Decision Support with RFID for Health Care

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Abstract. The health care environment is rife with issues that are urgently in need of solutions that can readily be addressed using appropriate tools for decision support. Recent developments in RFID technology facilitate this process through continuous provision of instantaneous item-level information. We consider an existing decision support framework and instantiate this framework using an example from the health care domain using RFID-generated item-level information. We illustrate the process by developing a health care knowledge-based system and evaluate its performance.

Keywords: RFID, Health Care, DSS.

1 Introduction

Systems for decision support as well as automation have been used in the health care domain for several decades. However, even if the underlying work flow and processes in general may seem similar to those in other domains, the general health care environment is characterized by somewhat different perspectives due to invaluable human lives that are directly at stake. For example the health care environment typically has a higher than average safety factor, high tolerance for longer payback period on investments, and an overall conservative approach. Simultaneously, researchers and practitioners are continually searching for improvements in process efficiency while safely and uncompromisingly delivering health care services. While it is difficult to achieve dramatic improvements in efficiency in the delivery of health care processes, it is possible to provide appreciable improvements in several scenarios that when put together results in the overall improvement of the health care delivery process in terms of patient outcome, efficiency, accuracy, and cost.

RFID tags are increasingly being used in the health care environment with varying levels of success (e.g., Tu et al., 2009, Meiller et al., 2010). For example, tagging pharmaceutical items to prevent counterfeiting as well as tagging items in a hospital environment for inventory purposes have been fairly successful. However, certain RFID applications have faced resistance in a hospital setting where their electromagnetic interference could affect normal operation of medical instruments (e.g., Ashar and Ferriter, 2007; Seidmann et al., 2010; Togt et al., 2008). Nevertheless,

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in spite of some issues, there is a large potential for RFID applications in health care organizations.

We consider a scenario from the context of health care delivery in France that lends itself to improvements in efficiency and effectiveness (Meiller and Bureau, 2009). This scenario relates to the sharing of ancillaries used in prosthesis implantation and extraction among hospitals. We modify and instantiate an adaptive knowledge-based system framework to this scenario and study the dynamics. We utilize a framework (Piramuthu and Shaw, 2009) that has been successfully instantiated in disparate domains including intelligent tutoring systems, machine scheduling, automated supply chain configuration, CRM, among others.

The remainder of this paper is organized as follows: in Section 2, we provide a brief introduction to the scenario considered. In Section 3, we introduce the modified adaptive knowledge-based system framework adapted to the scenario considered. We also illustrate the instantiation of this modified framework to the health care scenario of interest. We conclude the paper with a brief discussion in Section 4.

2 The Scenario

We discuss the scenario of interest in this section. Specifically, we consider ancillaries that require tracking. The ancillaries of interest here are those that are used in the implantation and extraction of prosthesis in humans. Each of these ancillaries is designed to be used only with a specific brand, model, and type (e.g., hip, knee) of prosthesis. I.e., hip prostheses from two different brands or even models are sufficiently different that they are not interchangeable. This level of specialization has its related consequence of high unit cost and the sheer number of different ancillaries translates to reduced frequency of use for each ancillary. Given its infrequent use and the large number of available ancillaries, buying every (or, even a large number of) available ancillary is an expensive proposition both in terms of the cost of acquisition and the resources (e.g., storage, maintenance, accounting) that are necessary for their proper maintenance and use. This has led to the prostheses providers renting ancillaries to hospitals that use their corresponding prosthetic part. Renting naturally signifies the movement of these ancillaries among different hospitals throughout their lifetime.

This movement of ancillaries necessitates some means to keep track of their instantaneous location as well as history. This has to be done on each individual ancillary in the system. This scenario naturally lends itself to automation through an appropriate knowledge-based system with learning capability.

3 Adaptive Knowledge-Based System Framework

The adaptive knowledge-based framework (Piramuthu and Shaw, 2009) we consider (Figure 1) has been fairly successfully instantiated in disparate domains. We extend this existing stream by modifying and instantiating the adaptive knowledge-based learning system framework for the scenario under consideration. This adaptive framework comprises four primary components including Simulation, Learning, Problem-Solving, and Performance-evaluation. Given that this is a knowledge-based system, the Learning component is used to generate the knowledge-base which forms the core of this system. Without appropriate and necessary knowledge, this system will not be able to perform intelligently. The Problem Solving component comprises the Knowledge-base and the Problem-solver. The knowledge-base contains learned knowledge on the domain of interest. The Problem-solver uses the knowledge-base and an instantaneous snap-shot of the environment to generate the most appropriate decision. A common characteristic of a knowledge-base in any dynamic environment is its tendency to become stale sooner or later. This can be addressed through consorted effort by the other three (i.e., Learning, Simulation, and Performance-evaluation) components.

The Performance-evaluation component constantly keeps track of the performance of the system. When it determines that the adaptive knowledge-based system is beginning to perform below par, it generates the specifications for new training examples and the Simulation component generates appropriate training examples based on these specifications. The training examples thus generated are input to the Learning component, which incrementally learns new knowledge and accordingly updates the knowledge-base.

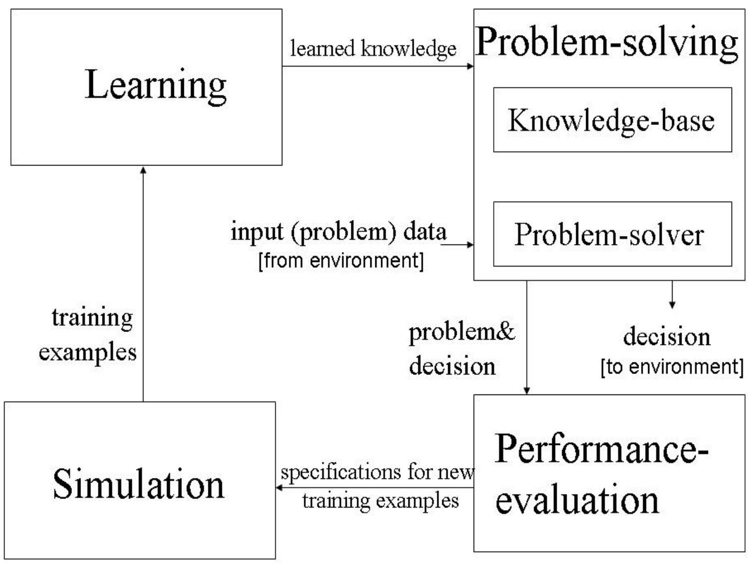

Fig. 1. Adaptive DSS framework

We modify this adaptive knowledge-based system framework for our purposes. The result of such modification to accommodate RFID-embedded systems in a health care environment is given in Figure 2. In this framework, the Learning component performs a similar function as the Learning component in the framework given in Figure 1. The Measurement and Evaluation components perform a similar function as the Performance-evaluation component in Figure 1. The knowledge base in the modified framework comprises four sub-components to accommodate the different functionalities that are required of the system including delivery routing and frequency, patterns of local demand and service provisions. The remainder of the components and sub-components in Figure 2 perform the functionalities of the Problem-solving component in Figure 1.

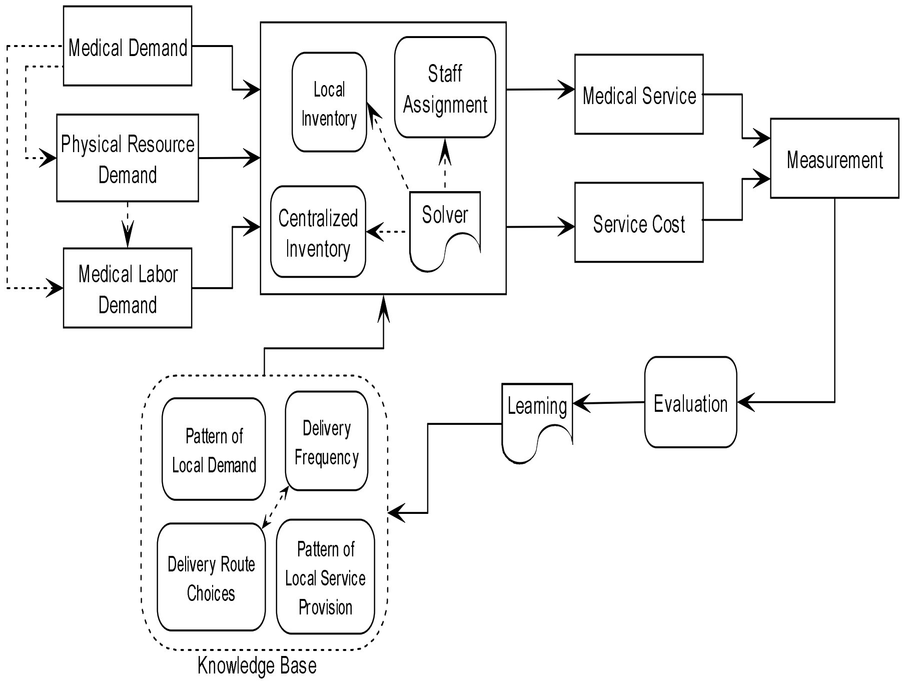

Fig. 2. RFID enabled Adaptive Learning framework for Health Care

The exogenous factors include the actual medical requirements that further become the demand on both physical and medical labor resources. With these inputs, the problem solver determines the appropriate local and centralized inventory, and effective assignment of staff in charge of inventory management. After a medical service is performed, both service quality and associated cost are determined and evaluated. Based on evaluation, associated benchmarks, and the extent of possible potential improvements, appropriate remedial measures are recommended and implemented.

3.1 Modified Adaptive Knowledge-Based Framework for Tracking Ancillaries

We model four hospitals in this scenario. All ancillaries are RFID tagged, and provide instantaneous information when needed. We consider both centralized and decentralized decision making scenarios. A schematic of the modeled scenario for the decentralized case is given in Figure 3. The scenario is operationalized as follows:

The ancillary provider has the option of either providing a centralized coordination mechanism whereby a hospital that needs an ancillary orders and receives the same from the central location. Once used, the ancillary is then returned to the central location by the hospital. The hospital pays rental fee on the ancillary to the ancillary provider for each day it has the ancillary in its possession. The other option modeled here is the decentralized case where the hospital pays the ancillary provider 100% of the daily rental charge only for the days in which it uses the ancillary. When no longer needed, the ancillary is transferred directly from this hospital to another hospital that has a need for this ancillary. The hospital in possession of the ancillary, in a sense, acts as its temporary repository when it's not in use. Moreover, the hospital pays a deeply discounted rental amount for the days it is in possession of an ancillary and the ancillary is not used. Here, each of the hospitals has its own local inventory of the ancillaries that it recently used until the next demand for this item is realized. This is beneficial for the hospital since it avoids the round-trip time (in the centralized case) and local inventory is beneficial in emergency circumstances.

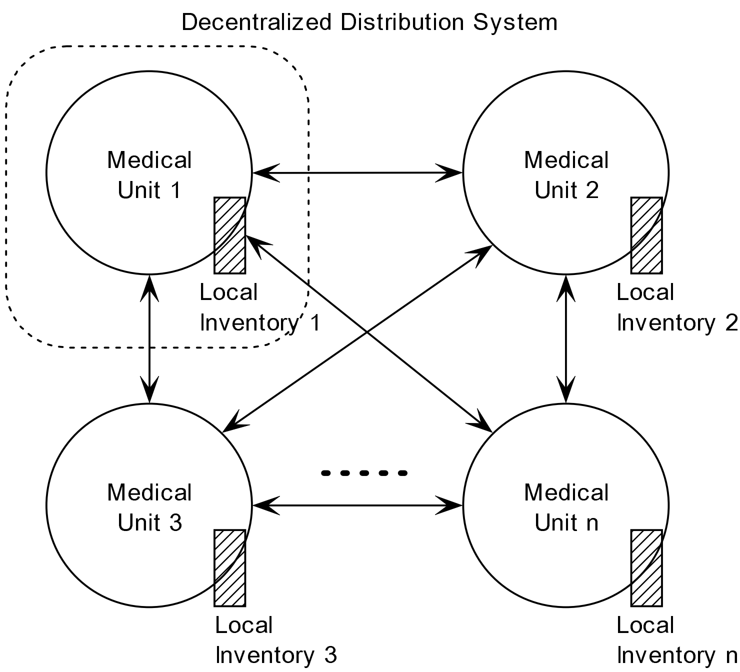

Fig. 3. Schematic of the modeled scenario for tracking ancillaries

We model these two (centralized and decentralized) cases and illustrate the proposed framework using simulation. We simulated the system for 365 days after a warm-up period of seven days, and the results are provided in Tables 1. The proposed framework was used to model both centralized and decentralized cases. To keep the model simple and yet be able to convey the gist of the scenario, we consider two identical ancillaries to be shared among four hospitals We modeled the rental cost in normalized form where all ancillaries cost the same for a day's rental (of 1 currency unit) when it is used and the rental charge is a small fraction of this amount for the days in which the ancillary is not used but is physically present at the hospital. This fraction is listed under the "Relative Cost" column in Table 1. The "Overall Cost" column lists the cumulative cost incurred by the hospital and it includes the deeply discounted rental charges for the decentralized case. The "# Items" column lists the number of ancillaries that were delivered to the requesting hospital. The "Cost/Item" column lists the unit cost of ancillaries that were delivered and used by the hospital. The "# Balked" column lists the number of hospital requests that went unfulfilled.

Table 1. Results for the centralized and decentralized scenarios

	Relative cost	**Overall Cost**	**# items**	**Cost/item**	**# Balked**
centralized	N/A	158	122	1.295	46
decentralized	0.005	165.595	154	1.075	9
decentralized	0.01	166.19	154	1.079	9
decentralized	0.02	167.38	154	1.087	9
decentralized	0.1	176.9	154	1.149	9
decentralized	0.2	188.8	154	1.226	9
decentralized	0.3	200.7	154	1.303	9

As can be seen in Table 1, the number of requests from hospitals that were not fulfilled is more in the centralized case. This is primarily due to the fact that in the centralized case, the round trip for an ancillary from a hospital to the central coordinating center and then to another hospital takes time. The other distinguishing characteristic of the decentralized case is in the cost/item, which is lower than a similar centralized case for low levels of the discounted rent value. With the parameter settings used in this study, the relative cost (i.e., discounted rental value) is about a third of the regular rental rate for the cost/item to be similar in both (centralized and decentralized) the cases. I.e., the ancillary provider can afford to charge a third of the regular rental price for days on which the ancillary is not used and still come even with cost. Note that we are ignoring the higher transportation cost in the centralized case (vs. the decentralized case for similar demand dynamics) because of the round-trips involved (vs. the one-way trip in the decentralized case). We are also ignoring inventory storage cost in the centralized case, and it is taken care of by the deeply discounted rent in the decentralized case. Including these would make the case for decentralized even stronger.

4 Discussion

We considered an existing adaptive knowledge-based decision support system framework and instantiated it to accommodate a scenario in the health care domain. Specifically, we considered the scenario where ancillaries are shared among multiple hospitals. RFID tags have begun to permeate a wide variety of application areas. Health care applications, where there is a need to accurately track and trace individual items at any point in time as situations dictate, and RFID tags are in a sense complementary to each other and can be synergistically used to improve performance. We showed that the proposed modified framework results in automating the processes involved. Moreover, we illustrated means to develop an adaptive knowledge-based system for health care applications.

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