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Computational Medicine

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Abstract— Computational medicine is an emerging discipline that harnesses the power of computers to solve real problems in the medicine and clinical research. As a scientific discipline, computational medicine encompasses all aspects of applying computers and computing models to support medical research in health care services. In this brief introduction, we will see how computing can address issues facing health sciences.

Keywords— computational medicine, computational modeling

I. INTRODUCTION

Computational modeling has been tremendously successful in engineering. A great challenge is to extend the success of computational modeling to fields outside traditional engineering, such as medicine. Computational medicine (CM) is a fast-growing method of using computer models to investigate how disease develops. With the assistance of CM, research in the field of medicine has gained tremendous benefits and expansion over the past few decades. Since biological systems are inherently complex, computational models are needed to understand their function in health and disease. In the new era of data-driven personalized medicine, we will rely more on the help of computational analysis [1].

The dramatic advances in software and hardware development during the past half-century suggest that our computational efforts in the next half-century will supercede all imagination. By applying digital tools, researchers have begun to build models that can unravel complex medical mysteries. The field of computational medicine is exciting and important.

II. COMPUTATION EXAMPLES

CM has successfully applied to cancer, diabetes, and heart disease. Winslow, who is first author of the Science Translational Medicine overview, describes examples of computational medicine [2]:

- Advanced mathematical models which allow researchers to understand how networks of molecules are implicated in cancer and then use this knowledge to predict which patients are at risk of developing the disease.
- Computational physiological medicine which uses computer models to look at how biological systems change over time from a healthy to an unhealthy state.
- Computational anatomy which uses medical images to detect changes, for example, in the shape of various structures in the brain.
- Computational models of electrical activity in the heart are on their way to being used to guide doctors in preventing sudden cardiac death and in diagnosing and treating those at risk for it.

To solve sample computation of a bioelectric field problem may involve the following steps [3]:

(1) Construct, manipulate, and display large-scale, three-dimensional geometric models,
(2) Develop a three-dimensional, finite element program for elliptic partial differential equations with general boundary conditions and source terms,
(3) Programs apply global and local regularization and solve the system of equations, and
(4) Visualization tools for displaying the results.

Visualization enables researchers to observe the results of their computation. NMR, CAT, and PET scanners are now routinely used in most hospitals. They allow the physician to simulate surgery before carrying it out on the actual patient [4]. These days, the four steps mentioned above are routinely implemented using finite element based software packages such as COMSOL and High Frequency Structure Simulator (HFFS). These packages put powerful tools and techniques, previously available only to full-time theorists, into the hands of health-care professionals [5].

III. CHALLENGES WITH CM

With the advent of powerful computing tools, researchers have been able to understand the intricate dynamics involved in diseases. However, these tools must often be checked with real-world data and adjusted accordingly [6].

A major challenge of computer simulation in medicine is the search for tools which are able to define the connection between the virtual world and the empirical world.

Determining the validity of a computer simulation model can be a difficult undertaking.

Another challenge in computational medicine is to demystifying the technology for nontechnologists. Computer scientists and medical scholars need to communicate effectively as they work together.

While computational medicine is provocative and important, it remains marginal to mainstream scholarship.

IV. CONCLUSION

Computational medicine has greatly helped in the analysis of biological information.

Computational tools are now in the hands of doctors who treat patients with all kinds of illnesses. They should be multilingual and user friendly so that they can be accessed by experts in different nations. The Institute for Computational Medicine at Johns Hopkins University offers a multidisciplinary undergraduate minor in computational medicine. Imperial College London is launching a 10 week module for undergraduate medical students learning computational medicine. Computational medicine will to provide a quantitative approach to our understanding, detecting, and treating diseases.

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