The Digital Human Program
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WHAT IS IT?

The Digital Human Program is a research and development program to produce an integrated modeling and database system that enables the efficient construction and utilization of a large class of quantitative models of the whole human body in order to simulate the function of the entire organism. These computer-based simulation models will be capable of structural integration, spanning multiple levels of biological organization, from the whole body through the organs, tissues, and cells to the genes and proteins. In addition, they will be capable of functional integration, integrating multiple coupled physiological subsystems and components of biological networks (circulatory, respiratory, musculoskeletal …) into a consistent whole-body model. Finally, such models will serve the important function of data integration, integrating empirical data and phenomenological observations with theoretical principles.

The Digital Human Program will develop the infrastructure that enables the community of biomedical scientists, medical personnel, engineers, and computer specialists to share their work and build constructively and incrementally on each other's efforts. The resulting Digital Human System would help biomedical researchers master the staggering complexity of their discoveries, assist physicians to use these discoveries effectively to improve health, and help engineers, human factors experts and computer specialists to imitate biological mechanisms, thus promoting improvement in artificial organ, robotic and safety-feature design and enabling revolutionary changes in computing capability.

COMPONENTS

The Digital Human Program involves four general types of activity (see Figure 1):

- Foundational Infrastructure Research & Development
- Bridging Projects
- Focused, Special-Purpose Projects
- Broad, General-Purpose Applications

Foundational Infrastructure

The foundational infrastructure activities involve developing:

- A general whole-body based modeling and data structure to enable future modeling and research activities to fit together in a consistent way;
- Physiologically-based ontologies of each system, organ or element of the body to enable clear, unambiguous communication within the investigator community;
- Physiological models that serve as the building blocks of the Digital Human;
- Database systems associated with the ontologies to enable rapid exchange of data and community utilization of data to construct and validate models and simulations;
- Community training programs designed to educate today's scientific community in current approaches to modern systems analysis, modeling and simulation;
- Basic and advanced computing and bioinformatics tools for general use by the scientific community;
- …

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Bridging Projects

Bridging project activities are those activities that focus on some of the most difficult problems related to the Digital Human. These problems include those that seek the way: to quantitatively connect the different levels of organization within the human body (structural integration challenges, e.g., realistically connecting tissues, networks, cells and proteins, and moving smoothly among the various time scales within these elements); to integrate different functional elements within the body (functional integration challenges, e.g., faithfully connecting such subsystems as the circulatory, respiratory and thermoregulatory); and to integrate empirical or phenomenological data and observations with known theoretical principles (data integration challenges, e.g., developing a functional whole-body model in the absence of certain fundamental data elements). Problems within the general area of systems biology are strongly related to the bridging projects, particularly those dealing with pathway reconstruction and other basic problems of functional integration.

Special-Purpose Projects

Special-purpose projects are those whole-body modeling and simulation activities that clearly fall within the domain of a single special-interest group. For example, the National Aeronautics and Space Administration (NASA) is very interested in developing a special-purpose "Digital Astronaut" capable of responding to the unique environmental challenges posed by space flight. The U.S. Defense Advanced Research Projects Agency (DARPA) is likewise interested in developing a "Virtual Soldier" capable of a number of military uses.

General-Purpose Applications

General-purpose applications include a wide variety of uses of broad benefit. Some of these applications are: general medical education and training, surgery, medical practice and patient care, drug development and therapy, medical and research data repositories, research interpretation, robotics, biomimetics, etc.

DIGITAL HUMAN PROGRAM BENEFITS

The human body is one of the most complex systems known today. This Program will lead to a deeper understanding of how the body functions, thus giving us unprecedented power to improve health. Carrying out this Program will develop the tools that are required to visualize the operation of complex systems within the body. One might, for example, view how cells assemble the miniature machines they need or how defects in electrical networks degrade the performance of a heart and how intervening with new drugs, surgeries, or other therapies can prevent or repair this degradation. It can also allow one to better view the combined effects of multiple factors on this complex system. The web of models created by the Digital Human Program could also allow one to visualize the operation of multiple physiological systems acting together, allowing one to analyze the impact of a stressor or treatment on these multiple systems simultaneously. The Digital Human Program will aid ***biomedical research*** by promoting the real integration of data from many different types of physiological research, allowing for a better understanding of the workings of the entire human body during normal or aberrant function and during exposure to extreme environments. It will also provide a new approach to certain problems of ***bioinformatics*** by creating ontological-based data systems. The Program will aid ***human factors, ergonomics and robotics*** development by allowing for better visualization and testing of impacts of safety measures on multiple systems. It will aid ***medical practice*** by assisting in the design and automatic control of artificial limbs and organs; the design and use of pharmaceuticals or specified dietary routines; and the treatment of accidental or intentional injury (collision, bullet wound, burn, etc.). In addition, this effort will provide a teaching tool for both ***general education and professional training***.

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