Biological Computing for the Human Organism

A proposal for the Information Technology Initiative

The purpose of this proposal is to propose a research group that would be supported by the LSU CAPITAL initiative and academic units at LSU-Baton Rouge and LSUHSC-New Orleans. This group would conduct research related to the broad spectrum of biological computing for the human organism, including, but not limited to theory development, basic hardware and software development, and applications of theories and technologies. More specifically, the most relevant research focus for this group would be modeling, simulation and visualization.

The State of Louisiana and its citizens would be benefit from such a project from the following areas:

- The research group will help to put LSU at the forefront of biological computing and create an intellectual human resource pool for the development of new technology;
- Generate new technology that will help establish new IT-related businesses and improve existing IT-related businesses;
- Improve and expand the existing industrial and occupational rehabilitation industry, which will have a direct positive impact on workplace efficiency and safety, as well as on the general quality of life of the state's citizens.

Biological computing is an important component of informational technology. Although researchers and investors have directed most of their attention to the cellular and ecosystem levels of biological computing, which represent the micro- and macro-systems ends of the biological computing continuum, they have given little attention to the organism level, which represents the middle portion of that continuum. For the present proposal, the particular interest at the organism level concerns the human perception-motor skill interaction. In the daily activities of people, perception serves as an instant resource to shape actions, whether these be in the workplace or elsewhere. Perceptual information derives its usefulness for these purposes as a result of life long experience and training. Our motor skill capabilities provide an essential basis of daily living and work functions. These capabilities often determine the degree of independence people have in carrying out their daily activities. Accordingly, the interaction between our perceptions and actions forms a critical part of the foundation of our quality of life.

The importance and benefits of investigating and applying the organism level of biological computing to human life have only recently been realized within the science and engineering communities. For example, the National Science Foundation (NSF) awarded in 2000 in its Information Technology Research Grants (NSF-ITR) program funding for a visual perception related project. This research project addressed fundamental problems in the fields of computational vision, computer graphics, and human-machine interactions. Improving human perception of computer graphics was one of the goals for the project. The same agency (NSF- ITR) also awarded funds for a virtual locomotion interface project for which the goal was to develop a system to allow a person to walk naturally through a large-scale virtual environment. The PIs claimed in their proposal that the availability of such a locomotion interface would impact a broad range of applications, including education and training, design and prototyping, physical fitness, and rehabilitation.

For the proposed research group, biological computing at the human organism level will consist of three components: modeling, simulation, and visualization.

- Modeling is the geometric counterpart to simulation in that the goal is not to describe function, but to quantitatively capture anatomy and physical locations of organs in space. From the locations of points in space, modeling seeks to define connections between these points in order to define areas, surfaces or volumes. The spatial relations of those volumes can then be defined. Models in biological applications define anatomy of tissues and organs in the body by means of discrete points joined to form polygonal elements such as rectangles, triangles, hexahedra, and tetrahedra. There is a natural synergy between modeling and simulations in that many simulations require a geometric description of the tissue whose function is to be simulated. Examples of models that arise in human biological simulations include models of the head and brain for localizing neural sources and models of the thorax and heart for simulating cardiac defibrillation.

- Biological simulation is the quantitative description of biophysical behavior in terms of mathematical equations. The reasons for performing simulations include the desire to replicate the function of living organisms, both as a test of our understanding, and as a tool to investigate conditions that are difficult or even impossible to create experimentally. Examples of simulation include the propagation of cardiac activation, skeletal muscle contraction, external fields from discrete and distributed neural sources, and the relationship between cardiac bioelectric sources and body surface potentials.

- Visualization is an essential component of biological computing that provides a means for viewing geometric models, experimental results, simulation results, and clinical observations. For example, visualizing a three-dimensional head model along with the MRI scans from the patient and the results from a source localization simulation requires the integration of many different types of visualization techniques -visualization of the geometrical mesh, visualization of the MRI data using volume rendering, visualization of the potentials and currents from the simulation using surface shading -all integrated into a single frame.

The proposed research group would enhance the capabilities of several programs on the LSU campus and in the State. For example, the Life Course and Aging Center Initiative (LCAC) on campus is a multidisciplinary task force created by the office of Research and Graduate Studies. The mission of LCAC is to respond to the unique needs of persons in Louisiana and throughout the country. Their approach is decidedly interdisciplinary in that we examine the biological, psychological and social aspects of development throughout the life course. Within this group, modeling can help us better understand biological and physiological changes that occur throughout the life span. Simulation can help us investigate the cognitive and motor control processes that underlie motor skill acquisition. Visualization can help us to understand the interaction between individual and environment.

In addition, the Occupational Medicine Research Center (OMRC) was established last year with a multi-million dollar grant from the Louisiana Board of Regents Millennium Trust Health Excellence Fund. This Center, which involves researchers from LSU Baton Rouge and LSUHSC New Orleans, focuses on the investigation of issues related to the prevention and rehabilitation of industrial injuries as well as the training of industrial workplace skills. The addition of biological computing that involves modeling, simulation and visualization of the perception and motor skill interaction will greatly enhance the capability of the Center to assist Louisiana industries improve the quality and health of their work force.

To function in an optimum way, the proposed research group should be able to work at all points along the entire spectrum of biological computing for the human organism. These include:

- Theoretical framework development. Research that address the uniqueness of the problem and identifies the appropriate directions for the research group based on the understanding of trend and need of the field-

- Hardware and software development. Hardware and software that would enable us to capture, compute, exchange, and present biological data.

- Research that can take advantage of the developments of the previous two points and apply them to various areas of concern, such as movement disorder detection and correction (e.g. cerebral palsy, Parkinson's disease), physical rehabilitation, and skill training (in 2000, NSF-ITR funded a project titled *Virtual Trainer).*

To establish the research group proposed in this proposal, we recommend the funding of at least two faculty positions. These positions would be filled by researchers who would lead the group in the following ways:

- Direct the development of hardware and software (1 position to be located within the Department of Electrical and Computer Engineering)

- Direct the application of and research concerning the hardware and software developed (1 position to be located within the Department of Kinesiology)

Although initiated and developed primarily by the Department of Kinesiology, this proposal has the support and interest of the Department of Electrical and Computer Engineering (LSU-BR), Department of Physical Therapy (LSUHSC-NO), Bioengineering Laboratory (Department of Orthopedic Surgery at LSUHSC-NO), and the Occupational Medicine Research Center (LSUHSC-NO and LSU-BR).

For further information contact:

LiLi
Assistant Professor
Department of Kinesiology
lli3@lsu.edu

Richard Magill
Helen "Bessie" Silverberg Pliner Professor of Kinesiology
rmagill@lsu.edu

Amelia Lee
Mary E. Baxter Lipscomb Memorial Endowed Professor of Kinesiology
amlee@lsu.edu