A Patient Care Workstation Based on User Centred Design and a Formal Theory of Medical Terminology: PEN&PAD and the SMK Formalism

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Abstract

The PEN&PAD clinical workstation is for use by clinicians for direct patient care. It is based on a highly structured and detailed medical record but is intended to be simple and intuitive to use, allowing clinicians to summarise and view information in many ways, and quickly enter information through structured forms. It also provides mechanisms for tailoring the system to individual users without compromising its overall integrity. This has been achieved by following a process of user centred design and by developing a novel formalism, Structured Meta Knowledge, to represent the terminological knowledge, the medical record, and pragmatic knowledge about clinical practice.

Introduction

The PEN&PAD project is developing workstations for doctors, nurses, and other health care professionals which they should find useful and usable for the direct care of patients [1, 2, 3]. The aim is that users should find the system simple and intuitive to use, while at the same time it should be capable of dealing with the complexity of detailed clinical information. However the clinical complexity inevitably requires a corresponding technical sophistication, and this can easily result in a confusing and counterintuitive system. PEN&PAD is addressing these requirements and attempting to resolve the implied conflict between perceived simplicity and technical complexity. It is essential to make the technology 'invisible', or at least so unremarkable, that it is never really noticed. The PEN&PAD system has been enthusiastically received in extensive formative assessments, and initial field trials are scheduled to commence in the autumn of 1991.

From its inception, the project has adopted and developed a User Centred Design methodology described in a separate paper. One aspect of making the technology 'invisible' is to fit it well to the users' tasks so that the functions required are always readily to hand [4]. However such intuitive behaviour and common sense are notoriously difficult to capture in computer systems, and the requirements thrown up by the user centred design process may have no simple implementation using conventional techniques.

PEN&PAD aims to capture all of the clinical information in the medical record in a structured formalism.* To achieve this, and to do so in a way which users find natural and intuitive, has required the development of a novel knowledge based approach to medical semantics which provides a unified formalism for medical terminology and medical records, Structured Meta Knowledge (SMK) [5]. A further outcome of this work is an improved understanding and models of the nature and function of the medical record [6]. The goals of SMK are to answer the question, 'What is it medically sensible to say in this situation?' and to provide a framework for expressing the pragmatic knowledge needed to answer the question 'Of all the things which it would be sensible to say, which things is this doctor most likely to want to say now?' The data entry forms which are at the heart of the PEN&PAD clinical environment are built from the knowledge base on the basis of the answers to these two questions.

The User Centred Design Process has re-emphasised the variations in the needs and wishes of different clinical users. The system must be able to cope with the major differences in clinical approach and content required by different users and clinical problems. Clinicians need to be able to extend and adapt the system smoothly without compromising its integrity. For example it is essential that the system be able to maintain different protocols for different doctors, patients, and practices, or for research

* By clinical information we mean that information which clearly falls in the clinical domain. For example, that John Smith's angina is aggravated by cold is within the clinical domain, that it comes on when he is passing the freezing compartment at the local supermarket includes concepts from the domain of everyday living and is not within the clinical domain.

groups to integrate the collection of information for clinical trials with routine patient care. A major function of SMK is to make it possible to extend the system in a principled way to include concepts such as "Dr. Smith's variant of the Capitol Health Center protocol for diabetic patients over the age of 50" or even "Dr. Smith's protocol for Jane Smith's diabetes".

Data Display and Browsing

PEN&PAD is based on a detailed and highly structured medical record which the user may browse in many different ways. Conceptually there are three primary axes: encounters, problems and investigations or treatments. The information may correspondingly be organised as notes of encounters, summaries of problems, and as graphs or flow charts of results or treatments. The system allows the user to switch easily from a view of the medical record at some point in time to a chronological perspective.

The simplest access is via the encounters. If a user selects an encounter, all of the information entered at that time is displayed, corresponding to the narrative text of a paper record. If a user selects a problem, he or she can use it either to bring together all of the relevant encounters or to produce a summary of the relevant investigations and drugs. If the user selects one or more investigations or treatments, he or she may produce a graph or flow chart of all of the corresponding results and prescriptions available in the record. More generally, any item - sign, symptom, diagnosis, test result, or treatment - anywhere in the display may be selected and used to generate a graph or time line showing all of its observations, or used to obtain all the details of the encounter at which it was entered. From the encounter other data items or problems can be focused upon and used to generate further graphs or summaries.

The user is thus provided with a flexible means of investigating the record following either the chronological flow of events or a series of linked observations and hypotheses. The user environment illustrates the prime result of the user centred design studies captured in the slogan 'There is no one best way'. Users are provided with a range of different ways of gathering information together. They can start either from the fixed displays in the initial summary window or from items which appear in other windows as the consultation progresses. Chronological data can be presented as either graphs or flow charts, since while most users prefer graphs, some have a strong preference for tables, and most find tables easier to use in certain situations. Multiple items can be graphed together.

Data Entry

Data entry in PEN&PAD uses structured forms which are generated from the knowledge base of terminological and pragmatic knowledge as required. The design of the forms has been amongst the most important outcomes of the user centred design process. Their initial success surprised the design team, and subsequent variations have led to a number of conclusions. Users find modest over inclusiveness preferable to over selectivity. Users ignore items which they feel are irrelevant to their particular situation as long as no response is required. In this respect, systems using a mouse or touch screen give completely different results from keyboard driven systems where the user must strike a key to bypass irrelevant items. On the other hand, having to ask repeatedly for more detail is awkward, slows down the consultation process, and is disliked by users. Wherever possible, a good first level summary can be entered on a single form. A second important point is that almost all questions on the forms can be answered by a single mouse click. There are no pull-right menus or multi-state buttons. A version which violated this constraint in order to reduce the physical size of the forms was a singular failure in its formative assessment.

The user can request a form in three ways, corresponding to three different clinical situations.

For return visits or old problems, the user may select any item in the record and ask for an entry form based on that item. The item does not have to be a 'problem' although this is the most common case. Any sign, symptom, diagnosis, or treatment can be used as the starting point.

For new but common simple complaints, there is a simple pop-up menu of those complaints most commonly seen by the particular user. These two mechanisms are expected to cover nearly eighty per cent of all encounters in general family practice.

For other new problems the user must locate a starting point using one of two techniques. The first is the 'Graphical Entry Tool'. This provides two axes - patho-physiology and body topography, which the user may freely browse. The user selects a physiologic system and a body part and is presented with a menu of possible signs, symptoms, and conditions to use as a starting point for further refinement. The second method is to type a key word or abbreviation to obtain a menu of candidate complaints.

The 'Graphical Entry Tool' again reflects the results of the user centred design process. Its functionality derives from the knowledge base and is designed for easy access rather than formal accuracy. The goal is that users should find items quickly and easily, so the system must accommodate

a reasonable range of common intuitions about how it should be organised. Many items occur in several places. For example, 'diabetes' can be found as an endocrine condition of either the entire body or of the abdomen or indeed of the pancreas. Similarly, little distinction is made between respiratory conditions of the body generally and respiratory conditions localised to the chest.

Terminology, the Model of the Medical Record, and the User Interface

The goal of PEN&PAD is to make it possible to say anything which is within the clinical domain in a structured way. Structured Meta Knowledge (SMK) is a highly generative representation for medical terminological knowledge bases, capable of combining primitive terms according to its semantics to create new descriptions. The goal is to create a core model of medical terminology such that 'all and only medically sensible statements should be well formed formulae'. The forms in PEN&PAD are generated by asking a knowledge base formulated in SMK what it is sensible to say. Conversely, generating the forms used in PEN&PAD provides an operational test of the completeness and appropriateness of the SMK core model.

The flexibility of the PEN&PAD interface is the result of a clean underlying model of the medical record and a sound semantics for medical terminology. The flexibility with which information can be grouped together is the result of separating the record into two distinct layers - the primary observations of the patient and the meta statements organising those observations into problems, episodes, and clinical dialogues [6]. The model is strongly object orientated, and concepts such as 'the pertinence of John Smith's weight gain to the problem of his diabetes' exist as first class objects.

Multi-Lingual Features

One of the benefits of using a strongly object-orientated and highly generative formalism is that it has proved very easy to develop multi-lingual systems, at least to the first level of literal translation. Because the knowledge base uses only a very modest number of primitives, by comparison to traditional classification and coding systems, the translation process is rapid and straightforward. Production of a new language version of the existing prototype requires between two and three working days for a bilingual doctor and a knowledge engineer working together. The existing system is trilingual in English, French and German. When the language dictionary is changed, the entire system is immediately translated into the new language. All information entered in one language can subsequently be displayed in any of the other languages.

User Centred Design, Formative Evaluation, and Advanced Information Systems

PEN&PAD illustrates both the effects of User Centred Design and formative assessment and the importance of sound theoretical and formal foundations to meet what may seem to be deceptively simple user requirements. Clinical users demand both a high degree of flexibility and guarantees of system integrity in the face of the variations demanded. Taking a radical approach to the user environment has required an equally radical approach to the underlying architecture, to our understanding of medical language, and to the structure of medical records.

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