Process Models for Telehealth: An Industrial Approach to Quality Management of Distant Medical Practice

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Process modeling is explored as an approach for prospectively managing the quality of a telemedicine/telehealth service. This kind of prospective quality management is more appropriate for dynamic health care environments compared to traditional quality assurance programs. A vector model approach has also been developed to match a process model to the needs of a particular site.

1. Introduction

Advances in communications technology have facilitated the practice of medicine in an electronic environment. Collectively, the practice of medicine in such an environment may be considered as telemedicine, whether consultations use e-mail in one city, dedicated high speed communication lines transcontinentally, or satellite links internationally. When patient education and risk assessment are added, the system more properly represents telehealth. The establishment of a routine process to measure the quality of medical practice across an electronic communication infrastructure will assist in identifying and correcting quality-related issues. The quality of medical care is traditionally considered to consist of two components: quality of medical personnel (both interpersonal skills and technical skills) and technical quality related to instrumentation such as acquisition devices and viewing stations [1]. Consistent with this definition, quality measurements traditionally include (a) measuring performance, (b) assessing if performance conforms to standards, and (c) improving performance when standards are not met [2].

This traditional approach to quality measurement has many limitations when applied to the practice of medicine in an electronic infrastructure. Most notable is the fact that the traditional approach to medical quality assurance is static in nature. It is intended to conform to a known standard (e.g. "Has the monitor met the resolution requirements?" "Is practicing physician licensed in this state?"). This approach assumes that some degree of poor outcome is acceptable [3]. Secondly, analysis in current quality measurement methods is focused on issues where standards have not been met (e.g. length of time required for transmission of large volume data). This assumes that there is not much to be learned from analyzing issues where standards *have* been met. The traditional quality assurance measurements can be enhanced by the application of process modeling to a telehealth environment. For example, a physician may be licensed and in good standing (traditional method), but not the most appropriate one for a given condition or sickness. The traditional retrospective methods of measuring quality seem insufficient to meet the needs of today's health care, particularly those related to the practice of medicine in an electronic environment.

2. An Individually Tailored Approach to Medical Practice Quality

The shortcomings of traditional quality measurements have led many scientists to seek alternative methods for improving the quality of care. Industrial quality management science has long been adopted on a large scale outside of health care organizations and has demonstrated improvements in both productivity and efficiency [3]. The availability of an electronic infrastructure and its use for medical practice provide for an opportunity to implement a continuous quality improvement (CQI) program (e.g. patients can benefit from consultation by national experts regardless of their geographic location).

In health care, specific needs vary not only among customer types (patient, physician, payor, researcher) but also among *individuals*. Overlooking a particular patient need because it is unique or an exception compared to other patients of the same general category may result in inappropriate health care procedure(s) that will adversely affect that patient's health status. In other words, to be effective, high-quality medical practice in an electronic environment relies on an *individually tailored* approach.

The timely recognition of individual variations to allow timely analysis and to find focused, individually tailored solutions is essential for continuous quality improvement [3]. It is also important to rec-

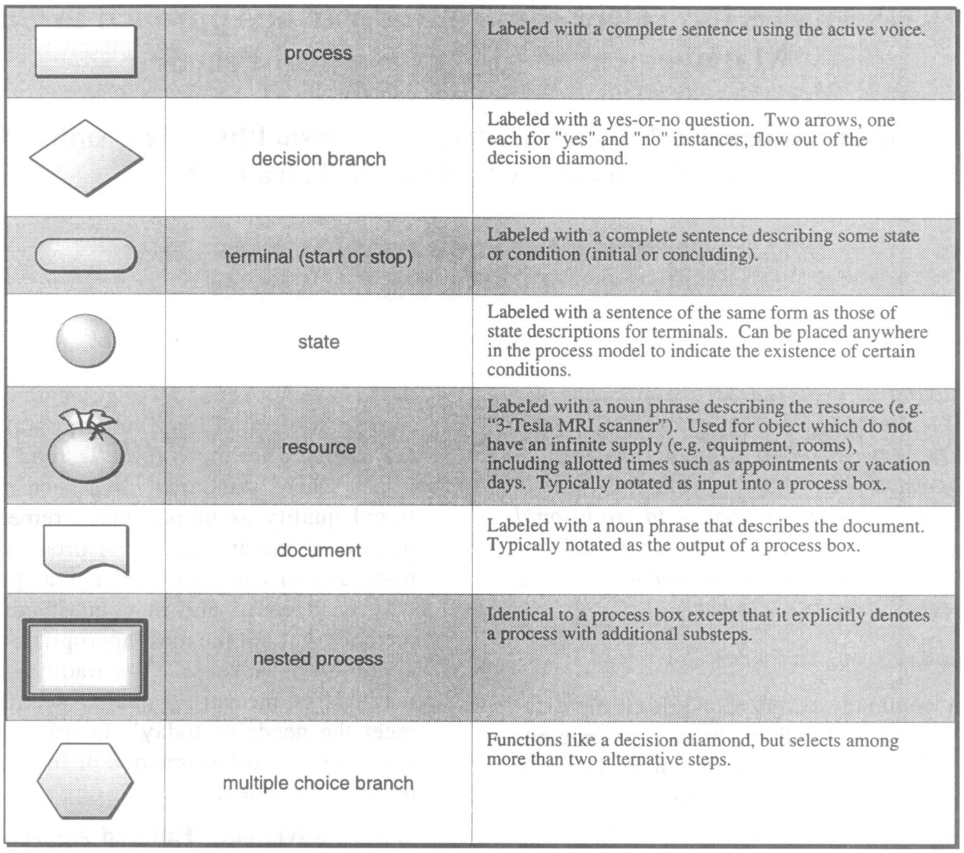

Figure 1. Process modeling notation summary.

ognize that multiple related elements of a telemedicine service may have problems concurrently and thus simultaneously contribute to these variations. These elements should be recognized appropriately and acted upon in a timely manner.

To proactively facilitate the identification, analysis, and solution of these service problems, we have adopted a *process modeling* approach consistent with other industrial and engineering domains [4]. With process modeling, a complete, formal view of a system's operation can be specified and analyzed. Potential points of failure are easily identified beforehand, and plans of action can be determined before the actual failures occur during system operation. The overall result of the approach is an increase in telemedicine service quality.

3. Process Models in an Electronic Infrastructure Medical Service

To use process models as a means to improve the quality of a telemedicine or telehealth service, the following objectives must be met:

1. the process model must be unambiguous, understandable, and agreed upon by all participants in the telemedicine/telehealth service,
2. the process model must have sufficient detail to facilitate implementation of the service,
3. whenever possible, steps within the process model must be expressed in terms of the customer(s) for those steps, and
4. the process model may not assume that all procedures within the service will succeed; specifically, potential points of failure must be identified and contingency plans must be delineated for whenever failures do occur.

Clarity and understandability are accomplished by using standardized notation (Section 3.1 and Figure 1). Sufficient detail is accomplished using a top-down approach to system design (Section 3.2). The benefits and potential pitfalls of the process modeling approach are discussed in Section 3.3.

3.1 Definitions

The process modeling notation used in telemedicine service described in this manuscript is adapted from standard flowchart notation [5, 6]. Standard flow chart notation was modified by adding symbols to address process modeling needs specific to improv-

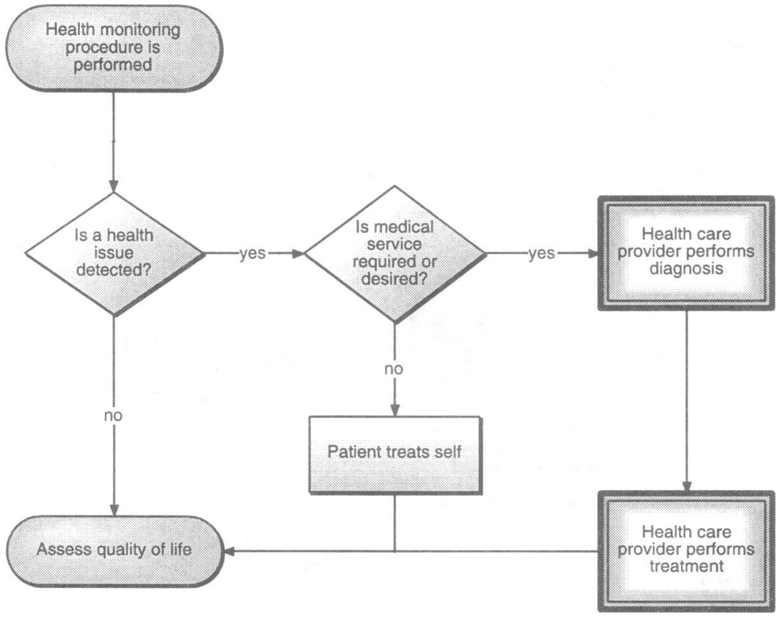

Figure 2. Example top-level process model.

ing telemedicine service quality. Figure 1 summarizes the process modeling notation, including notes about each symbol.

3.2 Implementation

Implementation of the process modeling approach is an iterative cycle of flowcharting, evaluation, modification, and addition of further details. This *top-down* approach to system design is adopted from the engineering and computer science domains. The telemedicine service is first specified in its most high-level, generalized form. As each layer of the model is specified, substeps within each process are delineated at greater and greater levels of detail, until sufficient detail is reached for service implementation.

Figures 2 and 3 illustrate top-level and detailed views of a patient's health care process, respectively. The flowchart shown in Figure 2 uses a patient's lifespan to define its terminals, and specifically indicates, in broad strokes, the phases involved in that patient's care. Health care phases of diagnosis and treatment are expressed as nested processes, clearly indicating that these phases decompose into further levels of detail. At the level of detail shown in Figure 3, the designers begin system implementation. A *timing diagram* style of flowchart arrangement has been adopted, illustrating who is responsible for what step in the process. The text in the process box can almost be copied in sequence to generate a procedural manual, and a table of responsibilities can be derived easily from the way the process symbols are arranged within the timing diagram.

These flowcharts may undergo multiple evaluations and modifications, with the system's designers and a sampling of its potential customers "walking through" and refining the processes. The process model definition cycle continues until the designers have developed enough flowcharts at a sufficient level of detail to proceed with implementation.

3.3 Benefits and Potential Pitfalls

When completed, the telemedicine/telehealth process model possesses the following benefits:

- provides a clear, unambiguous specification of the system,
- promotes mutual understanding about how the system works among both designers and users,
- pre-identifies potential points of failure and enables designers to design solutions beforehand,
- eases actual implementation work by clarifying procedural or policy issues at the outset, and
- eases documentation work by providing a natural translation from process model to procedural manual.

However, there are also potential pitfalls in the approach. The primary "trap" is a tendency to over-analyze a process or perhaps get stuck in a small issue when other aspects of the system still need process modeling. The system's designers must realize that changes to the design that are only apparent during implementation, and not during process modeling, are certain to arise. Through experience and

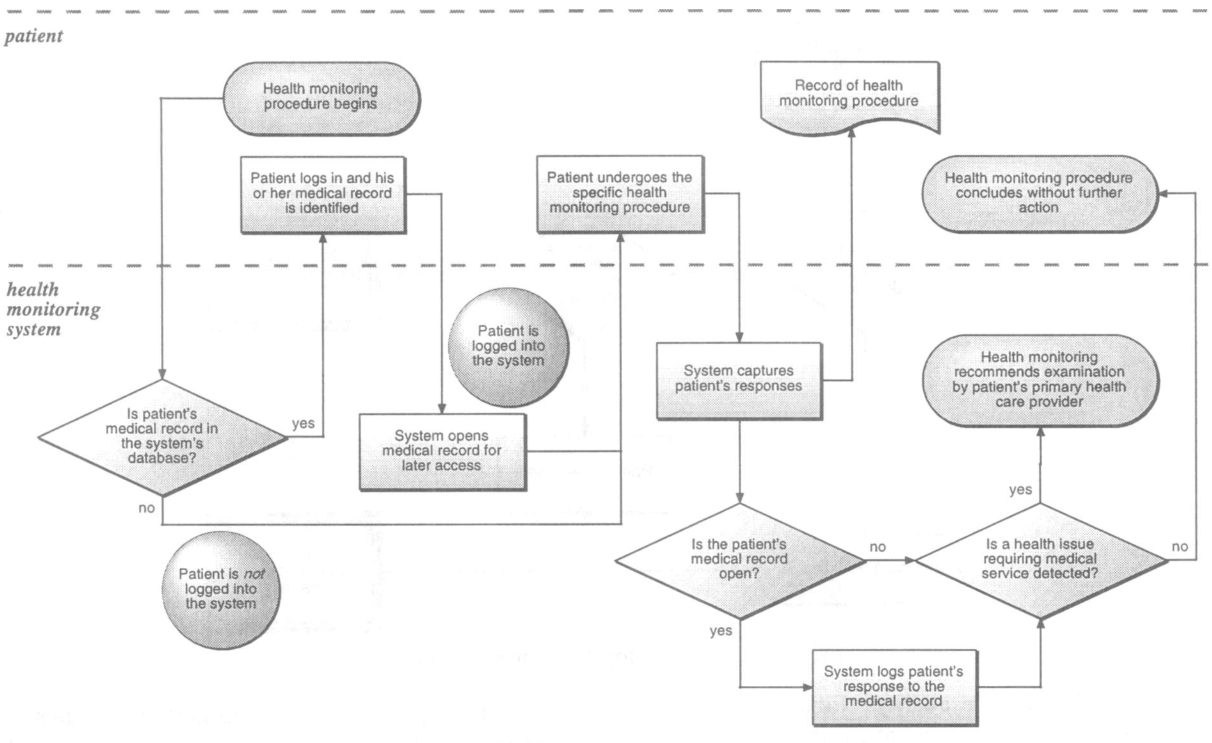

Figure 3. Example process model expressed at a sufficient level of detail for facilitating system implementation.

practice, designers must learn to determine when enough work has been done on the flowchart to move on with implementation.

4. Telehealth Vector Model

Telehealth characteristics can be viewed as axes in a coordinate space. A specific telemedicine service can then be expressed as a region within that space.

Using this approach, process models can be generalized so that eventually, known models may be automatically selected for new services or sites. This selection is accomplished by expressing a particular process model as a region within the same coordinate space as the service or site. A specific process model is viewed as appropriate for a site if that process model's region is contained within the site's region (Figure 4). Appropriately matching the requirements of a process or workflow with the facilities available at a particular site may then become an effective a priori mechanism for assuring quality of service.

The model is a multi-dimensional space, for which Figure 4 illustrates a simplified 3-axis subset. Two types of sites or services are illustrated, along with two process models. Their intersections indicate how these sites or services match up against a particular process of care.

Many of the model's axes describe the needs and characteristics of specific facilities, such as available equipment (e.g. echo, MR), study volume (e.g. studies per modality per day), degree of physician specialization (shown in Figure 4), and applicable languages for documentation and communication (e.g. English, Spanish). Other axes apply to sites that receive studies for telemedicine consultation, such as available storage, viewing station resolution, and viewing station memory.

Many axes are related to technology or infrastructure. Communications axes, for example, describe the range of media that sites can use for image and report transfer. These axes pertain to communication type (e.g. fax, telephone, video, network), bandwidth (shown in Figure 4), persistence (e.g. always on, requires dial-up), error rate, reliability, and security (e.g. physical access to devices, firewalls).

Interestingly, the axes that have been defined thus far tend to converge on the individual patient as the coordinate space's origin. In addition, Euclidean distance from a patient tends to translate to some form of real-world distance as well, whether physical or intellectual (e.g. amount of training or experience).

In Figure 4, the UCLA Medical Center fits the description for site A. It is a multispecialty medical group practice; it has a hospital; it supports a variety viewing stations (1K, 2K, Web-based) and has a high-speed network. Sites need not be physical in nature; for example, site B represents an Internet site that may be viewed from home using a Web browser. UCLA can support both traditional primary care and

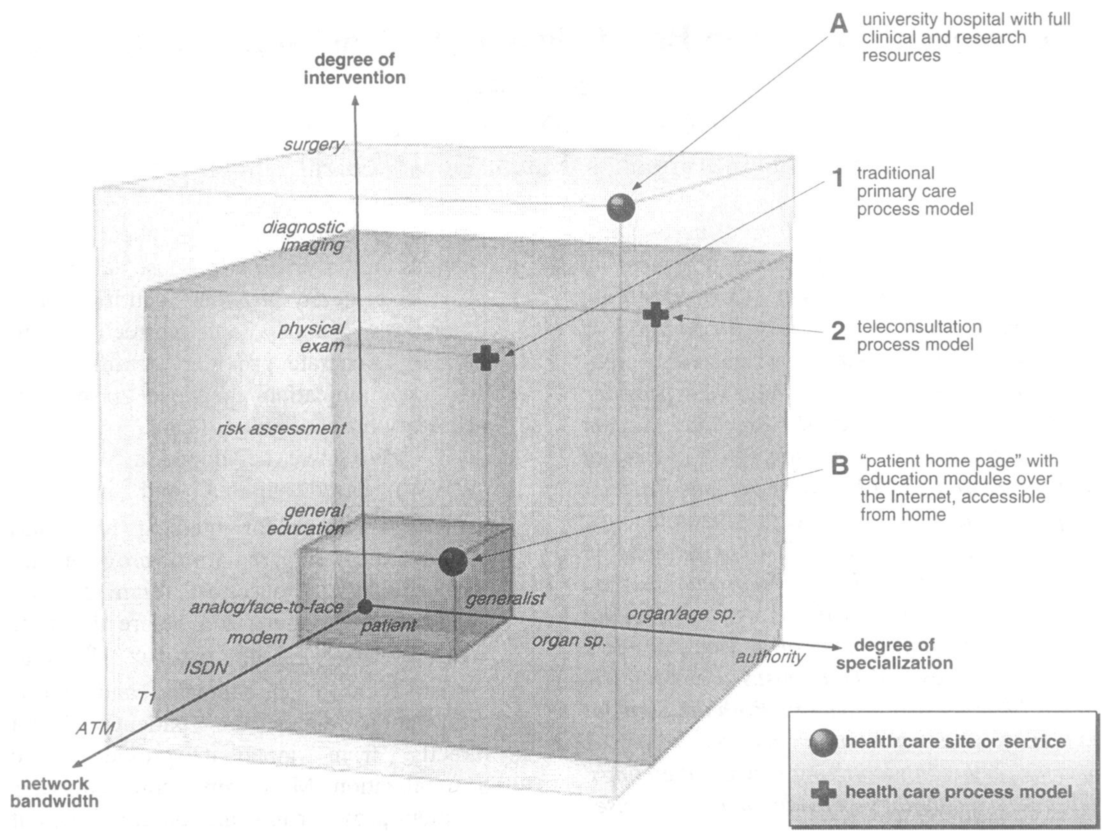

Figure 4. Characterization of sites and processes of care using a vector space model.

newer teleconsultation process models, while a patient home page can educate patients and provide online access to primary care physicians but cannot provide the physical exams that form a key component of a traditional primary care process.

5. Conclusions

Our experience has shown that process modeling makes development easier in a number of ways:

- the operation of the system is communicated easily to all personnel levels ranging from developers to users to managers,
- the process model is a natural method for creating documentation of the system,
- necessary modifications to the system, and their implications, are easier to identify and implement, and
- points of failure are easy to pinpoint, thus enabling operations managers to act on variations within the system quickly.

The overall effect of the process model was an enhancement to service quality, ranging from service modifications to fit users' needs better to the identification of process steps which can be performed equivalently with simpler solutions.

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