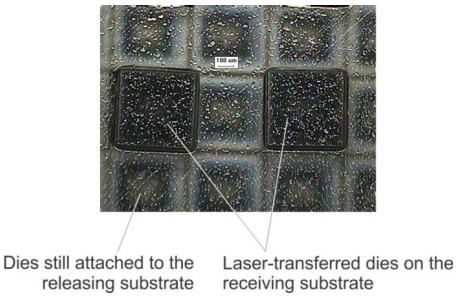

480µm square silicon tiles laser transferred over a 195µm gap between the releasing and receiving substrate.

Laser-Enabled Advanced Packaging (LEAP) for Flexible Electronics

Investigators: Val Marinov & Orv Swenson (Physics)

Departments: Industrial and Manufacturing Engineering /CNSE/Physics

Funding Source: DoD Defense Microelectronics Activity

Research Areas: electronics packaging, laser induced forward transfer

Research Statement: The use of lasers offers a unique opportunity to place small-size individual electronic components, including semiconductor bare dies with footprints down to 100 × 100 µm and thicknesses as small as 10 µm, on substrates that may not be compatible with traditional pick-and-place equipment. It is the most promising, if not the only feasible method for a high-volume assembly of small size, ultra-thin semiconductor bare dies, essential for the next generation of mass produced high-density miniature electronic devices. Also, the laser release is capable of much higher speeds of placement – 100 components per second compared to 2 components per second for conventional pick-and-place machines.

Research Methods: The basic concept of the technique known as Laser Induced Forward Transfer includes using a polymeric sacrificial layer to attach the components to be transferred to a laser-transparent carrier. The sacrificial material coated on the opposite side of the target substrate is heated or ablated by a laser pulse to generate gases that propel the component towards a receiving substrate placed in close proximity. Our team at CNSE built upon this idea to develop a new proprietary packaging technology characterized by a placement precision practically unattainable by the original method.

Major Results: In our latest experiments hundreds of silicon dies were transferred at more than 90% transfer rate and with a very high precision. There is no evidence in the literature to suggest that any other research team has been able to achieve similar results. The Laser-Enabled Advanced Packaging (LEAP) process developed by our team at CNSE is a disruptive technology for high-throughput, low-cost packaging of a wide variety of electronic devices with low to medium design complexity and using ultra-thin, ultra-small semiconductor chips. This technology is also suitable for other applications, for example, assembly of MEMS components and other sub-mm size discrete components.

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A highly-transparent, low-density silica aerogel monolith synthesized following the two-step TEOS based-catalyzed routine.

Highly Permeable and Transparent Silica Aerogels

Investigators: Val Marinov

Departments: Industrial and Manufacturing Engineering

Funding Source: -

Research Areas: nanostructured materials, silica aerogels

Research Statement: Aerogels are highly porous solids (>90% air) with a density is less than 0.1 g/cm3, formed from a gel in which the liquid is replaced with a gas. The aerogels have an extremely high specific surface area - the surface area of a small cube can be as big as this of several football fields. Aerogels are also characterized with an open nanoporous structure. These properties make them suitable for a wide variety of applications provided that the aerogel can serve as a supporting structure for a variety of other materials deposited inside it. The overall objective of this study is to develop a process for making silica aerogel monoliths suitable for thin-film deposition inside the pores. Such aerogels should have a less reticulated, stronger and more rigid silica network, smoother interparticle necks, high average pore-size and permeability. The aerogels must be optically transparent for their intended use as optical materials.

Research Methods: For a given molar ratio, the porosity of an aerogel can be controlled by aging in water solutions and/or by adding a poragen material such as polyethylene glycol (PEG). It was found that adding organic polymer in the precursor solution is more effective in increasing the porosity and transmittance. Making aerogels includes the following major steps: alcogel preparation, alcogel aging, and drying. Gels with different concentrations of catalyst and PEG were prepared following the two-step TEOS pre-catalyzed method explained elsewhere. These gels were aged in ethanol or water/ethanol solution for various periods of time. The gels were then dried in the supercritical CO2 drier, which we designed and build in our ALA 120 lab in the summer of 2010.

Major Results: The first successful silica aerogels monoliths with high transparency were synthesized on November 16, 2010. Eighteen samples with different chemical compositions subjected to different aging conditions were synthesized. The characterization of these materials is currently underway. The most successful combinations will be later used for an additional study on the effects of the post-process heat treatment on the aerogel structure.

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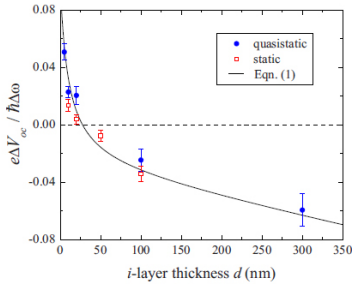

Open-circuit voltage change vs. junction thickness d. ΔVoc is positive for ultrathin junctions indicating capture of hot electrons, decreases monotonically with d, and becomes negative for d > 30 nm. (Kempa et al, Appl. Physics Lett. 95, 233121 2009)

Hot Carrier Transparent Solar Cells on Aerogel

Investigators: Val Marinov, Deyan Mihaylov (MS candidate, Physics)

Departments: Industrial and Manufacturing Engineering

Funding Source: DoE EPSCoR

Research Areas: extremely thin absorber solar cells, hot electron solar cells, atomic layer deposition

Research Statement: This project will investigate the feasibility of developing a solar cell with ultrathin junctions that harvests the energy of hot electrons and at the same time provides an extremely large cross-section for optical absorption of photons with a wide variety of energies. In a typical cell, photons with energy bigger than the bandgap will generate electrons but these hot electrons rapidly thermalize via direct phonon emission. Hot electrons are held as somewhat of a "Holy Grail" in the solar cell research community and reportedly will form the basis of the third generation cells. By absorbing the hot electrons, solar cells could achieve efficiencies of up to 67%. One way to harvest the energy of hot electrons is with ultrathin (< 30 nm) junctions. Yet, the maximum photon absorption requires a material that is orders of magnitude thicker. We propose to solve this dilemma by decoupling the photovoltaic film thickness from the device absorbing thickness.

Research Methods: To achieve the project objective, we will, (1) select, through a rigorous analysis and numerical simulation, appropriate materials for the proposed solar cell, (2) fabricate ultrathin single-junction and multi-junction (stacked) solar cells with various thicknesses on glass substrates, and (3) characterize the properties and performance of these cells.

Major Results: The project is currently in its infancy, no major results are available at this time.

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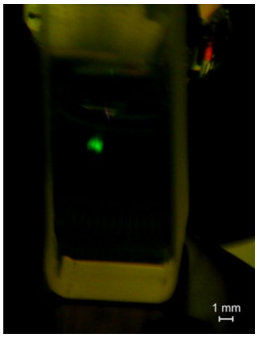

Single green voxel generated by two-photon absorption in a 7.97×1014 cm-3 concentration of 560nm Core-Shell CdSe/ ZnS QD in toluene. Photograph taken with a 950-1070 OD7+ filter.

True volumetric color display with semiconductor nanocrystals dispersed in aerogels

Investigators: Val Marinov, Ivan Lima Jr. (ECE), Ross Miller (MS candidate, ECE)

Departments: Industrial and Manufacturing Engineering | Electrical and Computer Engineering

Funding Source: -

Research Areas: advanced imaging technology and optical materials

Research Statement: The main objective of this project is to develop and study a unique nanostructured material for volumetric 3D color displays consisting of semiconductor nanocrystals (quantum dots, QDs) uniformly and randomly dispersed in a virtually transparent silica aerogel matrix, and excited with a focused infrared laser beam. The ultra-light and highly transparent aerogels may provide the best optical medium for true volumetric displays as they can be easily fabricated in the form of a large volume, low-scattering bulk material. On the other hand, QDs are a remarkable fluorescent material with high photostability and other optical properties superior to those of the conventional materials. QDs dispersed in aerogels hold a promise to become the most efficient display material for volumetric 3D displays.

Research Methods: Multicolor emission in the display material are generated by randomly dispersing in an aerogel matrix a mixture of core-shell CdSe/ ZnS quantum dots with emission peak in the red, green and blue visible wavelength ranges with different concentrations and excited by lasers with different wavelengths and intensities. To incorporate the quantum dots into the aerogel matrix without affecting the sol-gel chemistry of the aerogel process, the quantum dots are first recapped and then coated with a thin shell of silica.

Major Results: The initial proof-of-concept results of this work have been published in…

1) I.T. Lima, Jr., and V.R. Marinov, “Volumetric Display Based on Two-Photon Absorption in Quantum Dot Dispersions,” IEEE/OSA Journal of Display Technology, Vol. 6, No. 6, 2010, 221-228.
2) V.R. Marinov, I.T. Lima, Jr., and R. Miller, “Quantum dot dispersions: a new material for true volumetric displays.” Proc. SPIE, Vol. 7690, 2010.

The multicolor emission is an ongoing research and the results will be published shortly.

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MircoCT image of controlled-porosity ceramic sample [5mm x 12mm; 180μ pore size; 20% porosity]

Surface energy measurement on partially hydrophilic sample

SE micrograph of mouse osteoblasts adhering to sample surface

Orthopedic Surgical Implants [a.k.a. the Bison Microventure]

Investigators: David L. Wells, PhD, CMfgE; Professor, Industrial and Manufacturing Engineering and John R. Bagu, PhD; Director, Organic Spectroscopy Laboratory, Department of Chemistry, Biochemistry and Molecular Biology

Department: Industrial and Manufacturing Engineering (home department)

Funding Source: various small grants

Research Areas: novel implant designs; ceramic manufacturing methods; osteointegration kinetics

Research Statement: Development of a hydrophilic porous ceramic dental implant. Hypotheses: Ceramic is a more natural material for bone scaffolds than metal and will provide more durable and comfortable implants. Implants with well-designed and carefully-controlled porosity will permit osteoblasts to infiltrate into the implant, rather than merely attaching to the external surface, providing for more thorough healing from surgery. Hydrophilicity of implant surfaces will promote faster osteointegration, providing for more rapid healing.

Research Methods: Multidisciplinary research team (primarily undergraduate students) – roughly half from engineering majors and half from biosciences. Product Group (engineers) design and fabricate candidate implant forms. Evaluation Group (bioscientists) test osteointegration kinetics through in vitro experimental protocols. Both groups contribute to definition of experimental plans and collaborate on developing imaging and measurement methods. Microventure has been offered as a one-credit elective course, repeatable for credit, since Autumn 2007 (seven semesters and counting). A total of 34 students from eight majors in five colleges have been enrolled for one or more semesters. Eighty percent of those eligible for repeat enrollment have done so.

Major Results: Design of a porous ceramic construct for trials as an implant.
Development of processing methods (including fabrication of two special-purpose machines) for producing implants with controlled porosity.
Development of methods for producing controlled hydrophilicity on titanium surfaces – and design of methods for applying results to ceramics.
Development of in vitro experimental protocol for evaluating osteokinetics of implant samples.
Validation of in vitro osteointegration protocol with solid titanium samples.

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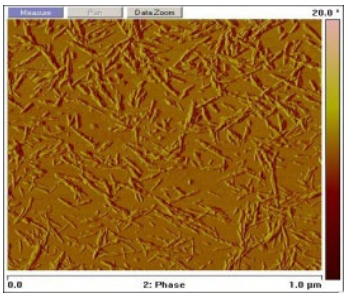
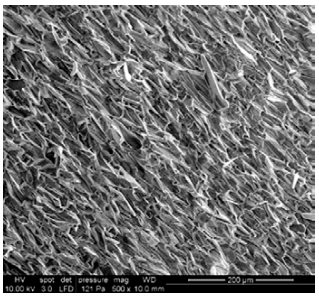
Mechanical Engineering

Soy protein fiber



Cellulose nanowhisker

PHBV-cell mass board



Phase change material

Developing Novel Functional Materials and Their Processing Methods From Naturally Renewable Resources

Investigators: Long Jiang

Department: Mechanical Engineering

Funding Source: EPSCoR Startup

Research Areas: bio-based polymers and composites, nanocomposites, thermal energy storage

Research Statement: Increasing concerns on unstable oil supply, rising awareness about the environmental degradation and growing demand for eco-friendly products are the major challenges facing today's industries. Developing renewable energy and materials has been identified as one of the top priories of the federal government. Tremendous efforts and resources have been invested in this area. Novel scientific and engineering ideas are in constant need to advance the research in this field. This research addresses both energy security and renewable materials.

Research Methods: Renewable resources such as soybean oil, soy protein, cellulosic fibers, starch, sugar beet pulp, DDGS, bacterial cell mass, etc. were utilized and processed into functional materials and products. The methodology of developing bio-based feedstocks into value-added products was established. Properties of the products were characterized. Formula and processing parameter optimization was performed according to end-product requirements.

Major Results: A wide variety of materials and products targeting different applications and markets are being developed. These materials and products can potentially replace many of the petroleum-based products which currently dominate the markets.

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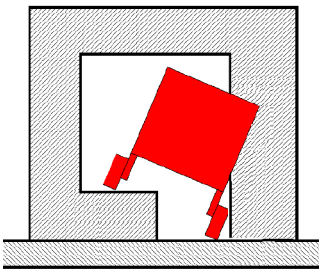
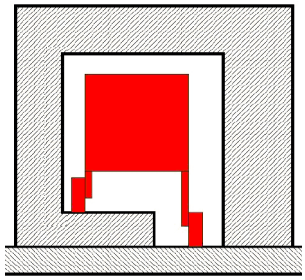


An untraversable 3D obstacle.



Traversability by Suspension control

Mobility Control of Robotic Vehicles in 3-D Obstacles

Investigators: Majura F. Selekwa

Department: Mechanical Engineering

Funding Source: NASA-ND Epscor

Research Areas: Robotics and Control

Research Statement: Although the demand for robotic vehicles in dangerous environments has been very high in recent years, fully deployment of robots has not been achieved. The fact that current robots are modeled assuming that the earth surfaces is locally flat while obstacles in most dangerous environments are 3D in form is one of the problems that must be solved. This research focuses on improving maneuverability of robots in 3D obstacles.

Research Methods: Algebraic modeling of the vehicle as a system of particles.

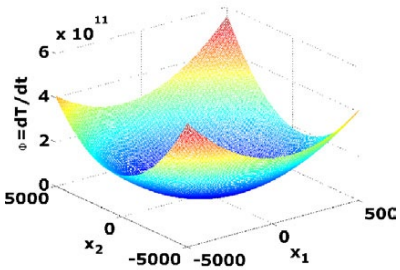
Numerical investigation of the vehicle suspension dynamics subject to mass constraints and geometric constraints

Experimental implementation and investigation of the navigation control system involving 3-D suspension dynamics

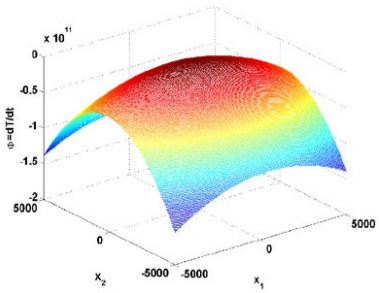
Major Results: Satisfactory preliminary results on algebraic modeling of the vehicle as a system of particles have been obtained.[1] It was found that such vehicle can conveniently be controlled using distributed control approach. The numerical investigation on the vehicle suspension dynamics is underway. Experimental investigations will follow after completing the numerical investigation.

1. M. F. Selekwa and N. Gupta “The Promise of Distributed Control for Wheeled Robotic Vehicles on Unstable Surfaces” Submitted to Robotica, June 2010

Contact: majura.selekwa@ndsu.edu / (701)-321-5667



Unstable energy dissipation



Stable Energy dissipation

Stability of Complex Dynamical Systems by State Kinetic Energy

Investigators: Majura F. Selekwa

Department: Mechanical Engineering

Funding Source:

Research Areas: Dynamical Systems and Control

Research Statement: Although Lyapunov theory describes well stability conditions on dynamical systems using the so called Lyapunov functions, it does not offer any information on the formation of the Lyapunov functions and on the stabilization of dynamical systems. This research seeks to establish the analytical relationship between the state kinetic energy and the stability of dynamical systems, and its application in stabilization of dynamical systems. This knowledge will simplify the process of analyzing and stabilization of complex dynamical systems found in most modern applications.

Research Methods: Differential geometry along with mathematical analysis to establish that the state kinetic energy dissipation gradient is related to system stability. Experimental verification using reversible dynamical systems to show that the stability of the system depends on its state kinetic energy dissipation properties.

Major Results: Preliminary results on the dependency of the system stability on its state kinetic energy have been estabilished1. It was found that systems can be stabilized by manipulating their state kinetic energy. The mathematical theory describing this relationship is currently under investigation by the PI. Experimental investigations will follow after establishing the mathematical theory.

1. M. F. Selekwa, Stabilization of dynamical systems by direct minimization of kinetic energy," Control and Intelligent Systems, vol. 38, no. 4, 2010, in press.

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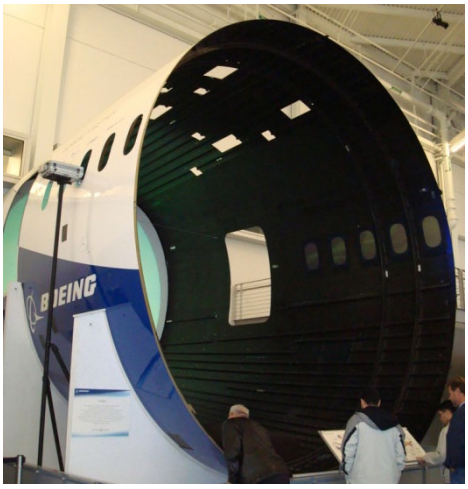

The new generation of Boeing 787 Dreamliner that is 80% composite. Noise control in such aircraft is a challenge.

Friction Damping in Nanocomposites

Investigators: Annie Tangpong

Department: Mechanical Engineering

Funding Source: NDSU ADVANCE FORWARD

Research Areas: Friction damping, nanotechnology, vibrations

Research Statement: Development of high performance space vehicles faces challenges in many areas including acoustic vibration control for long term and far space mission. Being lighter and stiffer than traditional metallic materials, nanocomposites have great potential to be applied in new space aircraft. Studies of friction damping in nanocomposites are largely experimental, and there has been a lack of understanding of the damping mechanism in nanocomposites. This research focuses on the modeling and analysis of friction damping. A micro/nano tensile tester is also being developed to be used in related experiments.

Research Methods: The concept involves a base matrix structure (here the polymer resin) that is in contact with a large number of nanofillers such as carbon nanotubes (CNTs) or carbon nanofibers, and mutual dynamic coupling is generated between the matrix structure and the nanofillers through sticking/slipping nonlinear relative motions at their interfaces. Statistic models of nanofillers in different dispersion situations in contact with the matrix will be developed. The results will serve as a guideline for development of nanocomposites with optimal friction damping without compromising other important mechanical properties.

Major Results: A new friction model has been developed that models the energy dissipation at the interface of CNTs and the matrix in a statistical sense. The new model was able to predict the damping behavior of nanocomposites under different conditions including different frequencies, actuating displacement amplitudes, etc. Effects of the CNT's orientation and concentration are also studied via this model. The results given by this model agree with some experimental observations in the literature qualitatively. A micro/nano tensile tester has been designed and a prototype is being built. The experimental investigation of this research is on-going.

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The *Left Caputo Fractional Derivative* (LCFD):

$$ {}_a^C D_t^\alpha f(t) = \frac{1}{\Gamma(n-\alpha)} \int_a^t (t-\tau)^{n-\alpha-1} \left(\frac{d}{d\tau}\right)^n f(\tau) d\tau, $$

and the *Right Caputo Fractional Derivative* (RCFD):

$$ {}_t^C D_b^\alpha f(t) = \frac{1}{\Gamma(n-\alpha)} \int_t^b (\tau-t)^{n-\alpha-1} \left(-\frac{d}{d\tau}\right)^n f(\tau) d\tau, $$

Fractional Calculus and Fractional Optimal Control

Investigators: Annie Tangpong

Department: Mechanical Engineering

Funding Source: ND EPSCoR

Research Areas: Fractional calculus, optimal control.

Research Statement: The mechanical behavior of many materials, particularly viscoelastic materials, can be better represented by differential equations of fractional orders. The dynamics of some systems are also better described by fractional order differential equations, for example, a sub-diffusion heat conduction problem (with an order less than 1) or diffusion-wave problem (with an order in between 1 and 2). There are critical needs to develop new numerical schemes to solve such problems.

Research Methods: Fractional optimal control problems of different systems, discrete and continuum, and in different coordinates including Cartesian, Cylindrical, Polar, and Spherical coordinates are investigated. Caputo fractional derivative and the Riemann-Liouville fractional derivative are both considered.

Major Results: The numerical schemes we have been developing are efficient, and the results converge toward the analytical solution as the order of derivative approaches integer values. Numerical schemes of a few problems have been developed. Experiments are being developed for applications of fractional calculus.

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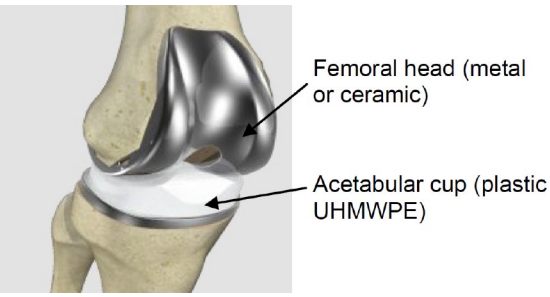

Friction and Wear Studies of Nanocomposites for Artificial Joints

Investigators: Annie Tangpong and Iskander Akhatov

Department: Mechanical Engineering

Funding Source: NSF/ CMMI – Nano and Bio Mechanics

Research Areas: Friction, wear, biotechnology

Research Statement: Total joint replacement is one of the most common and successful procedures in modern orthopedic surgery. Each year in the U.S., more than 200,000 people undergo knee replacement surgery, and over 170,000 hip replacement operations are performed. The life expectancy of artificial joints has been no more than 25 years, and there is an increasing need for artificial joints that can have much longer lifespan for younger patients. The objectives of this research are to understand the failure mechanisms of artificial joints, and invent new materials that will provide longer lifespan of those joints.

Research Methods: This research explores the impacts of both friction and wear to the lifespan of artificial joint analytically and experimentally. A new friction and wear model will be established considering the special properties of various materials including nano-enhanced UHMWPE. Both dry and lubricated conditions will be considered.

Major Results: We have conducted wear tests of newly developed nanocomposites in both dry and liquid conditions. The friction coefficients did not show clear trend of change with the addition of carbon nano fibers. Wear volume loss and debris analysis are on-going.

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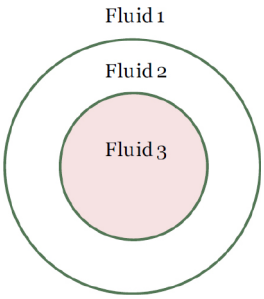
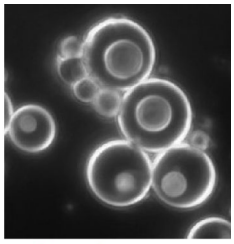
Iskander.Akhatov@ndsu.edu / (701)231-5860 / http://www.ndsu.edu/me/faculty/akhatov.php





Schwaneberg Group
Jacobs University Bremen

Figure 1: Illustration of a double emulsion droplet

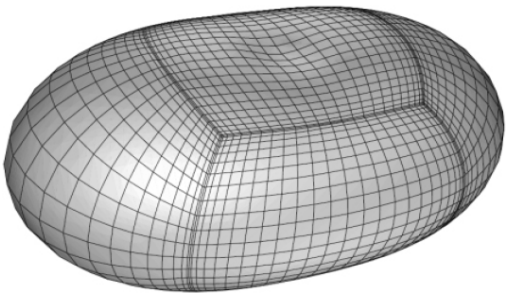


Figure 2: Discretized droplet interface in our numerical calculation.

Deformation of Freely Suspended Double Emulsion Droplets via a 3D Spectral Boundary Element Method

Investigators: Yechun Wang

Department: Mechanical Engineering

Funding Source: ND EPSCoR New Faculty Startup

Research Areas: Fluid Mechanics, Multiphase Flow

Research Statement: Great interest in the behavior of double emulsion droplets arises due to its numerous applications in petroleum, pharmacy and food industry. In this work, we employ a 3D spectral boundary element method to investigate the behavior (esp. the stability) of double emulsion droplets freely suspended in a linear flow.

Research Methods: 3D Boundary Integral Method

Major Results: On-going

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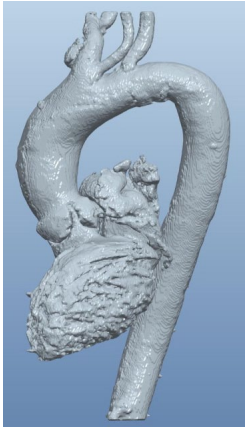

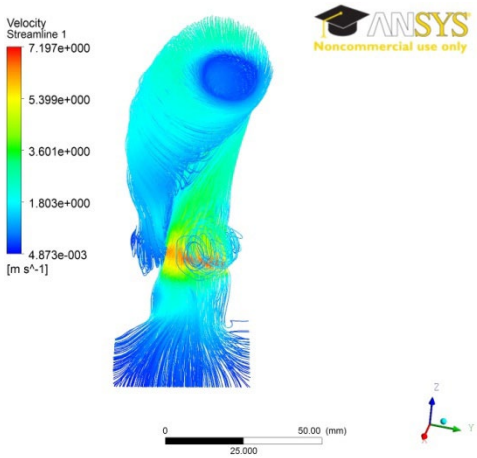

Geometry for the heart and the attached aorta obtained from Mimics analysis of an 80-year-old male patient, and the associated velocity streamline around the aortic valve of the heart obtained from ANSYS CFX.

Diagnosis of Aortic Stenosis via Blood Flow Simulation in Human Heart

Investigators: Yechun Wang, Yildirim Bora Suzen

Department: Mechanical Engineering

Funding Source: ND EPSCoR New Faculty Startup

Research Areas: Fluid Mechanics, Biofluids, Biomechanics

Research Statement: Aortic stenosis is a heart valve disorder that narrows or obstructs the aortic valve opening. The human heart starts to malfunction when the degree of narrowing becomes significant enough to impede the blood flow from the left ventricle to the arteries. By considering the fully 3D geometry of real aortic leaflets derived from the computed tomography (CT) images of patients, we use techniques in computational fluid dynamics to obtain detailed information on the hemodynamics around the real aortic valve area, investigate the interaction between the blood flow and the aortic valve leaflets, and further propose a more accurate formula in assessing the severity of the aortic stenosis.

Research Methods: Computational Fluid Dynamics, Computed Tomography (CT) images, Materialise Mimics, ANSYS CFX

Major Results: On-going

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A New Acceleration Factor for Corrosion Protective Coatings: Flow-Induced Degradation

Investigators: Yechun Wang and Gordon P. Bierwagen

Department: Mechanical Engineering, Coatings and Polymeric Materials

Funding Source: NDSU FORWARD Leap Grant and ND EPSCoR New Faculty Startup

Research Areas: Coating Characterization, Fluid Mechanics, Electrochemistry

Research Statement: Corrosion protective coatings on automobiles, aircrafts and marine equipment act as barriers preventing moisture, oxygen, electrolytes, etc to reach the metal structure underneath the coatings. The abilities to accelerate the coating degradation process without altering its mechanism, and to predict the service lifetime of decades within weeks' of laboratory experiments are essential. However, existing acceleration techniques either take a long experimental time or change the degradation mechanism of coatings from what occurs in the field. In a preliminary study, we found that as we increase the flow rate of the electrolyte solution flowing over an intact coating surface, the coating barrier properties decrease significantly. Motivated by this phenomenon, we propose to develop a novel fluid flow based acceleration methodology. The proposed project will have a great impact on the service lifetime prediction of corrosion protective coatings.

Research Methods: The Electrochemical Impedance Spectroscopy is used to characterize the coating's barrier properties. Laminar flow is used to accelerate the failure of the coatings.

Major Results: On-going

Contact: yechun.wang@ndsu.edu / (701)-231-6732 / http://www.ndsu.edu/faculty/yewang/

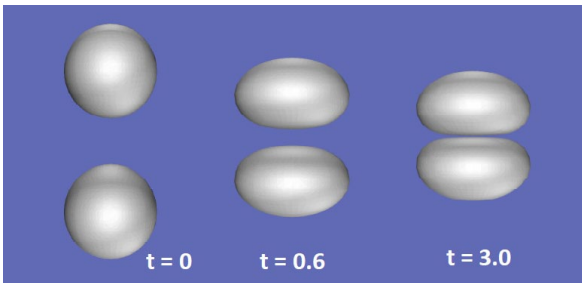

Fig 1: Two droplets in a planar extensional flow

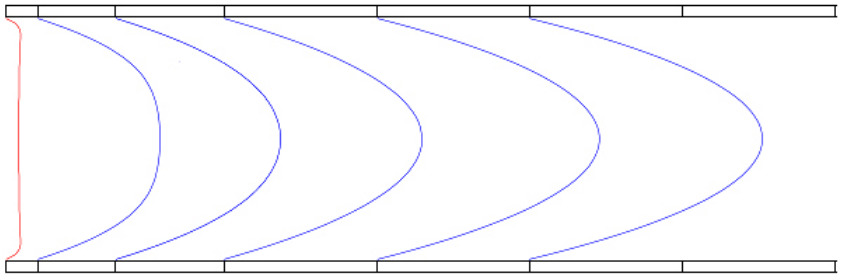

Fig 2: Velocity profiles in the plasma head at different locations

Theoretical Analysis and Computer Simulation of Plasma-Assisted Material Deposition

Investigators: Yechun Wang, Iskander Akhatov, Doug Schulz

Department: Mechanical Engineering

Funding Source: NDSU CCAST

Research Areas: Fluid Mechanics, Multiphase Flow

Research Statement: This study is to develop a theoretical/numerical method in defining the physics of aerosol-based deposition, e.g. Metal-Organic Precursor Plasma Spray (MOPPS). Direct numerical simulation methods are under development for the motion of multiple droplets in plasma flow which are predicted theoretically.

Research Methods: 3D Boundary Integral Method, theoretical modeling of the plasma flow in the plasma head, ANSYS CFX

Major Results: On-going

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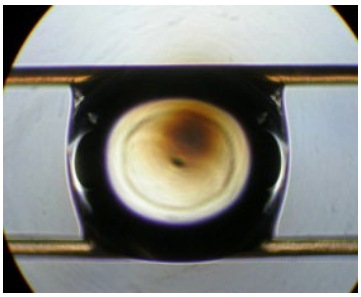

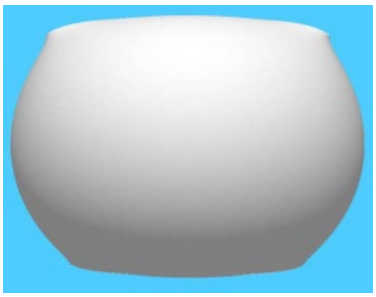

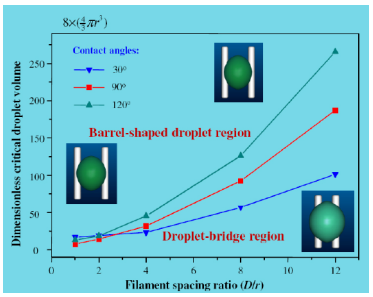

Wetting Properties of Hair-Care liquids

Investigators: Xiangfa Wu

Department: Mechanical Engineering

Funding Source: Ashland Aqualon Functional Ingredients, DE

Research Areas: Mechanics of filamentary materials, Microfluidics, Computational simulation

Research Statement: Surface hydrophobicity of human hair is considered a measure to characterize the extent of hair damage as a result of weathering and chemical treatment. This research is to provide the theoretical basis for the efficient differential wetting characterization technique developed recently in Ashland Inc., which is based on the droplet morphology assumed by droplets sitting on two parallel hair fibers. The research is to explore the dependencies of droplet morphology and wetting length on hair fibers upon contact angles, hair fiber diameters, spacing, and droplet volume, respectively, and relevant wetting and dewetting phenomena.

Research Methods: 1) Computational microfluidics; 2) Theoretical scaling analysis of droplet-filament systems; 3) Experimental wetting study of filaments.

Major Results: 1) Computational examination of experimental wetting differential characterization of droplets on hair fibers; 2) Determination of the critical conditions of morphology transition droplets on parallel filaments; 3) Determination of capillary toque in droplets forming between misaligned filaments

Related publications:
1) X.F. Wu, A. Bedarkar, and K.A. Vaynberg, “Droplet wetting on filament rails: Surface energy and morphology transition” 2009 J. Colloid Interface Sci. 341(2010)326-332.
2) A. Bedarkar, X.F. Wu, Abe Vaynberg, “Wetting of liquid droplets on two parallel filaments,” Appl. Surface Sci. 256 (2010) 7260-7264
3) A. Bedarkar and X.F. Wu, “Capillary torque in a liquid-bridge between two angled filaments,” J. Appl. Phys. 106(2009) 113527

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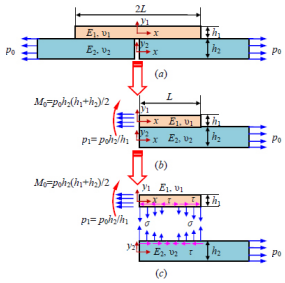

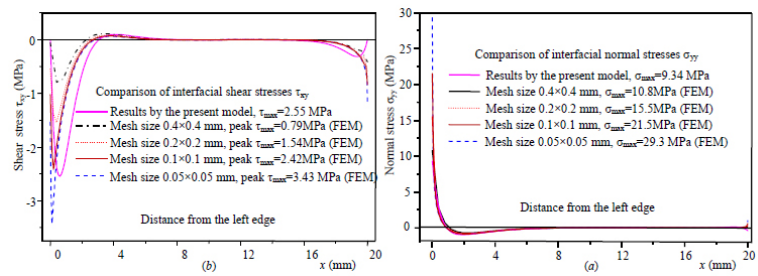

Mechanical Strength and Durability of Adhesively Bonded Multi-Material Joints

Investigators: Xiangfa Wu

Department: Mechanical Engineering

Funding Source: Department of Mechanical Engineering, NDSU; NDSU Foundation

Research Areas: Adhesively Bonded Joints; Structural Mechanics; Self-Healing & Self-Sensing Joints

Research Statement: Adhesively bonded joints have been extensively structured in aerospace, mechanical, civil, and electronic engineering due to their low costs, improved mechanical strength and fatigue durability. These joints are replacing substantial traditional bolted, riveted and welded joints in aircrafts and ground vehicles. Reliable use of advanced joints technology in various structures relies on understanding of the strength, mechanical durability, and damage suppression of various joints in view of Materials Science and Engineering Mechanics. The proposed research is to explore a general stress-function variational (semi-analytic) method for precisely determining the stress field of various adhesively bonded multi-material joints, novel techniques for interface toughening, self-repairing and self sensing, and related failure criteria and experimental validation.

Research Methods: Experimental: Fabrication of adhesively bonded joints of varying adherends (metal and composites); Development of novel nanotechnology-based interface toughening and biomimetic self-healing and self-sensing strategies; Strength and durability evaluation of various adhesively bonded multi-material joints. Theoretical: Development a novel stress-function variational method for stress analysis of multi-material joints; Modeling of interface failure criterion; Modeling of interface NDE

Major Results: Relevant publications:
1) X.F. Wu and R.A. Jenson, "Stress-function variational method for stress analysis of bonded joints under mechanical and thermal loads," Int. J. Eng. Sci. (in press)
2) X.F. Wu and R.A. Jenson, "Interfacial Stresses of bonded joints," (under review)
3) A. Rahman and X.F. Wu, "Computational scaling analysis of the mechanical properties of polymer/clay nanocomposites" (to be submitted)

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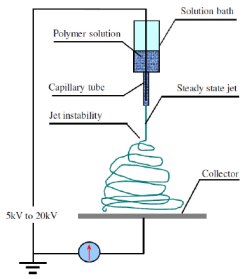

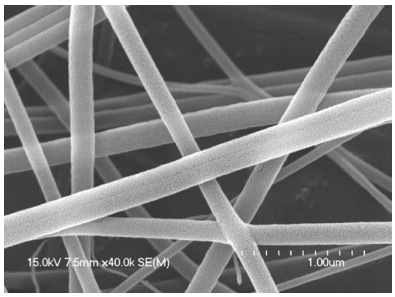

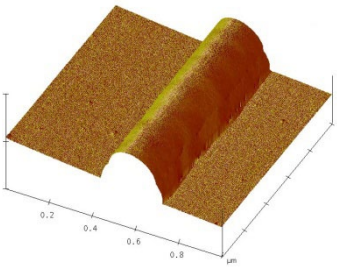

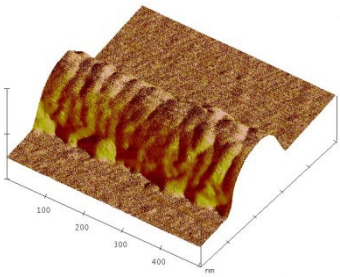

Electrospun nanofibers for advanced structural and multifunctional applications

Investigators: Xiangfa Wu

Department: Mechanical Engineering

Funding Source: Department of Mechanical Engineering, NDSU; DOE EPSCoR (SUNRISE)

Research Areas: Nanofabrication, Nanocharacterization, Structural and multifunctional nanocomposites

Research Statement: Electrospinning is a top-down nanomanufacturing technique based on the principle of electrohydrodynamics and is capable of producing ultrathin fibers from synthetic and natural polymers, ceramics, carbon, and semiconductor materials with the diameter in the range of a few nanometers to microns. Electrospun nanofibers have found broad applications in nanocomposites, ultrafine filtration, biomedical and bioengineering, MEMS/NEMS, chemical catalytic, templates for CNTs, and precursors for other nanotubes and nanofibers. The study of this research is to explore controllable fabrication, characterization, and relevant modeling of continuous high-strength and multifunctional nanofibers for advanced structural composites, energy storage/harvesting and sensing applications.

Research Methods: Experimental: 1) Fabrication of property-controlled nanofibers by electrospinning; 2) Study of conditions of controllable electrospinning; structural, mechanical, optical, electrical, magnetic, and electrochemical characterization of nanofibers; Applications of nanofibers for structural and multifunctional applications. Theoretical: Modeling of controllable electrospinning; Size effect in mechanical and other physical properties of nanofibers and nanocomposites.

Major Results: Relevant publications:
1) X.F. Wu, “Wave propagation in pre-stretched nanofibers,” J. Appl. Phys. 107 (2010) 013509.
2) X.F. Wu, A. Bedarkar, and I.S. Akhatov, “Capillary effect in the mechanical response of axially loaded soft fibers wetted with droplets,” J. Appl. Phys. 108 (2010) 083518
3) C. Cheng, J. Chen, F. Chen, X.F. Wu, D.H. Reneker, H. Hou, “High-strength and high-toughness polyimide nanofibers: synthesis and characterization,” J. Appl. Polym. Sci.116 (2010) 1581–1586.
4) X.F. Wu, Y.Y. Kostogorova-Beller, A.V. Goponenko, H.Q. Hou, and Y.A. Dzenis, “Rippling of polymer nanofibers,” Phys. Rev. E 78 (2008) 061804

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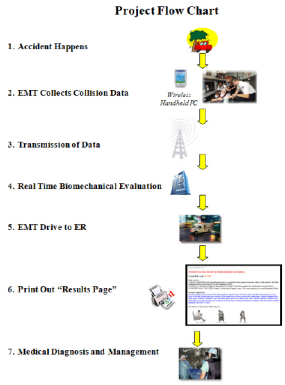

Figure 1. Process of Data Acquisition

Assessment of Mild Traumatic Brain Injury in Emergency Departments

Investigators: Mariusz Ziejewski & Rodney Swenson

Department: Mechanical Engineering

Funding Source: MeritCare Foundation

Research Areas: Mild Traumatic Brain Injury (MTBI), Emergency Medicine

Research Statement: Concussive injuries are widespread in pediatric and adult populations. Even a mild blow to the head may have serious and life-altering consequences. Mild brain injury accounts for up to 75% of significant trauma across all age groups. Accurate diagnosis of mild brain injury is extremely difficult in the Emergency setting and historically a significant percentage is missed (37% Childs, N.L., et al., 1993; 51% Moss, N.E.G., et al. 1996; 22% Brooks, et al., 2004). The purpose of this study is to test a biomechanical model as an adjunctive tool in the assessment of traumatic brain injury and to determine of the results of a biomechanical analysis makes a difference in the daily practice of an ER physician.

Research Methods: We developed a Web-based system to use the state-of-the-art knowledge in impact biomechanics to evaluate the patient in risk, to quantify their risk factors, and to stratify their overall risk levels. The system used an electronic version of our paper-based crash data form developed in our previous study. The data form consists of 21 data values in four major parts: General information, Vehicle Information, Position of Patient's Body, and three photographs of the vehicle damage from three different views. We designed our system as a three-tier architecture model using the currently most popular LAMP technology: Linux operating system, MySQL relational database, and PHP script language.We collected 317 crash cases with an overall completion rate of 82%. Our results demonstrated that EMTs could collect the MVC data, on scene, without affecting their primary duties.

Major Results: The validation results of the knowledge base were encouraging. We used 29 hypothetical cases (n=29) to validate the system. Based on detailed biomechanical analysis, in conjunction with human brain tolerances, 16 were affirmative MTBI cases (n1=16) and 13 were non-MTBI cases (n2=13). The system identified 22 of the total 29 cases at risk. Among these 22 at-risk hypothetical cases, 15 were affirmative MTBIs, which takes 94% of the 16 affirmative MTBI cases and results in the system sensitivity of 94%. We will evaluate cases of closed head injury where the biomechanical assessment tool identifies cases that are currently unable to be diagnosed accurately in a timely manner. We expect to demonstrate a significant improvement in functional outcome for these patients. We expect to demonstrate significant lessening of economic hardship suffered by these patients.

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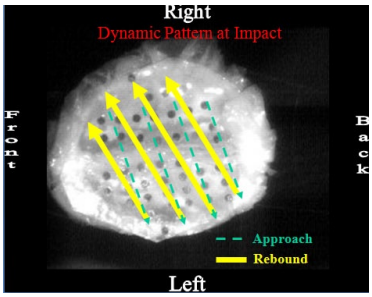

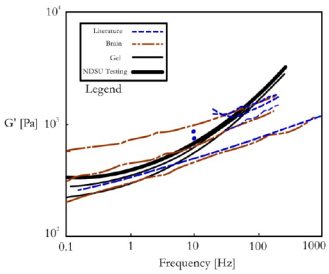

Mechanical Characterization of Silicone Gel as a Brain Substitute Material

Investigators: Mariusz Ziejewski, Ghodrat Karami, William Orrison Jr., Tim Mueller

Department: Mechanical Engineering

Funding Source: FM Area Foundation

Research Areas: Brain Injury Diagnoses, Brain Injury Simulation

Research Statement: Since it is not feasible to use actual brain tissue in collision simulation, it is necessary to find a suitable modeling material. The material should be viscoelastic and have a complex modulus similar to brain tissue when subjected to shear strain. The purpose of this study is to present the use of silicone dielectric gel as physical model for the study of brain tissue dynamics. Results from this investigation will be used to validate a finite element (FEM) computer model of the brain that is under development at the NDSU Impact Biomechanics laboratory.

Research Methods: Studies from different species (human, porcine, bovine) and from different parts of the brain (white matter, cerebrum, brainstem) have consistently demonstrated that the viscoelastic properties of brain tissue fall into a predictable range. Silicone dielectric gel (specifically Dow Corning Sylgard 527 A&B) has been demonstrated to have viscoelastic properties approaching those of actual brain tissue and has gained widespread acceptance as a physical substitute for brain tissue. The suitability of silicone dielectric gel is confirmed through the independent testing in this research using the accepted technique of measuring the complex modulus of brain tissue by applying an oscillating shear strain and measuring the resulting strain and the phase shift between input stress and output strain. Testing is conducted using an Advanced Rheometric Expansion System (ARES) Rheometer (LS714306), from TA Instruments, in the University of Minnesota's Rheological Measuring Laboratory (serial no. 199815770).

Major Results: The suitability of silicone dielectric gel was confirmed through our independent testing. Figure 1 shows the results of this testing along with results published in the literature, which includes tests of the same gel material, the results of testing with several samples of porcine brain tissue, and other findings in the literature.

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