Excerpts from URS Proposal 1

Research Project:
Early engineering students have few encounters with engineering design applications and are thereby limited in their exposure to design optimization and critical design decision making. This research project identifies and addresses several of these concerns by seeking to create a design application in which the student is not presented with the entire design process but rather focuses on the major multidisciplinary design aspects. This project will allow a complex design system to run in a program with only major design decisions dictated by the student. The student will not need to be familiarized with all the theoretical aspects of the project in order to conduct realistic design project and thus the application will not be limited to high level engineering students.

My role in this research is to determine the most appropriate way to model the aerodynamic flow over a rocket, or user specified object, so that it can be implemented into a larger design module. This includes addressing several methods of calculating the aerodynamic characteristics of a body and determining the most practical method for this educational model. This research will address the theoretical modeling of aerodynamic flow as well as verifying experimentally the accuracy of these aerodynamic models. After the best suited theoretical model is determined the method will be implemented in MATLAB and be incorporated into a larger design program in which the module will be ran in conjunction with other Aerospace engineering disciplines such as propulsion, structures, and dynamics. The final program will be one in which the student will specify certain design characteristics and be able to determine how specific design decisions impact the performance of their system.

I will also be examining how multidisciplinary design optimization impacts engineering design and address the efficiency of complex design systems. This will be approached in the project by identifying the trade-offs presented with each design decision made by the student. As students become more aware of the effects of specific design decisions it aids them in determining the most desirable characteristics as well as presents a realistic engineering design environment.

This project began in January 2011 and will be continue through the summer of 2012. My involvement with project began in early February of 2011 and will continue through the next school year. Dr. Scott Ferguson will be providing support by guiding theoretical inquiry and providing expertise in the design process through weekly meetings and reviews.

Relevance to NASA Mission Directorates:
This research project supports the Aeronautics Research Directorate by familiarizing young engineering students with the design process. Complex engineering systems present many challenges in design optimization and introducing the engineering students to these processes at an early stage of the curriculum will aid them in several aspects. Experience with the design process prior to entry into higher level engineering courses will allow the student to focus on the fundamental principles incorporated in the design rather than stumble through the decision making process. A better understanding of the impacts of decision making when considering tradeoffs will also enable the student to make more informed decisions about the features of their design and to identify the reasoning behind certain design characteristics. Each of these lessons will aid the student as they advance into industry to optimize the engineering design and design process and thus help to maximize the efficient use of resources in industry.

Excerpts from URS Proposal 2

Research Project:
According to astrophysical measurements, much of the mass of our universe is undetectable by standard methods. This dark mass may be ultra-cold gas, very diffuse warm gas, or matter with unknown exotic properties. By measuring the fractions of neutral atomic hydrogen gas and stellar mass (M*) in a galaxy and comparing these gas mass and M* profiles to the rotation curve of a galaxy, it is possible to infer the mass of additional dark matter present in a given galaxy.

This research project will develop two types of computational code for use in astrophysical research and education. First, it will develop a program designed to infer the dark matter profile and gaseous and stellar mass profiles of a galaxy. The second aim is to develop free educational programs to engage high school students with astrophysical concepts like gravitation and dark matter via the same data used in the research portion of the project. These programs will be developed under the UNC-Physics and Astronomy summer computational program, an unfunded initiative by four research groups involving joint seminars and training for UNC undergraduates. The educational part of the program will be part of the high school teachers research mentor training workshop organized by UNC-Teach For America; both the research and the educational part of the project will be supervised by Dr. Sheila Kannappan of UNC-CH and will occur from 23 May to 31 July, 2011.

The programming and data analysis environment IDL will be used to develop a mass decomposition tool that measures dark matter as a function of radius. The tool will be applied to the galaxy NGC7360, which is of particular interest for two reasons.

First, dark matter may account for an unusually high portion of the galaxys mass composition. The galaxys rotation curve appears smooth, even as the observable M* drops off quickly and the gas mass remains stable out to a large radius. By applying the mass decomposition tool to this galaxy, it will be possible to show if the dark matter in the galaxy has an unusually high value relative to M* and gas mass components and therefore accounts for the smooth rotation curve. If this is true, any accurate analysis of the galaxy would require a mass profile for the dark matter.

Secondly, in spite of having 10-20% gas fraction and a companion galaxy that could trigger gas to form stars, NGC7360 demonstrates little star formation and lacks the characteristic spiral arms of star-producing galaxies. If dark matter in NGC7360 takes the form of invisible warm or ultra-cold gaseous matter that is also incapable of star formation, NGC7360s lack of star formation would be explained. Significant amounts of this mass may be counter-rotating, inhibiting the formation of stars; in order to make simulations to determine how counter-rotating elements may affect the galaxy, the dark matter profile of the galaxy is required. The mass decomposition tool will be used to obtain the dark matter profile and the fit parameters for an analytic halo model for NGC7360. These fit parameters will be given to Dr. Hugo Martel at Univerist Laval; his group will then simulate how the presence of counter-rotating components would affect ability of the gas in the galaxy to condense and form stars.
(Kannappan, Matthews, et al., in prep.)

The data on NGC7360 were obtained in 2001 May using the MMT telescope. I will start programming the mass decomposition tool through IDL in 2011 May, under the supervision of Dr. Kannappan. The rotation curve of the galaxy has already been obtained; IDL will be used to determine the M* and cold gas profiles and infer the amount of dark matter present by subtracting both from the rotation curve. Towards the end of providing useful tools to the research community, the entire code will be published online at http://resolve.astro.unc.edu by the end of summer 2011.

The program developed in IDL will infer the amount of dark matter present in a galaxy, given appropriate data. The data will be used to develop a series of educational programs in SciLab, a freely available programming language. The programs will be beta tested in July, when UNC-CH and UNC-Teach For America will host a week-long summer program focused in engaging high school students in exploring research. The programs will allow students with little computational background to observe how a galaxy's composition of matter and kinematics might change based on input parameters.

Relevance to NASA Mission Directorates

This project will support the Science NASA Mission Directorate by exploring the universe beyond our solar system. Because the mass decomposition tool will be designed with exportability in mind and freely hosted online, the final result of the project will assist observations of enigmatic facets of the universe beyond our solar system. Just as the NASA Joint Dark Energy Mission seeks to investigate the structure and evolution of the universe, so this projects exportable tool will be useful for obtaining new knowledge regarding the makeup of galaxies. In addition to producing an open-source, general tool for astrophysical investigations, it will also provide the analytical fit parameters necessary for collaborators at Universit Laval to explore how dark matter and counter-rotation affect a specific galaxy. Finally, educational programs will be developed around the same astrophysical data and concepts present in the research. Aiming to engage and teach high school students with little to no background in astrophysics, these programs will provide students with a free opportunity to explore otherwise inaccessible astrophysical data. Since the educational programs will be beta tested in the summer by high school students during UNC-CHs Teach For America high school teachers research mentor training workshop, the code will be refined before being hosted freely online. In this way, the project may contribute to inspiring the next generation of scientific inquirers while simultaneously providing specific knowledge and a general tool for astrophysical investigations.

Excerpts from URS Proposal 3

Research Project

Research into the dynamics of fluids and grains is an emerging area that offers many challenges. Because predicting the interactions of grains with different rheologies and of grains within fluids is so computationally intensive, any advancements in a physical understanding of grain behavior that would enable fast numerical refinements in applications such as coastal engineering simulations would be welcomed. In 2008, Calantoni & Thaxton received the Berman Journal Article Award from the U.S. Navy for their contribution to the advancement of granular physics. The publication introduced a relation governing sand transport under wave forcing conditions, the most important part of which was new information on the relationship between the transport rates of grains in bimodal distributions (that is, configurations of two different grain sizes). Many large-scale models currently rely on the relative computational ease of using beds of uniformly-sized grains. The Calantoni-Thaxton (C-T) Power Law should allow these models to more effectively represent sand transport, bedform evolution, and coastal morphology without the need for empirical corrections.

To provide further support for the C-T Power Law roll-out to large scale models, we have modeled a bed with a bimodal cross-shore grain distribution in two dimensions. The computer model, termed BedCell, tracks the distribution of both large and small grains, using established net transport relationships and the C-T Power Law to govern the time-evolution algorithm for the bed. BedCell incorporates parameterizations from discrete particle models and empirical relationships from literature, using time-steps on the order of one wave period and longer in an effort to show pattern formation and nearshore bed evolution over longer time periods. BedCell will soon incorporate the use of various, well-established total transport equations and other constitutive relations; hopefully this will shed some light on the relative utility of the differing techniques within the valid range of application. The result should reinforce the necessity of incorporating the C-T Power Law into nearshore morphology models. We are in the process of expanding the model and running simulations on the bed with various wave conditions. We began work on the model via an Appalachian State University undergraduate research grant and the NC Space Grant last year, and will present our interim results at the Symposium on Two-phase Modeling for Sediment Dynamics in Geophysical Flows in Paris, France this April by invitation. Collaborators with the Naval Research Labs (Stennis Space Center, MS) will be performing wave tunnel experiments in support of our model development, and I will be visiting the facility in February to work with them.

The research would take place from August 2011 through May 2012 at Appalachian State University. Dr. Thaxton will continue to guide the overall direction of the project and we will work closely together on further code development and running simulations. He will continue to provide me with relevant literature, so that I can immerse myself in the field. Our future work will focus on validating our functional morphology model based on data obtained from the wave tank experiments to be performed at the NRL Stennis facility in 2011 and archival data, namely the USACE FRF at Duck, NC (DUCK 94, SandyDuck 97, DELILAH 1990; see *www.frf.army.mil*). The long-term goal is to integrate this module into ROMS v3.0+ similar to Warner et al. (Computer & Geosciences 34, 2008, 1284-1306) in collaboration with Chris Sherwood (USGS, Woods Hole, MA).

Relevance to NASA Mission Directorates

Granular physics research has far-reaching implications for NASA. We have some understanding of how grains behave on earth, from repeated observation. Less is known about how different grains behave in wildly different environments, such as on other planets. A better understanding of the aggregate behavior of grains would enhance understanding of what conditions create various features and dynamics we observe on other terrestrial surfaces in our solar system.

More importantly, Earth science is a significant part of NASAs general science directorate, and NASA is directly interested in coastal and interior erosion and morphology in accordance with its Earth Surface and Interior area of focus. The computational model and its long-term implications would be an enormous asset to making predictions from and correlating with NASAs coastal satellite data. With the future of Earths climate in question and its potential implications to vulnerable coastal regions a concern, a more thorough understanding of medium to long-term nearshore morphological processes could enhance the capabilities to predict and mitigate coastal erosion.