7 Self-Organized Scheduling in Hospitals by Connecting Agents and Mobile Devices

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Abstract. This chapter describes the conceptualization and realization of a real-time managed mobile information system in healthcare. The particular application addressed is a dynamic, self-organized scheduling of the treatment of patients. Building blocks for this project are locatable, interactive Personal Digital Assistants (PDAs) to connect medical staff and patients; physical resources are connected by locatable Radio Frequency Identification (RFID) chips. These physical objects are represented in the information system by software agents. The multi-agent platform EMIKA implements a negotiation-based schedule system to enable a dynamic planning process. The EMIKA-System has been developed to prototype level and functionally tested in a real-time laboratory [SaEM2002]. Lessons learned from the realization pertain to technical functionality and to privacy and security issues.

7.1 Problem Definition and State of the Art

In classical information systems, a centralized scheduler using allocation rules creates an optimized appointment plan; however, due to the high dynamics of the hospital environment, the appointments have to be constantly adapted. This way scheduling becomes a continuous, never-ending process. Especially in life-crucial environments, as in hospitals, any hold-ups can have severe consequences. This chapter addresses a flexible real-time reaction to hold-ups. Scheduling patient logistics can be regarded as an ill-structured task [Schl1990], since it requires the assessment of treatment priorities and the allocation of resources, e.g. doctors’ time and availability. Unforeseeable hold-ups due to emergencies, delayed patients and varying treatment times prevent a complete advance mapping of the entire tasks and thereby a reliable planning of individual treatment sched-
ules. Various planning goals compete with one another. A minimum throughput time of patients and a maximum allocation of resources cannot be simultaneously optimized [Gäfg1990]. Different scheduling mechanisms work in parallel. Outpatients are summoned to prefixed appointments; emergency patients always lead to a real-time adaptation of whatever schedule exists at that point in time and inpatients are summoned from the wards in the event of under-allocated resources [ScCZ1996]. All three scheduling types have in common that, for treatment, patients need resources in the form of a doctor and diverse medical equipment.

The approach to handle this complexity of scheduling in EMIKA\(^1\) is to divide the complex task into several less complex subtasks [CyMa1963]. The divided tasks, however, remain loosely connected, in order to buffer goal conflicts and to model a highly dynamic and complex environment like a hospital for three reasons:

1. There are three types of patients with conflicting scheduling strategies:
   Outpatients require planning reliability to be able to coordinate the appointments with their activities outside the hospital (predictive scheduling). Inpatients are summoned directly in the course of time when the required resources are available (dispatching). Through urgent appointments (emergencies) or cancellations, the already existing and optimized appointment sequences must be additionally amended (reactive scheduling). Other projects using software agents focused on improving predictive scheduling concepts, which try to generate an optimized patient flow sequence under several scheduling constraints and optimization parameters well in advance of the real treatment execution time (see III.3 and III.4). The EMIKA project can acknowledge such optimized sequences and incorporates changes initiated by real-time events.

2. Optimizing schedule sequences: Even when only a limited number of auxiliary conditions are observed, this is an NP-hard problem due to the exponential number of alternate solution paths [GaJo1979]. The non-observance of dependencies on other appointments, the full utilization of the resources and the aims of the actors would create further disruptions in a ‘domino effect’ and thereby lead to a generally less efficient coordination result.

3. Because the requirements and general conditions in a hospital are not precisely known in advance, uncertainty is inherent in the system and makes exact planning almost impossible. Job-shop scheduling using

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\(^1\) Echtzeitgesteuerte mobile Informationssysteme in klinischen Anwendungen (Real-time mobile Information Systems in clinical Applications) – Institut für Informatik und Gesellschaft, Abt. Telematik (http://www.telematik.uni-freiburg.de/emika/)