Prognostic Models in Medicine: Artificial Intelligence and Decision Analytic Approaches

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Abstract

This paper is meant as an introduction to the workshop on *Prognostic Models in Medicine: Artificial Intelligence and Decision Analytic Approaches* held during AIMDM'99. Prognosis – the prediction of the course and outcome of disease processes, either or not changed due to interventions – is an important aspect of medical tasks like diagnosis and treatment management. Techniques for building prognostic models vary from traditional probabilistic approaches, originating from the field of statistics, as used in decision analysis, to more qualitative and model-based approaches originating from the field of artificial intelligence. The workshop brings these two fields of research together in the hope that a fruitful exchange in ideas will take place.

1 Introduction

Prognosis, the prediction of the course and outcome of disease, is a subject that lies at the heart of patient management. There is little sense in delving into the cause of particular symptoms and signs in a patient, and to initiate elaborate diagnostic procedures, if it is known beforehand that no effective treatment of the considered disease exists. Furthermore, also treatment selection invariably involves taking possible future beneficial and harmful effects into account, i.e. prognostic information [4].

Of course, the process of patient management concerns issues other than prognosis as well. The primary role of the physician is to guide the patient through the disease process, which involves much more than prognostication. Even the processes of diagnosis and treatment selection may be seen in this light of guidance of patients. This view may explain why prognosis, despite its central role in medicine, is not clearly recognised as such in typical medical textbooks, like *Harrison's Principles of Internal Medicine* [1]. The subject of prognosis is only paid attention to when it is obviously important, such as in cancer treatment.

It is likely that this situation will change in the near future, and that the role of prognostic models in medicine will increase. Medicine as a field is becoming increasingly complex, as is reflected by the annually increasing number of different diagnostic tests and therapies from which a clinician must choose. Prognostic models are required to assist clinicians in this selection process to ensure that the patient will benefit from further progress in medical science.

2 Prognostic models

As has been said above, there are a number of fields in medicine, where prognostic models are of particular importance. Examples of such fields are: oncology, transplantation medicine, and trauma medicine. Usually, prognostic models focus either on long-term or short-term effects. For example, long-term effects dominate in treatment considerations in oncology, whereas short-term effects are more significant in trauma medicine. Adequate prognostic information is of major importance in these fields so that prognostic models of various kinds, not necessarily mathematical in nature, have been in use for quite some time. Often these models are coarse and lack detail. The TNM staging system that is used to assess a primary malignant tumour in terms of its size (indicated by T_0 to T_4, where an increase in subscript corresponds to an increase in tumour size, as defined for a particular type of tumour), regional lymph node involvement (N, also supplied with a subscript), and presence of distant metastatis (M) is an example of a simple qualitative tool to assess prognosis in cancer patients. Another example is the Apache III scoring system, which is based on a logistic regression model, and that has been shown to have a good predictive ability for patients with severe illness, and for a large variety of diseases [2].

As one may expect, clinicians are only prepared to accept prognostic models when it is obviously that they will contribute to quality of care [7]. Prognostic models are not only used in a clinical setting. They are also used, and may even have had a larger impact, in the design of clinical trials, counselling patients and in medical technology assessment.

In general, and independent of particular applications of prognostic models, the problem of the design of accurate prognostic models is the capturing of the many possible subtle interactions among variables that exist. It is largely determined by the (mathematical) modelling tools used to what extent such interactions can be expressed, and learnt from data, possibly augmented with background knowledge.

3 Artificial intelligence and decision analysis

Medical artificial intelligence is generally concerned with the development of medical models for various purposes, but usually the aim is to assist clinicians in the processes of diagnosis, treatment or prognosis of diseases in patients. A key characteristic is the *explicit* representation of the medical knowledge involved, i.e. the explicit representation of meaningful interactions among the factors that play a role in a particular medical problem is favoured [3]. However, there are a number fields in artificial intelligence, such as neural networks, where goal of explicit representation is less dominant. There is now an entire array of different techniques from which medical AI pratitioners may choose. One of the difficulties has been the representation of temporal patterns. Progress in the field has yielded new, flexible techniques, like Bayesian networks , neural networks and genetic algorithms that offer new opportunities for dealing with the issue of prognostication.

Medical decision analysis offers a systematic approach to medical decision making under conditions of uncertainty [5; 6]. It has studied the use of prognostic models in the process of decision making now for more than two decades. An enormous amount of practical experience in building medical models has been built up during these years. However, there has been little progress in the field with respect to new techniques and tools that may be used to carry out a decision analysis.

Until recently the fields of artificial intelligence and decision analysis appeared to have only in common that in both model building is of crucial importance. In the field of artificial intelligence there has been a revival of interest in numerical methods stemming from probability and decision theory, and from the field of neural networks. The new ideas and techniques that have come out of this, has not passed by unnoticed by the medical decision analysis community. There currently seem to be much interest in that field with respect to applicability of these technique. At the same time, medical artificial-intelligence researchers realise that much can be learnt from the more mature field of medical decision analysis. This workshop is therefore a timely opportunity to exchange ideas and opefully to learn from each other.

4 Road map to the workshop papers

To conclude this introductory paper, we shall briefly summarise the contents of the papers in the working notes.

The paper by S.S. Anand, P.W. Hamilton, J.G. Hughes and D.A. Bell, titled *Utilising censored neighbours in prognostication*, discusses an extended version of the k-nearest neighbour algorithm, which is applied to the problem of prediction of the survival of patients with colorectal cancer. Novel is the possibility of dealing with censored patients, which is typical for survival analysis in medicine. The paper by S. Antel, L.M. Li, F. Cendes, Z. Caramanos, A. Olivier, F. Andermann, F. Dubeau, R.E. Kearney, R. Shinghai and D.L. Arnold, with title *A naive Bayesian classifier for the prediction of surgical outcome in patients with temporal lobe epilepsy*, focusses on a number of important issues that arise when one wants to develop prognostic models the are clinically useful. The development of a Bayesian classifier for the prediction of the outcome of patients with temporal lobe epilepsy that undergo surgery is reported. Bayesian classifiers are also the topic of the paper *Robust outcome prediction for intensive-care patients* by M. Ramoni, P. Sebastian and R. Dybowski, but here the main issue is how to deal with missing values in clinical data. A comparison is made between logistic regresssion augmented with an imputation mechanism and what is called a *robust* Bayesian classifier in which no assumptions are made with respect to the mechanisms underlying missing data.

In the paper by H. Dreau, I. Colombet, P. Degoulet, G. Chatellieri, titled *Identification of patients at high cardiovascular risk using a critical appraisal of statistical risk prediction models* not techniques, but different statistical risk-prediction models are compared. This paper sheds light on the assumptions underlying statistical models, and on the question to which extent assumptions are valid and may affect the conclusions that may be drawn.

There are a number of papers in which statistical or decision-analytic techniques are compared or combined with AI techniques. For example in the paper by L. Ohno-Machado and S. Vinterbo, *Influential case detection in medical prognosis* it is studied whether a genetic algorithm offers advantages over conventional techniques for the selection of cases in the construction of prognostic logistic regression models. The prediction of the prognosis of trauma patients has been chosen as an example domain. I. Zelič, N. Lavrač, P. Najdenov and Z. Rener-Prime in their paper *Impact of machine learning to the diagnosis and prognosis of first cerebral paroxysm* compare ID3-like decision-tree induction with naive Bayesian classifiers from the perspective of machine learning. The comparison is carried out in the medical domain of epilepsy.

The remaining two papers focus on medical applications of techniques from the areas of artificial intelligence. In the paper by N. Peek, *A specialised POMDP* *form and algorithm for clinical patient management* the formalism of partially observable Markov decision problems (POMDPs) is studied. This formalism has originally been introduced in artificial intelligence as a means to handle planning problems under conditions of uncertainty. POMDPs, however, have also been suggested as a suitable formalism for medical treatment planning. Since the formalism is known to be intractable in general, this papers proposes the use of Monte Carlo simulation to render the formalism practically more useful. The paper by R. Schmidt, B. Pollwein and L. Gierl, titled *Prognoses for multiparametric time course of the kidney function* also discusses the suitability of a technique from the field of artificial intelligence to the development of prognostic models, namely the application of case-based reasoning to the prediction of kidney function. Advantages and limitations of case-based reasoning are clearly discussed.

We may conclude that the papers in the workshop, although all dealing with the issue of prognostic mocels, are indeed varied; both methods and techniques from the fields of artificial intelligence, decision analysis and statistic are covered by the papers. Sometimes these techniques are dealt with separately, sometimes they are combined and in some papers they are compared to each other. It may therefore be concluded that the title of the workshop does indeed reflect the contents of the papers in the workshop notes.

References

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