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# SIMULATION OF PHYSIOLOGICAL SYSTEMS

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Simulation, according to Webster, is the act of representing, feigning, giving an appearance, or assuming. This definition is quiet appropriate in physiological systems. Unlike the technological system, the problem is not the design or the improvement of the system, but rather the understanding of its blueprint. This process is a bit by bit effort in an attempt to unravel a system which has developed slowly over thousands of years of evolution.

There are major difficulties in this process, which account for the relatively slow understanding of the workings of the human body. Firstly, there are thousands of subsystems each providing individual functions. Many of these subsystems are interconnected in massive feedback and control networks. The eye alone contains a network of millions of connections and interconnections. Size of the system is, in itself, often a major stumbling block in the simulation process.

Another stumbling block is the variation in physiological data for normal individuals. The range of data is often so large that it is difficult to perceive if a model is working correctly. Of course, much of this variation is due to the myriad of interconnecting systems. However, a large deviation in physiological variables allows for an inherent slackness in physiological models. It often becomes necessary to break the model down into smaller and smaller pieces in order to isolate and lessen this variation.

Another problem is that physiological systems are invariably nonlinear. This is due to the wide range of input to the body which must be processed in abridged fashion. The eye is a perfect example. The range of light entering the eye is quiet large. The eye adjusts so that only under very dark conditions is ones vision seriously impaired.

The overriding issue is that a physiological model is never quiet exact, always somewhat questioned. As more and more pieces of the puzzle are put into place, a clearer picture begins to develop. Often times, however, more questions arise which add a further complexity to the problem. The final answers always seem just out of reach. The process is certainly difficult, the results questionable, and the methods, at times, arbitrary.

Why then is physiological simulation so important? It is more than simply a curiosity in trying to understand the workings of the human body. The process of diagnosis and treatment of many diseases is based on this understanding. For too long, the science of physiology has been merely a collection of data, with little or no knowledge as to what one is measuring nor why. Many pharmaceutical treatments are still not well understood because of this lack of knowledge of the workings of the system.

The entire field of prosthetics and orthotics requires one to be able to mimic the actions of organs and limbs. The development in this field are slowed somewhat by technological advances in mechanics and electronics. However, the lack of understanding of the physiological system being replaced or repaired is often times the major stumbling block. The field of orthotics is still limited by the need to understand such issues as neurological connection and control, tissue ingrowth and bone connection. Prosthetics development, such as the artificial heart is slowed by the need to understand the rejection phenomena, endothelialization, vascular feedback systems, neurological controls and blood rheology.

There are few viable alternatives to the modeling process. Physiological measurements are often times utilized as a substitute in order to increase the data set in an attempt to intuitively understand the system. However, the measurements are often difficult, painful and costly; and the inherent variability of the data is usually counterproductive in the path towards understanding. The measurements themselves are somewhat questionable since the vast majority are indirect and therefore somewhat subjective. The verification of physiological models is somewhat a difficult process in itself since measurements are at times not reliably repeatable. However, measurements and simulation need to go hand in hand. The process is invariably slow and laborious, but the need for the marshalling of these two efforts is important if medicine and biomedical technology are to ever advance.

Three distinctly different examples of physiological systems are presented in order to cover a gamet of applications. The first system describes the intricacies of ionic transport across cell membranes in relation to the epileptic process. The fields of mass transfer, electricity and physiology are all blended into the description of a basic function of the human body; the generation and transfer of bioelectric events. These events represent the major, fast action means of communications and control in the body. The second system describes the human eye with its millions of interconnections. This system represents a truly nonlinear package of a vast amount of data being communicated in a short amount of time. The resulting data base can be monumental and the difficulty in obtaining a unique description of the connection "map" is at times overwhelming. The third model is one which describes the workings of the human mitral valve, the inlet valve to the left heart. This valve is often replaced by artificial valves and its performance has been connected to sudden death and disability. The understanding of this system involves fluid mechanics and solid mechanics as well as anatomy and physiology.

Physiology provides a vast and fertile field for simulation efforts. It is still one of the major unknown fields that requires models to understand the basic workings of the system. The advances in analog and digital simulation are welcome since the need for intricacy and data handling are important requisites in many models. There are still many questions that must be answered.