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Dynamic composition of medical support services in the ICU: Platform and algorithm design details

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ABSTRACT

The Intensive Care Unit (ICU) is an extremely data-intensive environment where each patient needs to be monitored 24/7. Bedside monitors continuously register vital patient values (such as serum creatinine, systolic blood pressure) which are recorded frequently in the hospital database (e.g. every 2 min in the ICU of the Ghent University Hospital), laboratories generate hundreds of results of blood and urine samples, and nurses measure blood pressure and temperature up to 4 times an hour. The processing of such large amount of data requires an automated system to support the physicians' daily work. The Intensive Care Service Platform (ICSP) offers the needed support through the development of medical support services for processing and monitoring patients' data. With an increased deployment of these medical support services, reusing existing services as building blocks to create new services offers flexibility to the developer and accelerates the design process.

This paper presents a new addition to the ICSP, the Dynamic Composer for Web services. Based on a semantic description of the medical support services, this Composer enables a service to be executed by creating a composition of medical services that provide the needed calculations. The composition is achieved using various algorithms satisfying certain quality of service (QoS) constraints and requirements. In addition to the automatic composition the paper also proposes a recovery mechanism in case of unavailable services. When executing the composition of medical services, unavailable services are dynamically replaced by equivalent services or a new composition achieving the same result.

The presented platform and QoS algorithms are put through extensive performance and scalability tests for typical ICU scenarios, in which basic medical services are composed to a complex patient monitoring service.

1. Introduction

A computerized ICU is an extremely data-intensive environment, resulting in enormous databases. It is generally assumed that every patient generates around 16,000 different values on a daily base. This figure represents an accurate count of the Intensive Care Information System (ICIS) of the ICU in Ghent. The amount of data and the heterogeneity calls for automated data processing in the ICU. The ICSP, presented by the authors in [1,2], facilitates the abstraction of relevant information and supports the physicians through medical

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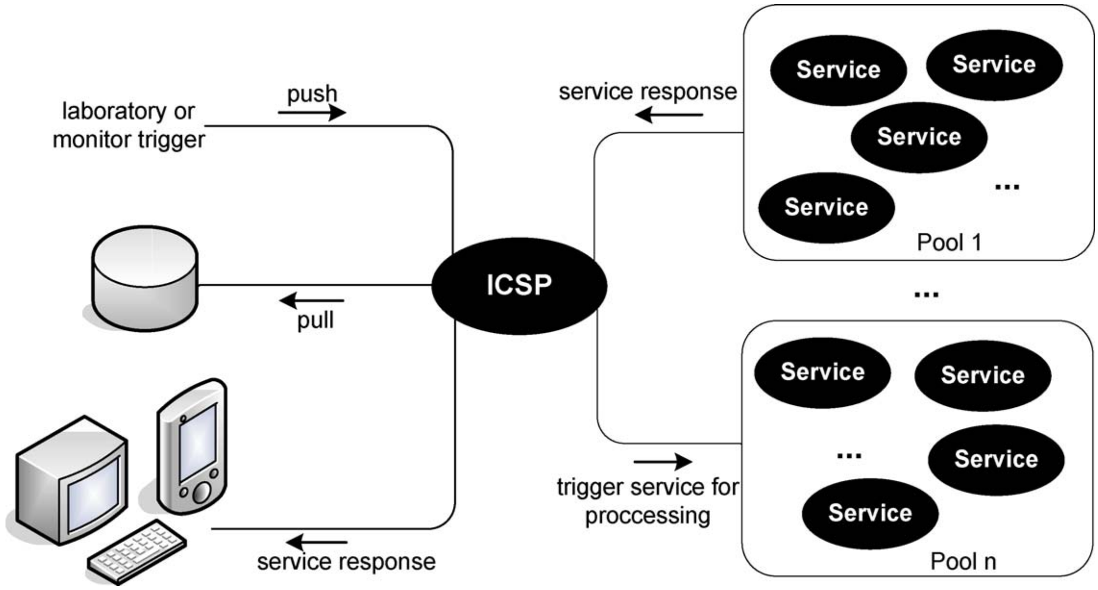

Fig. 1 – General concept of the Intensive Care Service Platform.

support services. The use of medical support services and computerized systems in the ICU has been gaining momentum and optimally using and visualizing data has been an important research topic in the recent years [3]. Within the ICU of Ghent University Hospital, several implemented medical support services already exist, namely a service detecting the kidney dysfunction based on the RIFLE (Risk Injury Failure Loss End-Stage Kidney Disease) criteria [4,5], a service calculating the CPIS (Clinical Pulmonary Infection Score) score, multi-service systems for prescribing antibiotics in the ICU and services calculating the SOFA (Sequential Organ Failure Assessment score) score [6,7] as a predictor for the patients' outcome.

The ICSP is designed based on the principles of Service-Oriented Architectures (SOAs), wherein all components are implemented as Web services. The Web service technology enables the required integration for the ICSP platform which acts as a generic communication system in which services can easily be plugged. ICSP provides efficient management and data subscription for medical support services. As can be seen in Fig. 1, laboratories or monitors provide medical data to the platform. These data are processed by the medical support services and, depending on the priority, results are sent to the patients' bedside terminal, the physicians' PDA or smart phone, or to an e-mail address. There is also the possibility to activate services at regular times (e.g. every night, every hour, etc.) by creating a cron trigger that will pull the required data from the database and activate the according medical support services for processing it and sending the results to the physicians' e-mail address. During ward rounds or when needed, medical support services can also be invoked on request to query for overviews of historical decision outputs and results. For a more detailed description the authors refer to [1].

It is expected that in future ICU information systems, hundreds of medical support services will be active simultaneously in order to optimize the care of critically ill patients. With an increased deployment of these medical support services, reusing existing services as building blocks to create new services not only offers more flexibility to the developer but accelerates also the design process because the existing parts are already tested and evaluated.

For example, the creatinine clearance service compares the level of creatinine in urine with the creatinine level in the blood. This creatinine clearance service is used as building block within the RIFLE service for evaluation of the renal function and within the ABDose (Antibiotic Dose) [8] service to tune the antibiotics dose and define the threshold value. Another example is the P/F service calculating the PaO2/FiO2 ratio and used as building block in the SOFA, CPIS and SIRS (Systemic Inflammatory Response Syndrome) [9] services, who respectively calculate the SOFA score describing organ dysfunction/failure in critically ill patients, the CPIS score for diagnosing VAP (Ventilator-Associated Pneumonia) and the SIRS service evaluating the criteria for systemic inflammatory response syndrome.

In order to support easy development of new medical algorithms by composing existing medical support services, the authors describe in this paper an application for the dynamic composition of medical support services into new software modules without the intervention of and programming by the ICT department.

The following features are required:

1. The design of *reusable* services for gathering data values from the continually updated ICU database and other calculating patients' state will result in a *component-based* system. These components could be combined for the execution of a more complex calculation.
2. *Automating* this collaboration requires a system capable of understanding the meaning of available data and operations achieved through the use of *semantics*.
3. Part of the automatic solution should be resolving technical complications like the unavailability of the medical services. If this event should occur, the system should react