MEDINFO 2010
C. Safran et al. (Eds.)
IOS Press, 2010

doi:10.3233/978-1-60750-588-4-106

Process-Aware EHR BPM Systems: Two Prototypes and a Conceptual Framework

Charles Webster, Mark Copenhaver

EncounterPRO Healthcare Resources, Atlanta, USA

Abstract

Systematic methods to improve the effectiveness and efficiency of electronic health record-mediated processes will be key to EHRs playing an important role in the positive transformation of healthcare. Business process management (BPM) systematically optimizes process effectiveness, efficiency, and flexibility. Therefore BPM offers relevant ideas and technologies. We provide a conceptual model based on EHR productivity and negative feedback control that links EHR and BPM domains, describe two EHR BPM prototype modules, and close with the argument that typical EHRs must become more process-aware if they are to take full advantage of BPM ideas and technology. A prediction: Future extensible clinical groupware will coordinate delivery of EHR functionality to teams of users by combining modular components with executable process models whose usability (effectiveness, efficiency, and user satisfaction) will be systematically improved using business process management techniques.

Keywords:

Electronic health records, Workflow management systems, Business process management, Clinical groupware, Modular architecture

Introduction

Productivity is the ratio of an output to the input required to generate it. EHR productivity is EHR output—value of accumulated digitized patient data—divided by EHR input, or cost to obtain this data. The relationship between EHR effectiveness and efficiency is mediated by EHR processes, and EHR productivity cannot be improved without flexible EHR processes. The maximum EHR productivity that can be achieved within an interval of time is a function of all three of initial EHR effectiveness, efficiency, and flexibility. The concept of EHR productivity is relevant to both meaningful use of EHRs and EHR business process management.

A concise and common sense description for meaningful use of an EHR is "Processes and workflow that facilitate improved quality and increased efficiency" [1]. This resembles BPM's systematic optimization of process *effectiveness*, *efficiency*, and *flexibility*. At this point it is worthwhile to define some terms:

- Systematically optimize: improve in a consistently organized manner
- Objectives to be optimized
    - Effectiveness: ability to achieve output goals
    - Efficiency: ratio of output goals to required input resources
    - Flexibility: adaptability to changing goals and environmental conditions
- Environmental conditions
    - Dynamic: changes over time
    - Uncertain: difficult to predict
    - Risky: rewards and penalties apply

A closed-loop control system uses the difference between observed and desired output to automatically generate system inputs that will reduce the observed difference (Figure 1). For example, a thermostat compares observed temperature to desired temperature to decide whether to turn a heater on or off. Feedback control theory [2, 3] includes models and techniques to automatically optimize system behavior in response to changing environmental conditions. A negative feedback control system formulation of BPM, applied to systematic optimization of EHR performance, serves a useful purpose. It places EHR BPM into broader historical context that leads back to cybernetics and control theory [2].

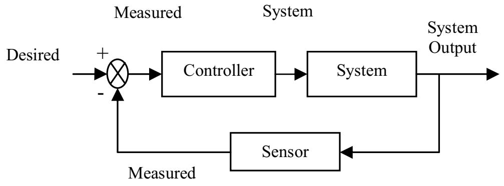

Figure 1 – Negative Feedback Control

Process-aware [4] EHR business process management systems are ideal vehicles for implementing closed-loop patient care systems [3] because there is a means—workflow engines executing process definitions—to directly influence EHR behavior and state. For example, minimizing the difference between observed and desired measures of health population status, or between observed and desired levels of medical practice efficiency, are forms of closed-loop optimization.

Future evolution of EHR technology will create greater effectiveness, efficiency, and flexibility in the face of dynamic, uncertain, and risky environments. The only practical means by which this will be achieved will be if EHRs include within their very technological nature the ability to systematically change internal processes and workflows to better meet set objectives while operating in typical environments. For these reasons the next generation of EHR systems will be process-aware EHR business process management systems.

Materials and Methods

Two EHR BPM Prototypes

We developed EHR BPM prototype modules to systematically optimize EHR effectiveness and efficiency. These prototype modules were built on a free and open-source EHR workflow management system (WfMS) with a modular component-based architecture. (Specialty-specific user interface and non-user interface components are combined into specialty-specific modules controlled by a workflow engine executing specialty-specific process definitions to generate workflow-based clinical groupware used by 4000 users at 300 sites in fourteen specialties [5, 6]).

Systematic Optimization of EHR Efficacy

For our measure of EHR effectiveness we chose a combination of compliance with medical protocols and control of key clinical values that affect patient health. PROCARE stands for PROvision-based Clinically Active Reporting Environment (Figure 2). PROCARE is a closed-loop patient care system that uses a patient class event hierarchy to trigger process definition execution by an EHR workflow management system. The patient class event system and associated process definitions improve measures of clinical performance over time.

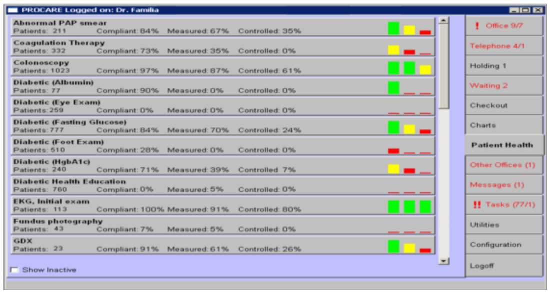

Figure 2 – PROCARE Clinical Dashboard

A provision is a forward-looking restriction or qualification in a contract or agreement. For example, a patient can be in a predefined class of patients provided they meet that class's predefined criteria (age between 0 and 18, BMI > 30, etc.). A patient class event hierarchy (Figure 3) detects at risk patients, calculates aggregate statistics that summarize clinical performance for a patient population, and automatically triggers workflows to help manage risk.

PROCARE's clinical summary dashboard (Figure 2) displays for each measure of clinical performance four numbers (corresponding to the four levels of the patient class event hierarchy): number of patients in the class for which the measure applies, percentage of patients in each class that are compliant with a predefined protocol, percentage of patients for whom appropriate and timely measurements are available, and percentage of patients for whom observed measures are controlled (within target normal limits).

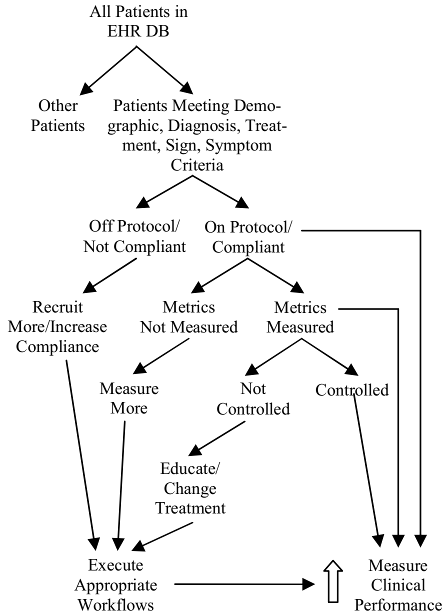

Figure 3 – Patient Class Event Hierarchy

Selecting a measure of clinical performance (such as colonoscopy in Figure 2) displays a patient list management screen (not shown) for creation or refinement of the policies that link patient class events to automated workflows. For example, process definition steps could include role or user work items, work items that appear when the patient is physically present, instructions that appear automatically whenever a patient chart is opened, or messages to external systems that trigger email or phone calls. Execution of appropriate workflow moves patients from non-compliance to compliance, unmeasured to measured, and uncontrolled to controlled categories, causing a shift from red to yellow to green graphical indicators on the summary dashboard.

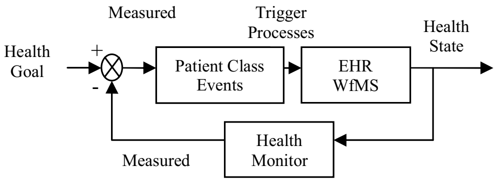

Figure 4 – PROCARE: Closed-loop Population Management

PROCARE uses a BPM approach (automated triggering of process definitions to systematically improve a measure of EHR effectiveness) to implement a closed-loop patient care system (Figure 4).

Systematic Optimization of EHR Efficiency

For our measure of EHR efficiency we chose to improve medical practice throughput and throughput time. PROCESS stands for PROcess Comparison for Efficient System Specification. PROCESS uses process mining [7] techniques to visualize, compare, and improve ambulatory EHR patient encounter task workflows. PROCESS is directing at improving processes in medical practices by:

1. Generating process models of existing practices.
2. Comparing measures of productivity (throughput and throughput time).
3. Explaining differences in productivity in terms of differences in processes.
4. Suggesting process improvements for low productivity practices.

We randomly chose nine pediatric practices relying on the same EHR workflow management system. We used process mining and visualization tools to compare throughput and throughput times across the practices for October (traditionally a busy month for pediatricians).

We looked for process activity patterns that might explain differences in global productivity measures (Figure 5). For example, practices 5 and 7 had high volumes but low throughput times, and displayed an accumulation of tasks between tasks H (Get Patient) and E (Current Meds) in Figure 6, which are both tasks for the nurse role.

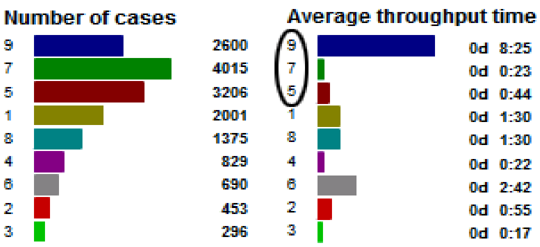

Figure 5 – Nine Medical Practices, Productivity Statistics

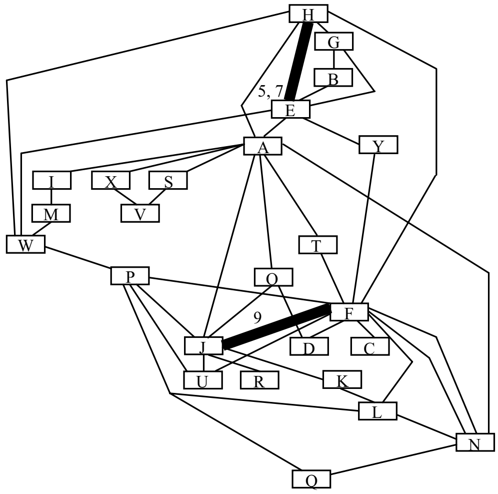

Figure 6 – Nine Medical Practices, Process Model

Table 1 – EHR Patient Encounter Tasks

A. Allergies	J. New Note	S. Sick/ Established
B. Anticipatory	K. Order Labs	T. Sick Visit, Est Patient
C. Chart Re-view	L. Order Tests	U. Sick Physical PPOP
D. Chart Re-view by	M. Order Treatment	V. SOAP Chart
E. Current Meds	N. Physical	W. View Chart
F. Examination	O. Preview Report	X. Well/Established
G. General Pediatric	P. Quick View	Y. Well Visit, Est Patient
H. Get Patient	Q. Quick View, Sick	
I. Labs	R. RTF Report	

In contrast practice 9 had lower volume but a dramatically higher average throughput time (Figure 5), and an accumulation of tasks between tasks F (Examination) and J (New Note), which rely on the physician role, a scarcer (and more costly) resource. This triggered investigation and consultations between the practice and a practice skills instructor to change and improve workflows.

In contrast to PROCARE, where our object is to systematically improve EHR WfMS effectiveness, our object with PROCESS is to systematically improve EHR WfMS efficiency, resulting in Figure 7 as a conceptual mapping back to the negative feedback control model initially presented.

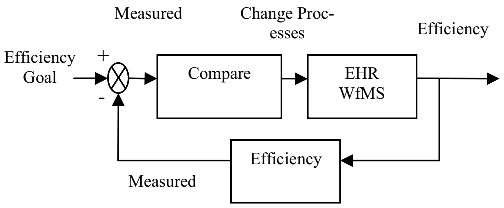

Figure 7 – PROCESS: Closed-loop Process Improvement

Practical and Conceptual Results

Our foray into EHR BPM had practical and conceptual results.

At the practical level, the PROCARE prototype played an important role in communication with regional clinical stakeholders using the same EHR WfMS. We used the prototype to explain the patient class event hierarchy and plan an enterprise-wide version of PROCARE as part of a regional health information exchange. The PROCESS prototype has been a valuable artifact to focus our internal discussion regarding developing a new service to provide to our EHR WfMS customers. Initial inspection of the resulting process models has already triggered useful practical investigations directed at improving medical practice workflows.

At a conceptual level, we became convinced that a business process management approach to systematically optimizing EHR effectiveness, efficiency, and flexibility is the most consistent, comprehensive, and useful framework within which to achieve meaningful use of EHRs at the point of care. EHR workflow engines, executing process definitions, can coordinate specialty-specific components, modules, and workflows to provide approximate specialty-specific clinical groupware solutions. These EHRs will still require BPM process optimization techniques to realize their full potential.

Combining EHR with BPM technology promises to (1) model and simulate interactions among physicians and other clinical and non-clinical staff, systems, and EHR components to create a shared mental model of how to optimize care coordination processes and results; (2) coordinate and manage handoff of patient care tasks within and across organizational boundaries; (3) provide real-time feedback to physicians and other care coordinators about care-in-progress to support in-line patient care process adjustments; and (4) monitor care coordination outcomes compared to performance targets and systematically improve care coordination process flows.

Conclusion

As summarized in Aalst and van Hee [8], the development of information systems has passed through four phases: (1) decomposition of applications, (2) movement of data into shared databases, (3) movement of user interface management out of applications, and (4) movement of process management out of applications into workflow management systems. Compared to other industries, today's EHRs, while complex and sophisticated in many ways, have not yet migrated process management into foundational workflow management systems.

Non-process aware EHRs *do not distinguish between unitary tasks at the same fine degree of granularity* as EHR WfMSs. Traditional EHRs often have high resolution screens with a multitude of simultaneous data review and entry and order entry options. Multiple user events, spanning multiple tasks, are often committed together to the underlying database, conflating together logically separate workflow steps. In contrast, an EHR WfMS typically presents just the data review and entry and order entry options on each screen that are relevant to single step in a task workflow sequence. For example, a nurse checking allergies and then current medications are two different tasks that at highly granular resolution should be distinct and acquire different time stamps.

Non-process aware EHRs *do not capture all the potential meaningful timestamps for those events that they do log*. They may log when data and orders are committed to a database but they do not typically log when tasks are first available to be accomplished, when they begin, when they complete, and other relevant timed-stamped events such as cancellation, postponement, or forwarding. Much of this missing temporal information is invaluable for understanding why bottlenecks occur, why certain tasks are subject to rework, and what slack resources are available elsewhere in the system.

Non-process aware EHRs, even if their event logs result in useful process models and actionable insights, *lack means to actively influence changes to workflow*. There are no process definitions or workflow engines to execute them; so there are no process definitions to change and thereby influence and improve effectiveness and efficiency. With respect to EHR effectiveness, a patient classification system without ability to trigger automated workflow is a passive reporting system (in which reports must be handed to staff for disposition, "Please put a note in each patient's chart so that the next time they have an appointment…"). A more active reporting system feeds directly back to a workflow management system to automatically perform useful tasks. With respect to EHR efficiency, even if a process model has an obvious flaw, there is no way to consistently and automatically deflect behavior at critical process junctures in order to improve throughput and throughput time.

In summary, compared to process-aware EHR workflow management systems, traditional EHRs (1) do not track tasks at high degree of resolution, (2) do not distinguish among a large number of useful time stamped events, and (3) have no means for process model insights to drive improvements through use of automated workflow. The next necessary step in the evolution of ambulatory EHRs is squarely at the intersection between electronic health record systems and workflow management/business process management systems. These hybrid clinical groupware systems will be more systematically optimizable than traditional EHRs with respect to clinical effectiveness, practice efficiency, and user satisfaction (that is, usability).

There are a number of research topics that we realize are relevant to EHR effectiveness and efficiency improvement modules such as herein described, including the relationship between process definitions and clinical guidelines [9, 10, 11]; ambulatory process patterns [12], mining [13], and flexibility [14]; and especially learning business process models [15]. As we continue development of EHR BPM modules, we will continue to absorb insights from these and other business process management and medical informatics research areas. In turn, we hope that our and other process-aware EHR systems can become useful sources for process data and case studies, and test beds for further research ideas and initiatives.

Acknowledgements

Many thanks to Prof. Wil van der Aalst for taking time to answer our questions about business process management research.

We also wish to acknowledge the larger academic medical informatics and business process management community. Work-a-day experience (and pressure) of maintaining and enhancing an existing EHR WfMS/clinical groupware product serving millions of patients, thousands of users, and hundreds of ambulatory medical offices does not typically afford us the opportunity to consider the larger intellectual enterprise in which we play a small part. Without the Web and the generous and open manner in which medical informatics and business process management research ideas and results are shared, we would lack access to information resources to contextualize what we have done and hope to do.

References

[1] Halamka J. Achieving meaningful use quality measures. National Committee on Vital and Health Statistics. http://www.ncvhs.hhs.gov/090428p04c.pdf (11 Oct. 2009)

[2] Weiner N. Cybernetics, Second Edition: or the Control and Communication in the Animal and the Machine. MIT Press, 1965.

[3] Pauldine R, Beck G. Salinas J, and Kaczka D. Closed-loop strategies for patient care systems. J Trauma 2008;64:S289-S294.

[4] Dumas M, van der Aalst, W, and Hofstede A. Process Aware Information Systems: Bridging People and Software Through Process Technology. Wiley-Interscience, 2005.

[5] Webster C. Workflow management and electronic health record systems. In: Proceedings, MedInfo: IOS Press, Amsterdam, 2004, p. 1904.

[6] Webster C, Copenhaver J. Structured data entry in a workflow-enabled electronic patient record. Journal of Medical Practice Management. 17:(3), 157-161 (2001).

[7] van der Aalst, W, and Weijter A. Process mining: a research agenda. Computers in Industry. Vol 53: 3, April 2004, Pages 231-244.

[8] van der Aalst, W., and van Hee K. Workflow Management: Models, Methods, and Systems. Boston: MIT Press, 2004.

[9] Tu S. Guideline models, process specification, and workflow. In Hofstede A, Benatallah B, and Paik H. Business Process Management Workshops, Springer Lecture Notes in Computer Science, 2008.

[10] Mulyar N, van der Aalst, W, Peleg M. A pattern-based analysis of clinical-interpretable guideline modeling languages. J Am Med Inform Assoc. 2007;14:781-787.

[11] Mans R, Schonenberg H, Leonardi G, Panzarasa S, Cavallini A, Quaglini S, van der Aalst, W: Process Mining Techniques: an Application to Stroke Care. MIE 2008: 573-578

[12] van der Aalst, W, Hofstede A, Kiepuszewski B, Barros A. Workflow patterns. In: Distributed and Parallel Databases 14 (1): pp. 5-51, 2003.

[13] Mans R, Schonenberg H, Song M, van der Aalst, W, Bakker P. Application of process mining in healthcare – a case study in a dutch hospital. In: Fred A, Filipe J, and Gamboa H, eds. BIOSTEC 2008, CCIS 25: Springer-Verlag 2008, pp. 425-438.

[14] Schonenberg H, Mans R, Russell N, Mulyar N, van der Aalst, W. Process flexibility: a survey of contemporary approaches. In: Proceedings of Advances in Enterprise Engineering I, 4th International Workshop CIAO! and 4th International Workshop EOMAS, 2008, pp. 16-30.

[15] Ghattas J, Soffer P, Peleg M. Learning business process models: a case study. In Hofstede A, Benatallah B, and Paik H. Business Process Management Workshops, Springer Lecture Notes in Computer Science, 2008.

Address for correspondence

Charles Webster, MD, MSIE, MSIS
EncounterPRO Healthcare Resources
2000 RiverEdge Parkway, Suite GL 100 A
Atlanta, Georgia USA
www.chuckwebster.com