Managing Clinical Incidents in General Practice

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Abstract

Clinical incident in general practice can be potentially harmful, costly and even fatal. Studies in general practice in Australia have shown that over three quarter of these incidents are preventable [Bhasale et. al. 1998]. We describe in this paper a holistic model which amalgamates three knowledge management methodologies (ontological, rule-based, and causal) and case based reasoning to provide an effective platform for managing clinical incidents in general practice. Clinical incident management includes clinical incident analysis, intervention advisory, incident report & browsing, incident repository maintenance, and incident knowledge maintenance. We demonstrate how each type of knowledge and reasoning mechanism can be built and integrated for clinical incident management. We also present the functional components of our web-based Clinical Incident Management (CIM) prototype that we have designed and implemented based on this synergistic architecture and approach.

Introduction

In Australia, general practice is the usual point of entry into the health care system. Of a population of 17 million, 82% visit a General Practitioner at least once in any year. Approximately 16000 General Practitioners conduct over 95 million consultations annually [Bridges-Webb, et. al. 1992]. Subsequently, there is substantial potential for incidents to occur which may harm (or potentially harm) patient. This paper examines an artificial intelligence based approach towards clinical incident management that combines the use of case base and knowledge base technologies.

In our context, clinical incident can be broadly defined as an unintended event, no matter how seemingly trivial or commonplace, which could have harmed or did harm a patient during the provision of general practice care. This criterion includes "near miss" where the harm may have been averted, but the potential for harm exists [Bhasale A., et al., 1998]. Our intelligent Clinical Incident Management (CIM) system is built upon a pilot incident monitoring study in General Practice. This pilot study was initiated by Australian's Commonwealth Professional Indemnity Review for Health Care Professionals and its subsequent quality taskforce study in identifying interventions to reduce the occurrence of adverse accidents [Miller, et al., 1995; Bhasale A., et al., 1998]. Interventions are viewed as cost-effective strategies to be implemented to prevent repetitions of incidents. Study in General practice has shown that more than three quarter of these incidents are preventable and thus can be effectively intervened [Bhasale et. al. 1998]. In our CIM prototype, we have designed and implemented a web-based intelligent system that can assist health professionals to prevent adverse clinical incidents and to manage clinical risks effectively during their provision of community based general practice care.

This paper describes the components of our CIM prototype, its case base and its generalised knowledge base, which integrates ontological, rule-based and causal knowledge. It also describes CIM reasoning module that combines case-based reasoning and rule-based reasoning for incident analysis and intervention advisory. Finally, it discusses CIM system design and implementation.

Components of CIM

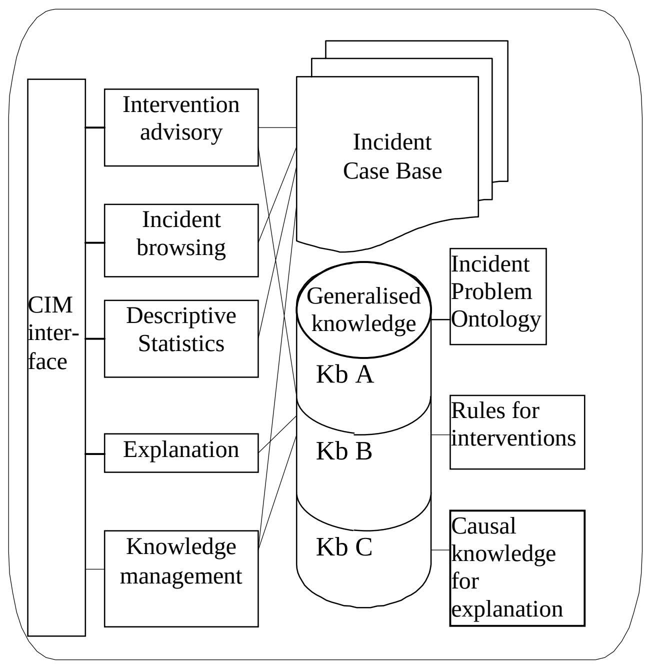

Figure 1: Components of CIM prototype

Our CIM prototype contains several functional modules as shown in Figure 1, an Intervention Advisory module, an Explanation & Justification module, a Browser module, a Statistic module and a Knowledge Management module:

- The Intervention advisory module assists the health professionals to analyse the incident and suggests relevant interventions. It allows health professionals to complete a structured incident report and provides possible interventions derived after a computer-assisted clinical analysis using both of CIM repository of previous incident cases and its generalised knowledge. New incident report can be automatically updated into CIM current incident repository.
- The Explanation module provides explanation of the suggested intervention based on its collection of domain expert rules and its knowledge of cause effect relationships between possible underlying problem and interventions.
- The Browser module allows Health professionals to browse CIM incident repository using various queries.
- The Statistics module supplies several useful descriptive statistics on CIM incident repository.
- Finally, the Knowledge Management module allows health care domain experts in General Practice to moderate, maintain and to update CIM generalised clinical incident knowledge with the newly reported incidents.

Integration of CIM case base and knowledge base

Figure 1 shows CIM generalised knowledge base, which integrates three types of knowledge bases: ontological knowledge base for incident analysis (Kb A), rule-based knowledge base for intervention advisory (Kb B), and causal knowledge base for explanation (Kb C).

Ontological knowledge for incident analysis

To assist a user to analyse the underlying problems of the reported incident, Kb A supplies a hierarchical and categorical ontology for incident analysis and provides guidelines for identifying the underlying problems. The ontological knowledge is represented by a series of conceptual pyramids. Each conceptual pyramid represents one problem type and is consisted of three layers (figure 2). The apex layer, the “problem-type” layer, shows the type of problem or incident, e.g. pharmacological incident, diagnostic incident, or equipment incident, etc. The middle layer, the “problem-feature layer”, presents the categories or problem features found for a particular problem type. For example, for pharmacological problem, the problem features include wrong drug prescription, incorrect dosage, drug interaction, etc. The bottom layer, the “possible-cause layer”, shows the possible causes found from studies that are linked to each problem feature. For examples, the possible causes for “incorrect drug prescribed” include spelling error, illegible writing, problem misunderstood, etc.

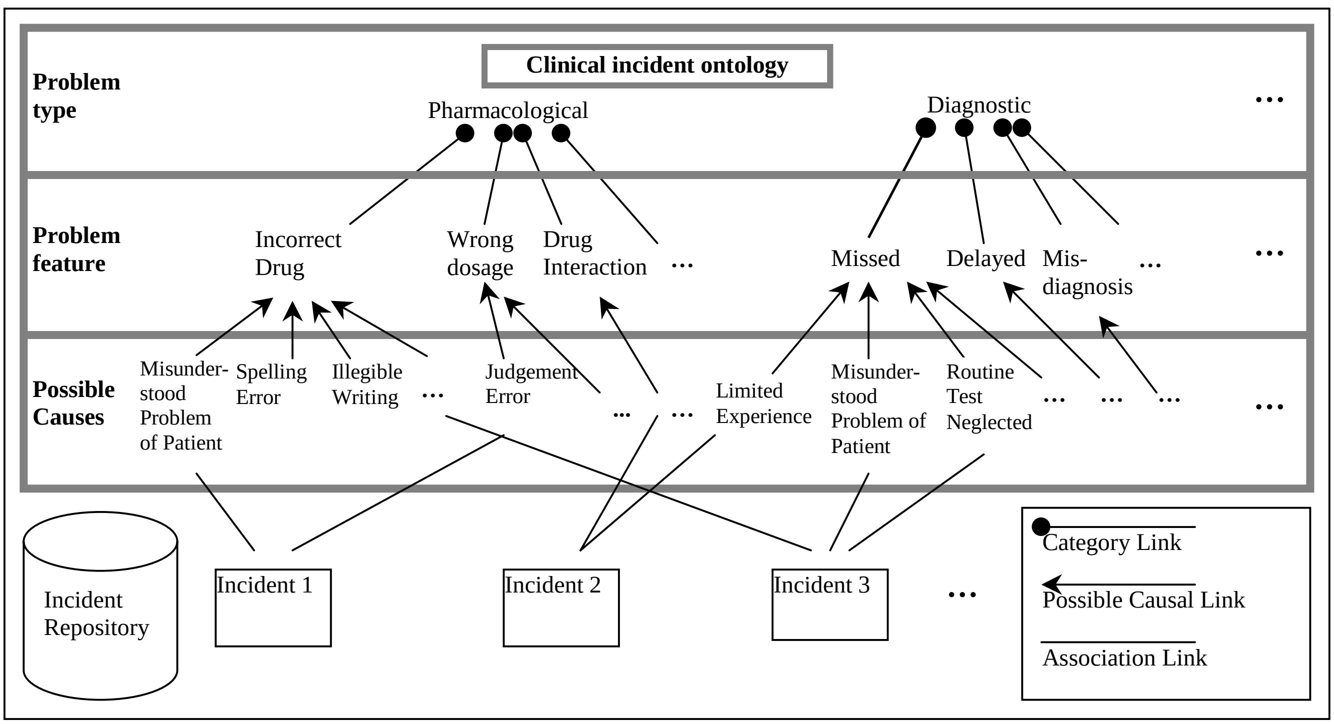

Figure 2: Ontological knowledge base for clinical incidents in general practice

Figure 2 shows two conceptual pyramids with an example from pharmacological problem type and another example from diagnostic problem type. Due to the unique context of problem type and its associated problem feature, sometimes, same possible cause can happen in several leave-nodes in the "possible-cause" layer. Repetitious possible cause can also be shared among different conceptual pyramids. An example of this shared possible cause can be seen in the possible-cause node labeled as "Misunderstood problem of patient" in figure 2.

These conceptual pyramids are built using experimental findings from the pilot study mentioned earlier. It is intended that the content of these initial conceptual pyramids will evolve and will be incrementally revised and be gradually focused with new knowledge gathered from CIM cases. These revised pyramids will be fed back to CIM for assisting user during the incident analysis phase.

Rule-based knowledge for intervention Advisory

To provide relevant intervention, Kb B maps a branch of the conceptual pyramid —which can be represented as a problem 3-tuple, (problem type, problem feature, possible cause) — to a set of relevant intervention. Each mapping of a problem 3-tuple to a set of relevant intervention can be seen as an if-then rule. Figure 3 illustrates this idea. The thickened line traces a path through a conceptual pyramid that corresponds to an antecedent of the if-then rule. Linked to the end of this path are three relevant interventions. For example, Kb B maps the problem 3-tuple (pharmacological, incorrect drug, poor handwriting), to a relevant intervention list {(General Practitioner can print/type prescription), (General Practitioner can prescribe using computerised system), …}.

Again these initial sets of relevant interventions are derived from the aforementioned pilot study in incident monitoring. It is also intended that these sets of relevant interventions will be constantly re-evaluated and updated through use.

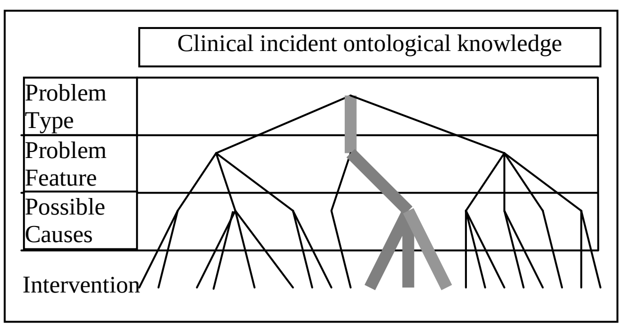

Figure 3: Rule trace linking a branch of conceptual pyramid to a set of relevant interventions

Causal knowledge for explanation

Finally to provide better explanation, Kb C contains a deeper knowledge base of cause-effect relationship between underlying problem possible causes and intervention strategic. This knowledge is used to supplement the shallow rule-based explanation obtained via backward chaining. The goal is to supply useful evidence based explanations that align well with the evidence based medicine currently practiced within the health professional communities [Coiera 1996; Coiera 1997]. It is of little benefit if analysts cannot achieve a better understanding of the causes of the "errors" [Johnson 1997; Lee et. al. 1999]. An example of this causal knowledge base is represented in figure 4 as a causal net showing a subset of cause-effect links towards prescribing wrong drug. We have also included within this causal knowledge some factual knowledge known for a particular cause. Figure 4 shows an example of factual information on similar drug names used in Australian pharmaceutical industry linked to the "similar drug name" cause. In this scenario, "lack of concentration" can trigger "spelling error" and thus "wrong drug prescribed". However, the causal net shows that it is more likely that the combination of "similar drug name" and "lack of concentration" makes the occurrence of "spelling error" more frequent. The causal net thus justifies and explains the recommended intervention to encourage pharmaceutical companies to change current similar drug names and to institute regulation for new drug name.

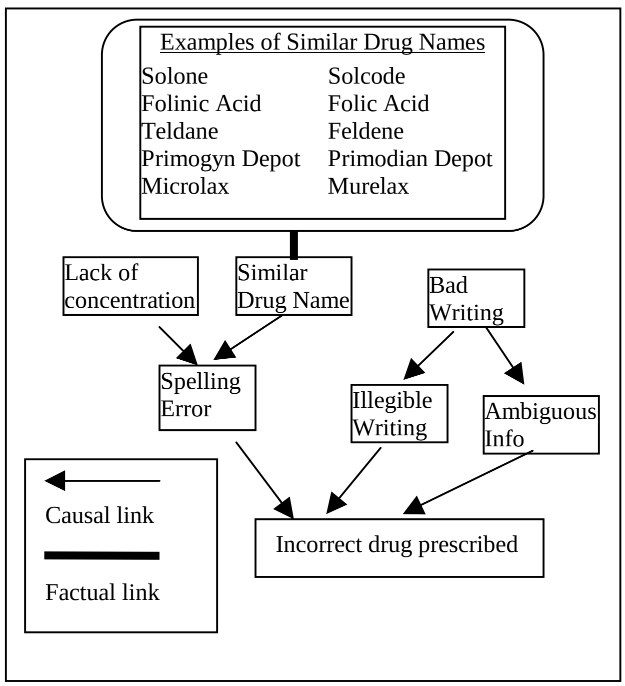

Figure 4: A glimpse of CIM causal knowledge as causal net

Case base for incident case repository

In addition to the generalised knowledge base, CIM's repository of incident cases has been designed as an incident case base (figure 1). The incident case base contains a collection of specific clinical incidents providing contextual information about problems and situations in incidents. Each incident case in the CIM contains the following:

- an incident profile which consists of patient age, sex, primary health problem, outcomes of incident based on immediate consequence & potential harm, description of the incident, and preventability.
- one or more sub-cases depending on the analysis of the underlying problems

As stated earlier, Kb A supplies a layered and categorical ontology for incident analysis. Kb A provides guidelines for identifying the underlying problems and helps to identify and index the sub-cases for each incident (figure 2). We then link each underlying problem, represented as a 3-tuple, (problem type, problem feature, possible cause), to a relevant set of interventions to form a sub-case. Thus, each complete sub-case can be represented as:

((problem type, problem feature, possible cause), (intervention list))

In this way, an incident case k can be seen as:

[(incident profile info $_k$), {(problem 3-tuple $_I$), (intervention list $_I$) | i = 1..n $_k$ }]

The incident case base is used during the intervention advisory, incident browsing and descriptive statistics reporting.

Reasoning Module

Case-based Reasoning (CBR) and Rule-based Reasoning (RBR) are applied in complementary to the incident cases analysis and intervention advisory. The CIM system searches through the incident case base. If a matched sub-case can be found based on the problem types, features and causes, the interventions in this sub-case are adapted as interventions to the problem. Otherwise, the rules in the Kb B will be used to produce recommendations for intervention. Because we believe that managing clinical incidents is currently an "experience rich knowledge poor" process and CBR provides a good approach to direct reuse of previous experience, we have consequently adopt this consecutive order of applying CBR first then RBR. The algorithm for "incident cases analysis and intervention advisory" is described below:

```
/* CIM uses Kb A to aid user to derive an incident analysis
tree whose branches identify all underlying problems or
problem 3-tuples contained in the reported incident */

Identify underlying problem types for a reported incident;
For each problem type
  (Identify relevant problem features;
    For each feature
      (Identify possible causes;)
  )

/* Generating interventions for all branches in the derived
analysis tree */

For each problem 3-tuple
  (Retrieve sub-cases from incident case base;
   If a sub-case is available
   Then adapt its intervention list
   Else apply rules from Kb B to deduce relevant
        interventions;
  )

Merge and display interventions [Zhang et. al. 1999].
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Systems design and implementation

CIM prototype is designed as a distributed three-tier server client architecture: CIM client, CIM server, and knowledge & incident repository (KIR) server. The KIR server handles the management of CIM generalised knowledge base and its incident case repository. It is implemented using a standard SQL capable relational database package. The CIM client provides the user interface and socket connection to CIM server via internal communication protocol. CIM server provides the reasoning engine and data processing. It also takes care of all communication between CIM client and KIR server by handling all socket connections between itself and CIM client and translating all inputs from CIM client into SQL queries for the KIR server and vice versa. Because portability, object-oriented design, multi-threading, flexibility and web advantage, Java 1.2 is the programming language used for implementation for CIM client and CIM server.

Conclusions

In health care, increasing interest in quality improvement has led to calls for more extensive and open investigation into errors in practice and adverse outcomes. Various incident monitoring and auditing techniques have become popular as the health professionals stress Continuous Quality Improvement models. These models promote continuous collection of detailed contextual information about the specific processes, systems and actions that lead to adverse patient outcomes [Britt H. et. al. 1997]. The emphasis is on improving systems rather than apportioning blame. By using a hybrid knowledge base and case base approach, an intelligent web-based clinical incident management system has been built that embraces the above quality improvement philosophy.

CIM allows health professional the ability to share and reuse knowledge/information on the web. It offers an intelligent computer-aided incident analysis process to report incidents. It provides experience-guided and expert-driven intervention advice so that any adverse event in community based general practice can be potentially avoided or prevented. It equips the health profession with an effective tool for risk management

Acknowledgements

We would like to thank Dr Helena Britt, Dr Graeme Miller and Ms Alice Bhasale of the Family Medicine Research Unit (FMRU), University of Sydney at Westmead Hospital, for their valuable inputs. We also would like to thank two vacation scholars, Matthew Ko (University of New South Wales) and Celestino Velasco (University of Sydney), for their efforts in implementation of the web-based clinical incident management system.

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