An Automated Second Opinion

can provide a lower cost alternative to the high cost of medical care in the US

Compsim White Paper

Abstract:

Recent advancements in technology allow many of the high cost / high risk decisions and actions in medical diagnostics and treatments to be automated. Automating the delivery of these services can:

- Reduce the cost of delivery
- Make quality disease diagnosis available to a broader population
- Reduce medical errors
- And thereby
    - reduce insurance costs
    - reduce medical litigation costs

Fundamental to automating these services is the ability to automatically interpret complex inter-related symptoms. This capability is available now using Compsim's Knowledge Enhanced Electronic Logic (KEEL®) Technology[1]. KEEL is not a form of "artificial intelligence". It is both: 1. a new way to process information, and 2. a new way to capture the reasoning and judgment skills of human experts. Human experts apply judgment and reasoning when they interpret complex information sets in order to choose a course of action (such as diagnosing disease and selecting appropriate treatment options). Decisions and actions controlled by KEEL-based designs are 100% explainable and auditable. This is a necessary attribute for Medical Informatics.

The Problems Exposed:

Training individual health care providers on every disease, every new and proven treatment option, and all the new environmental contaminants is already impossible. Individual health care providers specialize in smaller and smaller domains, just so they can hope to remain current in their area of expertise. This means that patients have to seek more and more health care providers as they are exposed to more and more problems. High insurance costs drive more and more tests in an attempt to avoid poor judgmental decisions in diagnosing and treating problems. In many cases high cost diagnostic imaging is never even viewed by the health care provider. Often these tests were blindly requested. Even with all the CYA tests, medical error continues to drive the cost of care higher and higher.

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[1] Compsim; "About KEEL"; http://www.compsim.com/AboutKEEL.htm

Anytime there are humans in the loop, there is a potential for errors due to:

1. Lack of attention
2. Failure to perceive
3. Limited short term memory
4. Poor judgment

While patients hope the human errors do not happen during their diagnosis and treatment, the errors still occur time and time again.

Computers (machines in general) do not have problems with lack of attention, failure to perceive, or limitations in short term memory. But up until now they have not had the ability to exercise judgment and reasoning. Computers are sequential processing engines that process rules. Judgment and reasoning have remained areas that have only been addressable by human with parallel processing "right-brain" functions[2].

The Judgment and Reasoning Issue:

Medical problem identification is complex, because so many variables have to be collectively considered. Interpreting inter-related symptoms and diagnostic tests is required in order to make an accurate diagnosis. Cost, quality of life issues and drug interactions must be considered in selecting from the available treatment options.

Often medical decisions are not fully explained to the patient. It has been stated that doctors utilize the following process when making a diagnosis:

- Number 1: Magic (physicians project that they are all the "experts")
- Number 2: Authority (hospital / group policy; aka profit)
- Number 3: Personal experience (it worked once / I've seen it before)
- Number 4: Peer pressure (expectations of peers)
- Number 5: Fear of malpractice suits (patient pays)
- Number 6: Science (up-to-date knowledge)

In most cases the patients are left in the dark. They don't know what options were considered. They don't know how their own personal situations impacted the decisions. They don't know what organizational biases drove diagnostic and treatment options. They don't know how current the health care providers are relative to the knowledge / wisdom behind decisions and actions taken on their behalf. And, the health care providers usually do not have the time to explain everything to patients. Often the patients do not fully understand the explanations anyway. And, who would expect the health care provider to explain their profit motives and their personal biases to the patients?

[2] **Roger Wolcott Sperry** (August 20, 1913 – April 17, 1994) was a neuropsychologist, neurobiologist and Nobel laureate who, together with David Hunter Hubel and Torsten Nils Wiesel, won the 1981 Nobel Prize in Medicine for his work with split-brain research.

KEEL Technology Automates the Distribution of Expertise:

Compsim's KEEL Technology can be used to automate the distribution of judgment and reasoning (the interpretation of complex information sets).

Automating human-like judgment and reasoning requires two services:

1. The ability to process information in a manner similar to how a human expert interprets complex inter-related information sets and balances alternatives, while considering sometimes conflicting goals.

2. The ability for a human expert to effectively describe how complex information sets need to be interpreted in a somewhat dynamically changing environment (ex. The human body is a dynamic operating machine; not a static data set).

There are other business drivers that also need to be considered:

The system must allow the expert's reasoning and judgment to be relatively easy to capture and deploy in an automated solution. One cannot expect the expert to have to expend any extraordinary effort to package his/her understanding in a new environment.

Decisions and actions taken by automated equipment must be 100% explainable and auditable. Presently, no decision taken by a human health care provider is ever explicitly defined (traceable to every measurable item in the decision-making process). The human verbal / written language is just not sufficient (this includes electronic medical records). Only a mathematical formula of some sort could provide that level. No health care service offers this capability today.

The questions of "how much" and "how important" are just not traceable (ex. How much above normal is the ____ count and how significant is ____, taking into account ____ in the diagnosis of ____ and how did it impact the treatment by applying ____ and why not ____ of ____ and ____.....). When creating a machine to provide the automated delivery of best practices, everything will have to be exposed. Only if there exists an ability to explain every decision and action (using mathematical precision) will (or should) such a system be trusted. Human nature is such that a patient develops trust in health care providers in the following ways: the way they present themselves, their advertizing material, their diplomas on the wall, the cleanliness of their facilities, etc. This "soft" trust will not be acceptable for the automatic delivery of knowledge. Judgment and reasoning behind every decision and action will have to be totally transparent.

New knowledge, new tests, new treatment options will also evolve over time. Automated systems *should* allow a rapid update a knowledge base to make use of the latest information. This means it must be easy to make changes to extend the system. If the systems cannot be explicitly defined, they will be almost impossible to change.[3]

The KEEL "Dynamic Graphical Language"[4]:

The KEEL "dynamic graphical language" provides a way for domain experts to describe complex, dynamic, non-linear, inter-related, multi-dimensional systems. The graphical nature of the language permits the domain experts to "see" functional relationships and "see" how change propagates through a model. The domain experts simply describe functional relationships by dragging and dropping wires and observing how the system responds. The resulting KEEL "cognitive engine" is being created automatically behind the scenes. In the past, domain experts have had difficulty in providing a textual explanation that is mathematically explicit, or trying to write a mathematical formula that described the information interpretation model. Now, using the KEEL dynamic graphical language, this task is much easier. Developing the model is likely to help the domain expert think about the problem at hand in much more detail than previously possible,

The KEEL "cognitive engine":

When the model for diagnosing a problem or selecting a treatment option is complete, the designer (the domain expert) clicks a menu item and a KEEL Engine is created for deployment in a broader system. KEEL Engines are platform and architecture independent, making it possible to deploy the knowledge base over the internet, within the "cloud", within diagnostic equipment or any other platform of choice.

Examples:

Example: (Diagnosing Anemia in Adults) [i]

In order to diagnose a case of anemia, health care providers take a blood test using a hematological analyzer. This piece of equipment gathers data on a number of blood related tests. A pathologist reviews the results and makes a diagnosis, identifying whether the patient has anemia and, if so, which type of anemia. The analysis process used by the pathologist evaluates about 250 combinations of test results in order to make the diagnosis. Often the pathologist never even sees the patient. They are provided with the patient's gender and age and the test results.

When creating a sample software application to perform this analysis it was necessary to provide a way to explain the diagnosis so that even the pathologist would trust the automated results. And then, to further explain the results, it was necessary to explain

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[3] This is why artificial neural nets provide an inferior solution for safety critical systems. Their decisions and actions cannot be explained. The only way to extend them is to start over with repeated pattern training. Even then the decisions and actions cannot be explained.

[4] Compsim; "Movie introducing the KEEL Dynamic Graphical Language"; http://www.youtube.com/watch?v=WBs-w1lgZgk

why other results would be incorrect based on the information interpretation model being used. This last explanation was required because the results were being compared with results that were considered correct at the time. This Anemia demonstration is provided on Compsim's website. It must be noted that this is just a demonstration and should not be used for production use. While it was developed with the help of a trained pathologist, there are still a couple of areas where the domain knowledge has not yet been finalized. This is exactly the reason why decision making models must be exposed so they can be corrected and extended when appropriate.

Example: (Patient Monitoring)[ii]

It is common to connect patients to monitoring equipment that can alert health care providers when an abnormal event happens. In some cases, the patient's metabolism is such that the exact timing of events impact how they are treated or evaluated. This may require constant monitoring by health care providers. Unfortunately, there are cases where constant monitoring is required, but humans are not able to be there 100% of the time. This patient monitoring demonstration allows the events themselves to adjust how and when changes in monitoring need to take place. This example allows the health care provider to create more adaptive models for monitoring.

Example: (Triage)[iii]

When patients go to emergency care, they must be evaluated before the exact nature and criticality of the issue can be determined. This is commonly handled by skilled practitioners using simple questions and answers. They acquire history and patient concerns in order to assist in their determination of treatment. There is seldom any traceability in the process. This demonstration shows how subjective information from patients can be integrated to determine a mathematically explicit level of concern in order to determine a course of action when a patient comes to the emergency room complaining of chest pain.

Summary:

By providing an automated second opinion based on unbiased medical guidelines, many medical errors can be avoided.

Automating the delivery of many primary care functions can make this level of care more accessible to a broader population (with very little increased cost).

Making it easy to package mathematically explicit interpretation of patient symptoms and medical diagnostic tests enables the creation of medical guidelines which can then be dispensed automatically.

Creating a knowledge base that exposes exactly how information is to be interpreted allows research to focus on correcting, extending and refining the knowledge base (and reducing the number of cases where untraceable guidelines are just “assumed” to be appropriate, thus delaying their correction).

Automating many tasks that are commonly handled by humans, can reduce their workload and eliminate more human errors.

Building a knowledge base of medical diagnosis and treatment options in a mathematically explicit and readily visible way can allow more research funding to focus on improving health care rather than funding insurance companies, lawsuits, and retraining of individual practitioners.

KEEL Technology provides both 1) a mathematically explicit language that is easy to interpret that allows value judgments can be captured, and 2) an information interpretation model that can be used to automate the dispensing of judgmental decisions in a manner that can be easily audited.

KEEL Technology is platform and architecture independent, making it suitable for delivery through almost any form, at almost no cost, once the knowledge base has been created.

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[i] Comspim, “Diagnosing Anemia Demonstration”, http://www.compsim.com/demos/d60/Anemia.htm

[ii] Compsim, “Patient Monitoring Demonstration”,
http://www.compsim.com/demos/d69/TimeBasedMonitoringWeb.html

[iii] Compsim, “Chest Pain Risk Factors”,
http://www.compsim.com/demos/d15/Chest%20Pain%20Risk%20Factors.htm