Modelling Personalized Value-based Healthcare
A Position Statement for Analytics Challenge in Healthcare

Prof. Yike Guo, Dr. Anthony Rowe
Dept of Computing Imperial College, London

Context within Grand Challenges

This submission relates to the new challenge of health area. It focuses on advanced computational analytics to tackle the challenges in a personalised medicine vision for value-based healthcare, where all the information about a patient, ranging from biological, life style and clinical information, will be integrated and analysed to provide an optimal healthcare plan for the individual. Our goal is applying information technology to help provision of healthcare at the best value - minimising the cost of healthcare but at the same time improving patient outcomes.

Personalized Value–based Healthcare

The cost of healthcare per capita is soaring; reasons often cited include an ageing population, changes in life style and environment and the ever more complex and expensive therapies. However, individual patient outcomes are not improving at a rate that matches the increased spending. A vision of personalised healthcare has received publicity recently. Such a vision could potentially hold an answer for both improved outcomes and reduced costs.

Personalized healthcare is becoming possible due to the rapid developments in advanced high throughput diagnosis and health monitoring technologies. Personal genetic information can now be easily acquired such that key information such as individual’s DNA variations may be used as risk indicators for certain diseases. Also, personal life style information, such as diets and exercise frequency, etc can now be easily monitored. When translated into clinical practice this type of understanding of personal biology and life style information could hold many benefits for developing and delivering improved treatments. Key challenge in this context include developing and applying advanced analytical computing technology and exploring the roles that healthcare information and systems-based modelling have in helping understand how the healthcare system responds to different stimuli and how the increased personalisation of medicine affects this understanding.

In last 10 years, we have been exploring such challenges in collaboration with large pharmaceutical companies and leading international research institutes. We have been working on systems that explore the challenges associated with the vision of being able to make use of all of the information about a patient to support data analysis and also modelling of the healthcare system. These research activities have been funded by EPSRC with the Discovery Net e-science project, Discovery Science platform grant, i-health grant, a recently funded grant on “Information Driven Optimization of Care pathways and Procedures”, BBSRC grant on “Integrative Biology in-silico: Application of Advanced Informatics to System Biology”, Wellcome Trust grant on “Biological Atlas of Insulin Resistance” and recent large EU IMI project U-BIOPRED project on translational medicine for airway system diseases.

Informatics Challenges to Understanding Healthcare

A Healthcare system is formed from a complex network of interacting actors, processes and sub-systems. The integration of personalized healthcare information in such a system is currently poorly defined and quantified. To help improve the value of healthcare, the challenge can be broken down into a number of specific technical challenges:

Information Management Challenge – Patient information is fragmented across the healthcare system from the hospital to the local GP surgery and rehabilitation services such as physiotherapy as well as with the patients themselves. To quantify both the clinical outcomes and costs of interventions across
these different pathways consistent metrics and information capture methodologies need to be developed to accurately represent the interactions of patients with the healthcare systems.

**Decision Support Challenges** – To understand and recommend best practice, decision support systems need to be integrated into clinical practice. Determining what tests are required and recommending a best practice course of treatment must be seamlessly integrated into the physician’s business process.

**Translational Challenges** – To personalise the recommendations of clinical best practice to the individual or cohort of similar individual then decision points on a patient clinical pathway need to be tied to key personal biological metrics such as biomarkers including Genetic, Genomic, Proteomic, Metabonomic information together with clinical data and hospital operational data. The translation of these biomarkers into clinical practice (Translational research) is a key challenge.

**Translational Healthcare Informatics Research**

Based on these research activities, we have developed the Translational Healthcare Information (THI) model with two main categories of data sources:

**Individual Centric Data**: this is data that is about an individual, two main streams of individual centric data are included in the THI: **Personal Life Style Data**: this is data that people are increasingly starting to capture about their own life style using devices such as smart phone based exercise logs and nutrition diaries. As individual medical sensors become more pervasive this stream will become increasingly important in monitoring the environmental factors affecting heath. **Biological Data**: this is personal biological information that enables the personalisation of clinical pathway by making clinical decision on the basis of biomarkers that indicate how a patient will respond to a specific therapy.

**Pathway Centric Data**: this is data that is collected from the clinical pathway that a patient follows when receiving diagnose, treatment and rehabilitation, two main streams of pathway centric data are include in the THI. **Clinical Pathway**: This contains information derived by tracking each patient treatment process in order to provide quantifiable cost and outcome metrics. **Electronic Medical Records and Hospital Operational Data**: this is the underlying transactional data on patients clinical history and in-house information on scheduling of hospital resource such a consultants, operating theatres and radiology facilities to understand the availability of such resources at any time.

Each of the different resources is then combined into a resource known as the Personal THI Model which is enriched with scientific knowledge from a range of biomedical sources such as literature and on-line databases. Based on such a model, we have been developing a wide range of technologies to enable an information-driven healthcare framework to help physicians select the best continuation of pathways for their patients. The aim is to offer the most beneficial outcome at the most effective cost at the level of the entire clinical pathway rather than at a specific intervention point.

Our technical research focus can be summarized along three strands: **THI Data Cloud**: where we aim to construct a novel multi-tenant data federation model to unify clinical, biological, life style and hospital operational data organized along the lines of the clinical pathway in a generic way so that it can be easily configured by any healthcare organisations for clinical practice; **Performance Model for Clinical Pathway**: where we focus on applying complex system modelling technology to model a clinical pathway with respect to various clinical cohorts. We use stochastic process calculus technology for the modelling and applying large scale simulation technology to evaluate the performances of models generated from a specification to provide a quantified measurement of performance on clinical decisions; **Disease based THI Matrix**: where we aim to develop KPI matrices for treatment performance for a set of diseases and use them with the performance modelling tool to provide a platform to investigate clinical pathways with specific patient features such a specific clinical measures, biological markers, genetic profiles and/or life style of the patient and the specific personalization strategy. The goal of the research is to build up a systematic framework to optimize a clinical pathway to improve the overall value of the pathway for a clinical cohort.