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Soarian™ – Workflow Management Applied for Health Care

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Summary

Objectives: To describe and comment on functionality and architecture of the software product Soarian™ developed by Siemens, to identify key differentiators to related products, and to comment on predecessor systems and beta versions. This has been done in the framework of a conference on health information systems of the IMIA.

Methods: Analyzing existing literature. Site visit of a predecessor system at Haukeland Sykehus, Bergen. Pilot of a beta version at the Erlangen University Medical Center, elaborating on major characteristics in discussion rounds.

Results: Soarian is a functional comprehensive, clinically oriented software product to support health care processes and to be used for health care professional workstations. It is a software product, designed and written completely new. Three major key differentiators were identified in comparison to related software products: Soarian's workflow engine, its embedded analytics, and its 'smart' user interface. The targeted reduced installation time is stated to be 12 months or less.

Conclusions: Soarian has good chances to become one of the major software products for health care professional workstations in the international market to support patient-centered, shared care. Its global design may help to better support and maintain national or language specific versions. The first installations of Soarian will be critical, as they will show how the system will be accepted. To use such software products efficiently, organizational aspects within hospitals as well as between health care institutions have to be considered, e.g. strategic IT planning.

Keywords

Health information systems, clinical information systems, electronic patient record, workflow management, IMIA

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1. Introduction

1.1 From Hospital Information Systems to Health Information Systems

Today information processing is usually still primarily directed towards the information needs of the respective institutions, e.g. of a hospital or of a general practitioners' office (GP office). This stands in apparent contradiction to the fact that patients may not be solely treated in one GP office or hospital. More information processing towards patient-centered, shared care would better support high quality as well as efficient health care (1, 2). It would also help to improve patient safety (3). As an important prerequisite, a patient-centered electronic patient record (EPR) is needed (4). This problem is not new, but still a challenge in health care. Pushing to overcome this deficiency remains an important task for medical informatics (5-10).

Already in the early seventies, Morris Collen argued for having "electronic data processing and communications equipment" … "for patient data within one or more general medical centers, including both hospital and outpatient services" (11).

In 1994, a working conference of the International Medical Informatics Association (IMIA), organized by its Working Group 10 'Hospital Information Systems' (IMIA WG10, (13), was devoted to 'information systems with fading boundaries'. One of the outcomes was summarized in the statement: "Whereas the preceding" ... "conferences considered the scope of the Hospital Information Systems (HIS) to be restricted to the information systems within the borders of the institution, this conference was of the opinion that functions outside the hospital also need to be included in the definition, i.e. HIS broadens its meaning to Health Information Systems" (14).

In addition, we had to recognize that not only technical problems but also organizational problems within and between health care institutions had and still have to be solved (15, 16).

Furthermore there is a clear need for functionally comprehensive software products to support the work of health care professionals, which consequently support such patient-centered, shared patient care. In 1993, IMIA WG10 discussed the design and implementation of such information processing tools in its working conference on health care professional workstations (17).

New information and communication technologies are also needed to improve the efficiency of health care processes (18).

1.2 Aim of the Paper and Questions of Interest

In the framework of an IMIA WG10 working conference on health information systems, that took place in April 2002 in Heidelberg, Germany, a session on 'practical HIS experiences: scientific presentations of HIS functionality, architecture and experiences' was organized. The major aim was to report about such functionally comprehensive software products for health care professionals and with the experiences made on implementations.

The first author[1] of this paper was asked to describe and comment on Soarian™, the new software product of Siemens Medical Solutions Health Services (SMedHS). With the intensive support of his co-authors from the Erlangen University Medical Center (ErlangenUMC) and from SMedHS[2], answers to the following questions are presented in section 3 of this paper:

1. What are specific characteristics of Soarian's functionality and architecture?
2. What are key separators of the system?
3. Which design strategy has been chosen?
4. Which implementation strategy is intended?
5. What is known about Soarian's customer base?

As it is not possible today to report about experiences of a full version of Soarian, used in clinical routine, we also decided to report on the use of a predecessor system, DocuLive at Haukeland Sykehus, Bergen, and on an implementation of a Soarian beta version at ErlangenUMC. These reports can be found at the beginning of section 3.

2. Methods

In order to elaborate on answers to the above-mentioned questions, four kinds of activities took place.

- Literature about Soarian and Soarian features was studied by R.H. and C.S., from brochures (19), via press releases (online access via (20), e.g. (21-28), to journal publications (29-31) and reports (32).
- On March 5 and 6, 2002, a site visit was done in Bergen, Norway. In Haukeland Sykehus, Diakonissehjemmets Sykehus Haraldsplass we did site visits to observe how health care professionals worked with DocuLive EPR, a predecessor system of Soarian. We also visited one of the GP offices, which receives online reports from DocuLive EPR. In particular we investigated possibilities for sharing patient data in different hospitals and for electronic communication with GP offices.
- At ErlangenUMC a beta version of Soarian (Soarian Clinical Access) is in the process of being implemented and validated.
- In two meetings that took place in Malvern (February 10 and 11, 2002) and in Bergen (March 5 and 6, 2002), we discussed the characteristics of Soarian, focusing on the properties of Soarian Version 2.0.

3. Results

3.1 Introductory Remarks

Soarian – a Brief Overview. Introduced by Siemens Medical Solutions[3] in October 2001, Soarian is regarded by Siemens as "a new generation global health information solution that will dramatically change the way healthcare is delivered" (23). Experiences with existing software products of SMedHS shall be integrated into this new product. However, Soarian represents a total rewrite of clinical and financial applications.

Following this integrated concept, Siemens wants to reduce the amount of interfaces and its related problems from and to departmental solutions, also by developing e.g. operation theatre, cardiology, radiology system functionality and integrating them in Soarian. Furthermore, Siemens wants to take advantage of its global resources and to combine its expertise in medical devices and information technology. E.g. Siemens mobile computing devices were also considered at the Soarian development. Soarian's development was driven by process

[1] Reinhold Haux was a member of the IT strategic board of ErlangenUMC from 1998 to 2000 and was involved in strategic IT planning at ErlangenUMC as well as in the selection of an appropriate software product for its health care professional workstation.

[2] Christof Seggewies is member of IVMed, the IT department of ErlangenUMC. He is project leader at ErlangenUMC for the health care professional workstation project, in which Soarian has been selected as the software product and in which its implementation and test is currently done. Helge Reichert is working as product manager of SMedHS Clinical Systems in Germany as well as project manager at ErlangenUMC. Peter Kullmann is site manager for Siemens Medical Solutions in Norway as well as project manager for the implementation of Soarian at the Norwegian beta customers Ullevål Universitetssykehus, Oslo. Ullevål is pilot for all 5 Norwegian university hospitals, with the intention to test, assess, and introduce Soarian. Lutz Luedecke is international business developing manager for SMedHS Clinical Systems and so responsible for market introduction of Soarian in the international (non US) market. Wilfried Baldauf-Sobez is group vice president of SMedHS Clinical Systems. Hubert Seibold is director of IVMed.

[3] *Siemens AG* as a leading global electronics and engineering company employs some 450,000 people in 193 countries, and reported worldwide sales of more than 74 billion US$ in the 2001 fiscal year (27). The annual global investments in research and development range between 5-6 billion US$.
Siemens Medical Solutions of Siemens AG is one of the largest suppliers of health care equipment in the world. Siemens Medical Solutions offers a broad range of products, services, and solutions ranging from imaging systems for diagnosis to therapy equipment for treatment, to electromedicine and hearing instruments to IT solutions that optimize workflow and increase efficiency in hospitals, clinics and GP offices. Employing approximately 30,000 people worldwide, in the 2001 fiscal year, it reported preliminary sales of 7.2 billion Euro (27).
An integrated part of *Siemens Medical Solutions, Siemens Medical Solutions Health Services* Corporation, Malvern PA, USA, offers a broad range of clinical, financial, and management applications and outsourcing and professional services to support health providers across the continuum of care. As an application service provider in health care, the company operates applications for over 1,000 health providers and processes 107 million transactions daily (27). Health Services is employing approximately 7,000 people and has approximately 5,000 customers worldwide. *SMedHS Clinical Systems* is responsible for the development of Soarian Clinicals. The second component, Soarian Financials, is developed by the financial division of SMedHS.

management for software development to be built under ISO 9001 to ensure high quality management (22).

Soarian consists of two parts: Soarian Clinicals, focusing on the patient-oriented aspects, and Soarian Financials, focusing on general administrative functionality. Soarian Clinicals intends to support the health care professional's actual work around rounding on a patient, transferring and discharging a patient, administering medications, documentation, order entry and result reporting.

The current (March 2002) Version 1.1 of Soarian is regarded by SMedHS as a version that is mainly used as part of the implementation process, Version 2.0 as the first full (global), web-based version. Version 2.0 is announced for the US, the UK and for Scandinavian countries for the first quarter of 2003. This version will be in production at beta sites and will be announced as generally available afterwards. For the Germany beta installation at Erlangen UMC, it is intended to install and test the system on pilot wards by the end of 2002.

In this paper we report about Soarian Clinicals. With the exception of section 3.2 we will deal with Soarian Clinicals, Version 2.0.

3.2 Predecessors and Beta Versions of Soarian

The software products DocuLive EPR (V4.9, Siemens) and Melior (V1.5, Siemens) as well as Invision (formerly SMS, now Siemens) are regarded by SMedHS as the major predecessor systems of Soarian, being used for its functional specification and for requirement engineering. It was mentioned that work on online physician order entry using the Soarian predecessor system Invision received the Nicholas E. Davies Award because of its improved patient outcomes (21, 29). In the upcoming beta projects in the US the administrative part of Invision (Patient Administration) will be interfaced to Soarian Clinicals through HL7 messages, so all demographic information is communicated between these systems.

3.2.1 DocuLive EPR at Hospitals in the Bergen Region

DocuLive EPR Functionality and Architecture. DocuLive EPR intends to provide continuous documentation for all kinds of medical information which is relevant for the diagnosis and treatment of patients. It preserves the advantages of the paper-based patient record, while providing the possibilities of electronic information handling. DocuLive EPR supports updating and maintaining a paper-based copy of the patient record. Version handling of all data elements, including signatures, validation, invalidation data and the cause of changes is maintained.

The navigation is based on context-sensitive pop-pup menus, available both with mouse and keyboard interaction. XML/HL7 interfaces provide electronic data exchange to external systems like laboratory, patient administration or information systems for general practitioners. The database part is implemented in Microsoft SQL 2000, with utilization of stored procedures and tuned indexing. The client side is programmed with C^{++} and consists of a desktop frame utilizing various presentation and interaction components specific to the various modules.

The Application. Its use in daily production at Haukeland University Hospital, Bergen, (Haukeland Sykehus, approx. 1,100 beds, 53,000 inpatients stays/year, 230,000 outpatient visits/year, and 6,000 employees) started in early 1997. In 2001, DocuLive became multi-site enabled for hospitals in the region of Bergen and today also supports the Hospitals of Stord (Stord Sjukehus), Voss (Voss Sjukehus), Haraldsplass (Diakonissehjemmets Sykehus Haraldsplass), Hagevik (Kysthospitalet Hagevik) and Betanien (Hospitalet Betanien) with shared patient records. Up to approx. 500 concurrent users had produced approx. 385,000 patient records by March 2002. Approx. 3,500 named users for DocuLive, mainly physicians, health care professionals from auxiliary units, and secretaries, but only few nurses, used the system (March 2002). EDIFACT laboratory results have been communicated since 1993 to now more than 180 GP offices. The first electronic discharge note was sent to a GP office in June 2000 (as an XML message from DocuLive EPR, converted to EDIFACT in Cloverleaf, prepared for external mail and cryptography in separate solutions, and put in the X.400 mailbox and retrieved by the GP office). In March 2002 messages to approximately 26 GP offices including approximately 200 physicians were sent out in routine.

DocuLive EPR is in use at all 5 Norwegian university hospitals, in the hospitals of the regions around Bergen and Trondheim, and in several other hospitals in Norway (31).

Impressions at the Site Visit. DocuLive EPR is in full production and intensive use in the above-mentioned hospitals. Having most (but not all) documents included, it is used in addition to the paper-based patient record. For documentation tasks and access to patient data it provides considerable benefits for its users. Order entry, however, which is also part of DocuLive's functionality, is still done manually. Although the data are stored as attributes in a generic relational data model, the user interface has been designed according to the paper forms and documents the health care professionals are using.

Of particular benefit is the access to patient data at different hospitals. If a patient is treated at several hospitals, access can be given to the health care professionals of different hospitals treating this patient but viewed as part of the electronic patient record of the respective site.

Also highly beneficial is the possibility of transmitting lab findings and discharge letters to GP offices online. These documents were automatically put into an input queue of the software systems used in GP offices. Of great advantage here was the unique person identification number for Norwegian citizens.

3.2.2 Soarian at Erlangen University Medical Center

History. The project of implementing a health care professional workstation throughout ErlangenUMC (approx. 1,500 beds, 55,000 inpatients stays/year, 380,000 outpatient visits/year, and 6,000 employees) started in 1998 with a collection of requirements. These requirements were based on the catalogue of the working group on health care professional workstation of the German Society for Medical Informatics, Biometry and Epidemiology (33). Health care professionals at Erlangen UMC added additional requirements.

In 1999, a detailed process analysis added the workflow perspective and identified areas that could be optimized by the support of a health care professional workstation. The process analysis focused on patients with colorectal and breast cancer and monitored these patients throughout ErlangenUMC.

The results of the process analysis showed that the main optimization potentials beside document management could be found in coordinating and remodeling the clinical workflow. A market survey in 2000 focusing on the requirements and the major aspects of the process analysis lead to the decision, to set up a pilot installation of Soarian as a joint project of Siemens and ErlangenUMC.

Collecting German Requirements. Based on the existing specification of Soarian for several countries, Siemens and the Erlangen UMC identified detailed requirements for the German market in 2001. The main differences as part of the gap analysis could be found in different billing systems throughout the countries. Although billing was not the key aspect for the clinical workflow, clinicians and clinical information often drive the billing process. Especially with the DRG system being implemented in Germany until 2004, clinical information has to be put into an administrative context understandable by clinicians.

Timeline for Implementation at Erlangen University Medical Center. Being a beta implementation project, the timeline for implementing Soarian at Erlangen UMC currently follows the implementation timeline of Soarian. The adapted version of Soarian Clinical Access including German requirements will be piloted and validated starting in October 2002. Additional requirements for Germany will be added to Soarian V2.0 and V2.1 available in 2003.

Implementation of Soarian Clinical Access. Soarian Clinical Access as the first web-based component of Soarian will be piloted in a surgical and a medical department of ErlangenUMC. By importing administrative patient data from the patient management and billing system SAP/IS-H via HL7, basic patient and visit information will be available in Clinical Access. The results of eight chemistry laboratories using the laboratory information system of Erlangen UMC will be collected. Text results from Radiology, Microbiology and Pathology can be passed to Clinical Access. Associated radiology pictures can be displayed by calling the web-based PACS-Viewer MagicWeb. A CCOW-service allows for access to MagicWeb without separate authentication. Clinical Access is based on a customizable cumulative presentation approach thus allowing for problem oriented views to the clinical data. Specific context oriented views will be developed at ErlangenUMC.

Roadmap for Soarian Version 2.0 at Erlangen University Medical Center. With Soarian V2.0, extensions and adjustments for the German needs will be provided. Standard functionality for a localized clinical workstation include order entry, patient management, support for discharge summaries and patient care documentation, scheduling and DRG-documentation. Diagnoses and procedures can be documented, mapped into official coding systems like ICD-10 or ICPM and transferred to the billing system without forcing clinicians to switch to a different application. An adjusted module for medication documentation in Germany and application of the rules engine will help to address adverse events. Offering the set of functionality needed in the specific context of patient treatment will help to avoid time intensive navigation for the needed functionality. Workflow support will be widely enhanced by the integrated workflow engine. Actively monitored and controlled queues will replace passive queues for documents in given status, thus enabling e.g. the passing on of a document after a certain period of time. Embedded analytics will offer the possibility for extensive data mining in various fields, e.g. quality management.

3.3 Soarian Version 2.0

3.3.1 Functionality

Soarian Clinicals intends to support the health care professional's actual work around rounding on a patient, transferring and discharging a patient, administering medications, documentation, order entry and result reporting.

Figure 1 shows a screenshot of Soarian Clinicals directly after login. The clinical situation corresponds to that of a physician who wants to get an overview about his patients and her/his remaining tasks. Each user sees his own task-list. User related tasks, which are considered as 'bulkware' in the user's mental model, are shown on the left side. Getting the tasks done or an overview of remaining tasks is more important than the individual patient at this time. On the right side the patient related part, the census display, is shown. The physician is able to get an immediate overview of which patients require attention. She or he can also check the current status on a high level by clicking on the patient's name. If necessary the full patient record can be accessed directly from this screen.

The screen in Fig. 2 shows a possible view on results within the patient record. The elements on the screen contain the patient information, an encounter navigator, a result navigator and the results themselves. This reflects the clinical situation, when a physician needs to look up specific results in her/his clinical context (opposed to just acknowledging new results). A distinct navigation intends to allow the users to put together and compare results horizontally (result changes over time) as well as vertically (compare results out of different categories e.g. blood sugar and glucose in urine). The navigational concept intended to be tailored specifically to the users' mental model. Also the visual layout tried to capture some extra information one would get in the paper world (e.g. oxidized paper, thickness of patient record etc.). The encounter navigator provides information about length of stay and frequency of visits in an unobtrusive way. Photo-corner-like widgets allow navigation through time. The result navigator provides the stability of a flowsheet and shows up in front, for which categories results are available and for which they are not. The third level of navigation lets you page through results and also align them for a specific time on one click.

Patients can be registered and admitted as outpatients, emergency outpatients, clinic outpatients, referred outpatient, or as an inpatient in the hospital network. The administrative admitting process in Soarian allows capturing all needed data like birth information, insurance data, next of kin, referral information, etc. The extended administration functionality contains bed management.

In case of false identification, two patient records can be merged together. Merged records appear with all patient information pertaining to the two records visible in one record. Merging patient records is a manual process since in case of inconsistencies a decision will have to be made, which information will be displayed in the retained record. The merged record can be modified.

Assessing and Treating Patient Needs. The health care encounter, or visit, is a meeting between a health care provider and a patient for the purpose of receiving one or more health-related services. A patient problem is usually established during the visit, and is the preliminary diagnosis upon which care is based. Patient problems in Soarian can be chosen from predefined templates in the problem template catalogue, or edited or created if necessary. One or more predefined care plans, or individually created plans, mapping the treatment path for a patient problem, can be associated to each patient problem. Care plans contain user- defined and specialized (orders, prescriptions) activities to be scheduled to help a patient to meet specific treatment goals. Care plans are constantly monitored throughout the treatment process. Predefined care plans can be edited to tailor them specifically to the needs of a particular patient; new care plans can be created. Unscheduled activities appear in a worklist to be processed.

Soarian lists the activities by scheduled day, and the care plan view groups them by care plan. Using the record content viewer and the record explorer activities, care plans, and patient problems can be searched for. As part of patient treatment, Soarian Clinicals supports the placement and monitoring of orders, placement of specialist requests, results presentation, sample collection, replies to incoming referrals, and replies to outgoing discharge reports. Orders are placed with predefined ordering documents, or through the site-specific service catalogue.

Fig. 1 Example of a Soarian worklist/census screen.

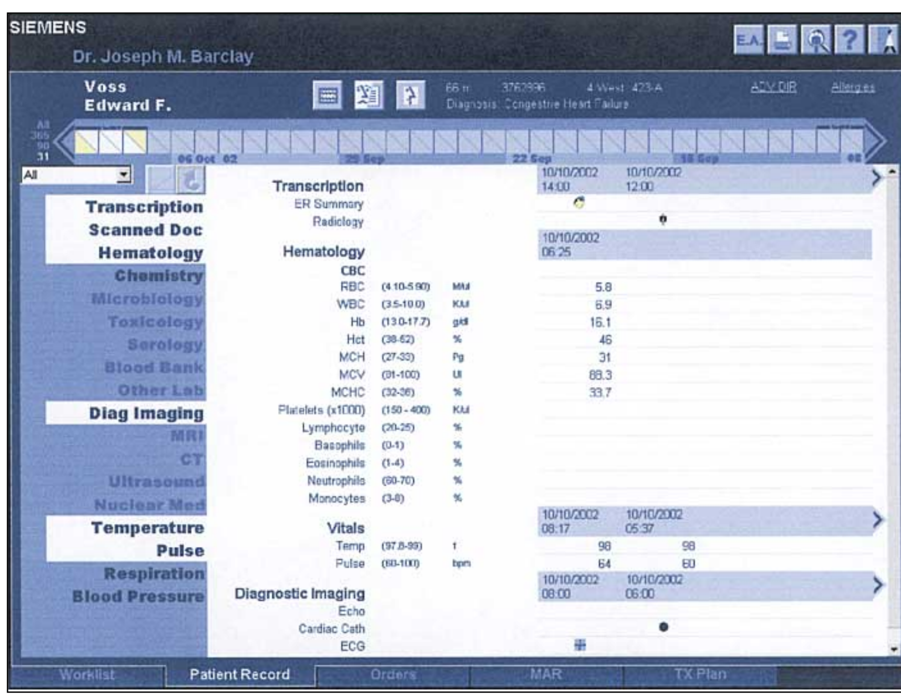

Fig. 2 Result display.

The multiple and/or repetitive order requests can be defined, orders can be stopped by canceling, discontinuing, or invalidating them and giving a reason for doing so. All orders for a patient appear in the order monitor providing an overview of the status of all the orders that have been placed, from creation to completion. All samples to be collected incl. details like instructions are added to a worklist. The clinical overview provides relevant patient information grouped in sections. Relevant parts of the patient record are accessible from the clinical overview. The clinical overview is also the main entry point when working with patient medications. A list of prescriptions for a particular patient including names, forms, and strengths of the drugs and the tools used in the prescription planning process are available. A warning displays in case of a documented allergy to the drug being prescribed, or if the drug interacts with any other prescribed drug. Drug information is available from the physician's desk reference. Pharmacy requisitions for the patient can be printed, and old requisition forms and print copies are available. Printing copies of narcotic prescriptions is rejected, based on security and drug class.

Patient Documentation. A document is the data interaction and viewing environment for patient information. When a document is added to the patient record, a document history is kept for that document. This history logs revisions and print history, and contains the user identification of the user making the change. The history can be viewed, and the document can be restored to any revision chosen from the revision history. Clinical documents can be added to a patient record, and can be viewed through the record content viewer. Patient documents can also be retrieved by the record explorer, which allows for searching through documents associated with patient records using configurable search criteria. Information contained in the document can be added through digital data entry, or by scanning. Digital data entry allows for entering audio material from a dictation device into a patient record. Document worklists exist for attestation, dictation, pending correspondence, unfinished documents, and updates to paper records.

Each step of the document life is assigned a status, which appears on the document as a watermark visualized on screen and in print. In addition, documents can be designed to require only a signature, or a contra signature.

Printouts can be generated as individual documents as the need arises, as a full copy record for legal or audit purposes, single documents as a result of workflow, and for the maintenance of a paper based record.

3.3.2 Architecture

System Architecture. Soarian has been designed to support a classical n-tier deployment. All clients interact with so-called *user session management* functionality, running on application/web servers (currently MS Windows 2000, concerning Microsoft and Siemens see (24), which in turn communicate with the database servers (currently SQL Server 2000) using the database access layer component of the system. Examples for large-scale implementations with these products include an OLTP-System with 930 concurrent users on a 1.3 TB database (see (25)). The application server also processes requests coming from the connectivity module, which includes the 'OPENLink Interface Engine', to transmit data to and out of Soarian Clinicals. Fig. 3 provides an overview about these components.

Application Architecture. Soarian provides a workspace management framework to access all the functionality that a user has access to. The Soarian platform provides the infrastructure for developing all the Soarian modules (Fig. 4). The following features are provided:

- Persistence framework
- Security management
- Audit trail and version management
- Document management
- Event management
- Transaction management, and
- Cache management.

The base platform also provides a set of pre-defined document templates. Both the business objects and the document templates can be customized for a specific site.

Information security is critical in Soarian Clinicals. Soarian Clinicals delivers a powerful combination of task- and data-based security features. The core of its security management relies on data-based security. Task-based security wraps around data-based security, providing an easy-to-configure tool to specify security settings within the enterprise.

Siemens OPENLink is used as the Interface Engine that communicates with a Soarian Clinicals module called Connectivity. Connectivity uses services provided by the different modules to 'post' data into the Soarian Clinicals database (handling of inbound messages). It subscribes to events raised by the architecture to trigger outbound messages to external systems using the information stored in event tables of the architecture.

3.4 Key Differentiators of Soarian

Soarian intends to adopt a holistic approach to patient-centered information processing. It understands that results occur in the context of a patient, and the clinician wants to review those results and respond to them in a single process. The system intends to provide process-oriented views of data, aggregating data from multiple disparate departments and presenting it in a logical, clinically relevant view. The clinician can review results and respond to them on a single screen. The system intends to support the clinician's actual work; admitting a patient, rounding on a patient, discharging a patient, administering medications, not just looking up results, ordering, and documenting.

Siemens identified three major key differentiators in comparison to related software products: Soarian's workflow engine, its embedded analytics, and its 'smart' user interface.

Workflow Engine. Soarian intents to provide more than rudimentary worklist functionality found in traditional clinical information systems. Through the integration of proven workflow management technology, it actively coordinates tasks done by the many health care professionals, within

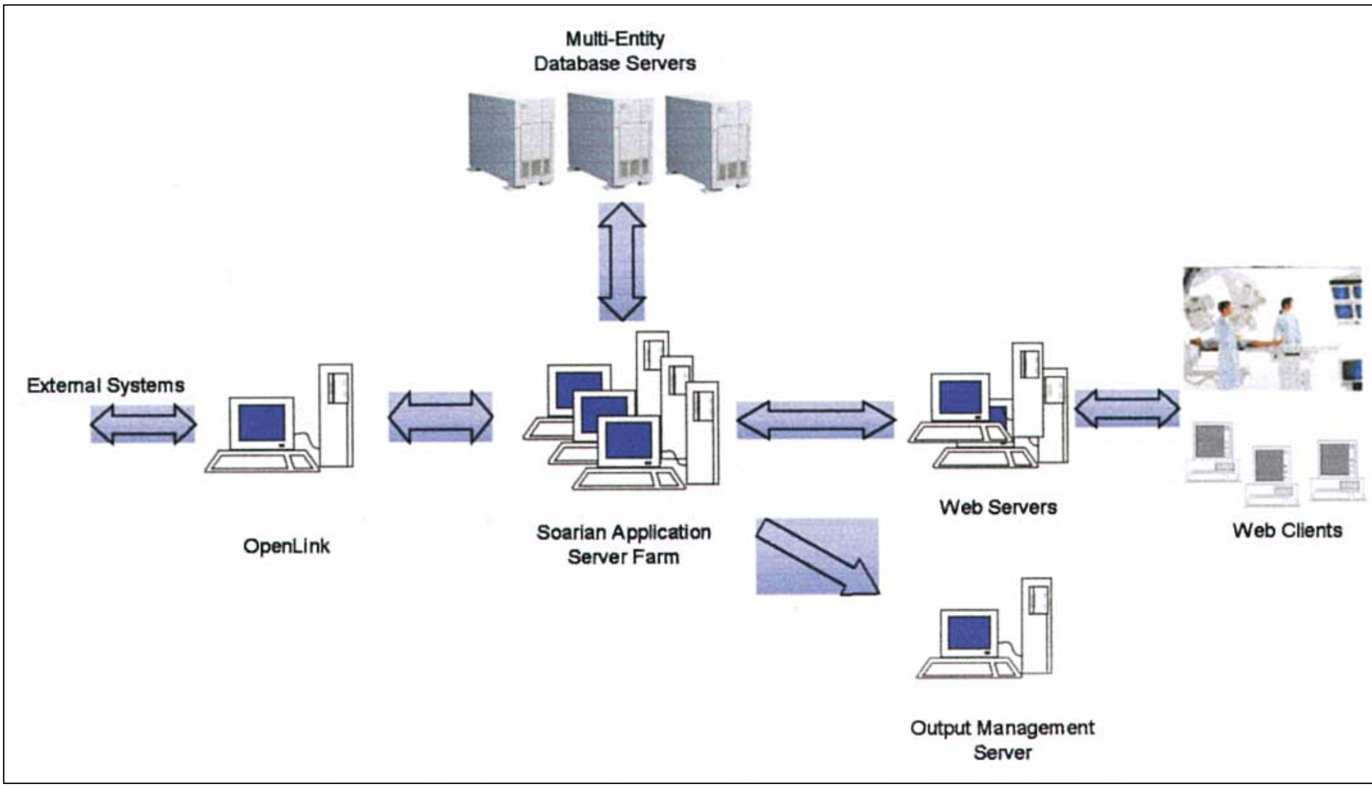

Fig. 3 System architecture components.

multiple departments, and thereby intents to minimize delays and failures, and to help to support improving patient care by encouraging health care professionals to follow best practice processes. In addition, the application integration capabilities of the workflow engine allow processes to include tasks done by or through non-Soarian systems and thus span the entire enterprise. Processes may even be extended to include business-to-business processes and business-to-consumer (hospital-to-patient) processes.

The integration of the workflow engine and Soarian occurs at a fundamental architectural level, and represents an expansion of both traditional workflow technology and traditional clinical system technology (27). This is manifest in three areas; the relationship between workflow process design and clinical workstep execution, the exposure of clinical functionality as services to be executed by workflow processes, and the publishing of health care events used to initiate new workflow process instances or to influence running ones.

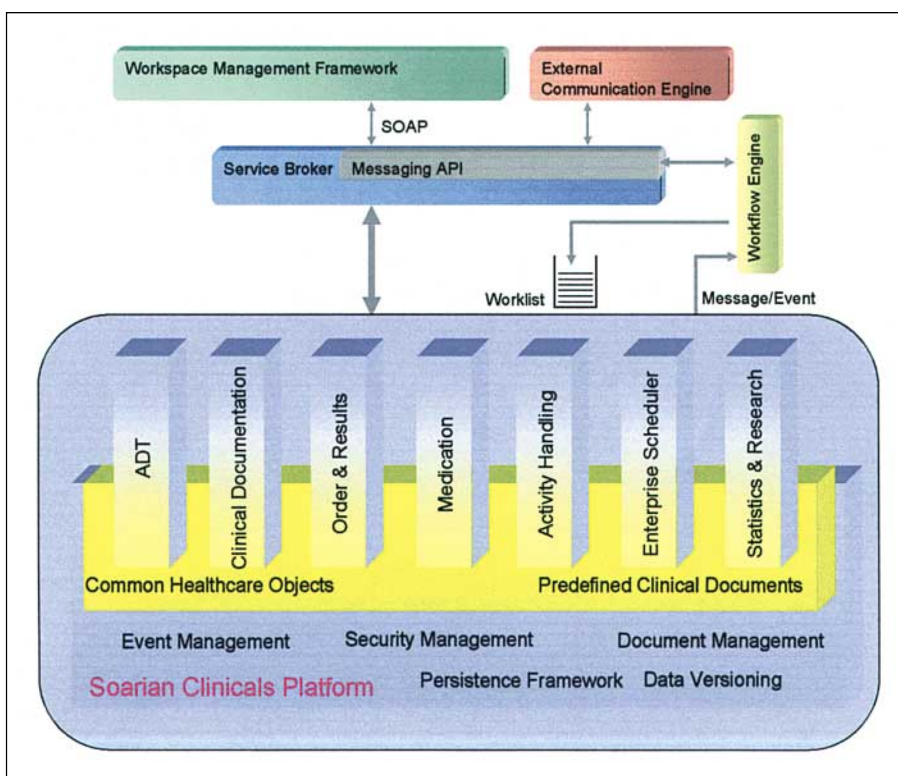

Fig. 4 Application architecture components.

The workflow configuration environment and the clinical user interface are designed to work coherently in the configuration and execution of workflow processes. Soarian expresses its user interface as a collection of programmatically callable activities. These activities represent discrete tasks done by a clinical user. They include activities such as medication administration, co-sign orders, perform nursing assessment, etc. Each activity is represented as an item that can be placed within a worklist, as a callable activity, and as an icon that can be drawn in the workflow configuration environment. These icons are organized within libraries, such as pharmacy, nursing, or surgery. A workflow process is designed using an iconographic design environment. Individual icons, representing work steps are dropped onto a pallet, connections are drawn to describe process flow, and the workflow decision points are specified. When a running workflow process executes the task represented by the icon, a corresponding work item is placed onto the appropriate clinician's worklist. This allocation is dynamic, and ensures that the task is always delegated to the appropriate individual responsible for doing that task on behalf of the particular patient.

When the user clicks on the work item, Soarian opens the appropriate screen interface used to perform the task, and populates it with all of the appropriate data needed to accomplish it. When the task is performed, the workflow management system is informed of its completion, and the workflow process continues with the next step in the workflow configuration.

Soarian further supports workflow integration with its service oriented architecture and event-based messaging infrastructure. Soarian exposes a message-based collection of services, which can be requested by running workflow processes as discrete actions. This permits workflow management to execute clinical actions such as changing a patient's isolation status and retrieving workflow relevant data such as a patient's clinical allergies. It enables workflow process to ensure successful execution of clinical system tasks.

The event-based messaging within Soarian, and its event monitor provides publish/subscribe capabilities for workflow processes. This enables newly configured workflow processes to be executed only when the appropriate trigger events occur. Soarian exposes orders, results, and clinical documentation as events. Workflow processes can be subscribed to one or more events, and the parameters of the events can be inspected and used to determine process execution. Thus, an institution can e.g. subscribe a newly created process for managing heparin anticoagulation to be instantiated whenever an order for the drug 'heparin' is encountered. Further the event monitor can determine whether an existing instance of the process is already running for a particular patient, and can avoid starting a new one if this is the case. The event-based messaging also provides the means for running workflow processes to respond to events. Thus if a medication administration process is informed of an event indicating that the patient has been transported to radiology, it can adjust either by arranging for the medication to be administered there, or by rescheduling the medication for infusion when the patient returns to his room.

The Soarian workflow architecture allows for an incremental approach to process automation. The health care organization may start with the definition of a few and relatively small processes and increase the complexity and number of automated processes over time as the organization gains experience. The workflow engine can scale up gracefully to accommodate such an approach. The engine can operate in a Microsoft Windows2000 environment, and it supports the SQL2000 database. High workflow transaction volumes (over 1 million per hour on a single server) have been demonstrated. Servers may be clustered. It is also possible to partition workflows in such a way that each entity (e.g. a hospital) operates its own workflow server and yet processes may be coordinated between servers. For example the workflow engine used by a centralized business office can coordinate its bill completion process with supporting processes hosted by the workflow servers of each of the member hospitals. In summary, Soarian integrates workflow engine technology at a fundamental architectural level, decomposing its clinical interface into tasks that can be configured in a workflow process definition, exposing its functionality for direction by the workflow engine, and by providing publish/subscribe mechanisms so that workflow processes instantly execute and respond to health care events.

Embedded Analytics. Tracking process metrics and the impact on clinical and financial outcomes together with patient data is an important aspect of workflow.

For example the outcome of implementing a physician order entry application can be measured by the turn-around time. A study at Ohio State University and Rush Presbyterian publications find that online physician order entry can reduce turn-around-time by 50% (21), (29). The Soarian module embedded analytics intends to capture the metrics (order time, administration time, result time, etc) for utilization of physician order entry, and therefore allows the continuous tracking of turnaround times.

An analytical database with process metrics, and clinical and/or financial patient data serves as base, Crystal Reports, and MS analysis services provide analytical cubes. Web publishing (a Siemens technology) provides access to reports and data cubes through Soarian for authorized clinical users. This way analytical and metrics tracking info can be provided throughout the organization. Email notification (a Siemens Technology) is available for rapid indication: if a certain metric exceeds or falls below a pre-set target, an email to a user is generated.

Smart User Interface. Built for the web, Soarian intends to provide a consistent, universally available, browser-based user interface. It can be accessed by authorized users from the hospital, office or home on a wide variety of devices. A team of industrial psychologists, linguists, physicians, medical informatics and communication and industrial graphic designers developed the user interface for Soarian – its page, language and navigation design.

Starting point for the user interface look and feel are the Syngo user interface principles. They have been extended from the modality use to the full clinical world. The

Syngo and Soarian user interface specialists work together in a workgroup on a regular basis and thus ensure a common user interface look and feel and an outstanding example of best practice integration and knowledge sharing (34). The result is an interface that – from the viewpoint of SMedHS – will be easy to use and will require little training. The use of a common look and feel facilitates access from any device and supports collaboration across clinical disciplines. Soarian's user-specific workflow design intents to present screens and data appropriate for each user's job function and work to be performed.

The main-goal of Soarian's 'smart user interface' is to deliver a transparent user interface, which supports the users accomplishing their tasks. That means, ideally the users' focus attention is only targeted at the task, not how to handle a system. So, from the viewpoint of SMedHS, a usable system should

- meet users' expectation
- support workflow
- and map the users' mental model.

To achieve these goals, some enhancements to the traditional software engineering are required. ISO recommendations and other standards should also be considered (35). The Soarian process has been added with the principles of user centered design methodology in addition to the wide spread object-oriented-approach (36, 37). This process allows task-oriented software design rather than feature/function driven.

One central aspect of this process is that due to SMedHS the task-oriented user interface work accompanies the whole solution lifecycle right from the beginning rather than being sent to a usability test after the design already took place.

Up in front that means an extensive task analysis is the beginning of the system design. The main philosophy is to capture context and task-information right out of the users' environment, their day to day business. A team of user interface experts translates the insights and results into user interface concepts, working side by side with the user interface architecture and implementation team. This approach shall allow Siemens to adapt the machine towards the users' needs rather than the other way round as much as possible.

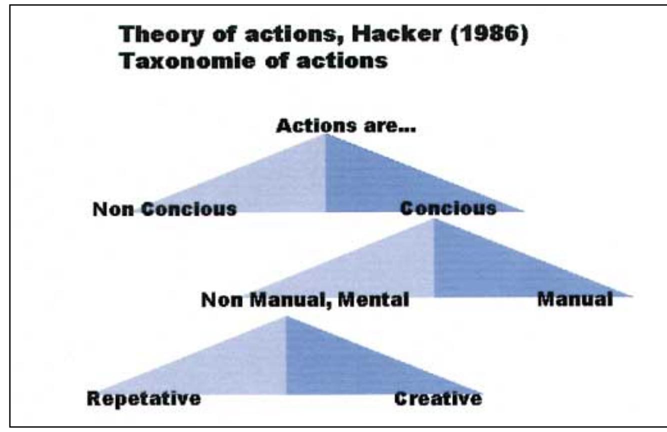

Fig. 5
Toxanomie of actions.

The 'smart user interface' is technically divided up in two aspects:

- the user interface concepts & design
- the contributions of the workflow engine.

These aspects work hand in hand, totally transparent to the end-users. The interferences of the workflow-engine are scaleable in this concept. If Soarian runs with the workflow engine not implemented, the users might perform the steps in the workflow manually, e.g. assign tasks to the appropriate nurse for a certain shift. If the workflow engine is set up and supports this workflow, the system is able to generate those tasks automatically. The receiving clinical end user, who got the tasks assigned, however, does not see any difference in the UI. The presentation of items for the user does not depend on the manual or automatic generation based on a set of activated rules.

This concept is in accordance with the modern understanding of workflow supporting systems and does not create any additional burden of learning or changes on the clinical end users.

How the smart user interface goals were put into practice is illustrated with an example: the physician's worklist and census list, presented in Fig. 1. Outcome of the task-analysis showed the need of patient related data and user related data side by side in order to help the decision process of organizing the next steps of the users' work in split seconds and also allow navigation to the most probable task performance immediately.

The processing of the task analysis and the allocation of its outcome is in great parts based on Hacker's principles of action regulation theory (38). Hacker allocated actions in a structure and also built a theory how these actions are getting regulated (Fig. 5). From UI perspective the branch of conscious, non-manual, mental actions is the interesting branch in this context, since that is what the healthcare providers do with IT-systems. Some of the tasks are highly repetitive (e.g. specimen collection in the morning) others require more thoughts and fall in the creative branch (e.g. adjust the medical therapy for patient who just received an organ-transplant). In a further step the regulation of tasks fall in three high level buckets: plan, execute and control.

The Soarian 2.0 scope addresses mainly the planning and performing of tasks in the clinical environment. As a conclusion and modification a 2 × 2 matrix was derived. One dimension distinguishes between "planning" and "doing". For the second dimension repetitive tasks were translated into user related bulk processing of tasks and creative tasks into single patient related tasks for the clinical world, i.e. "user related" vs. "patient related". The worklist/census deals with user and patient data and is focused on planning. When working with the patient record, it is important to act on the basis of patient data (Fig. 6).

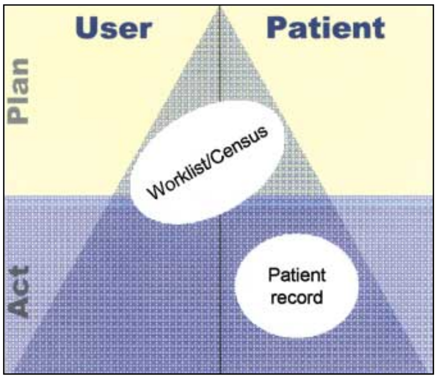

Fig. 6 User interface concepts for physicians.

The following aspects can be found in the screen conceptualization:

- user and patient-related view side by side
- lists of clinical tasks – bulk ware
- tasks could get automatically generated by workflow engine in a flexible amount
- patient data view optimized for clinical situation:
  overview about patient current status critical results, and
- minimalistic functional design enforcing the usability concepts.

3.5 Design Strategy and Requirement Engineering

Soarian is designed for the full adaptation of local requirements as an international software product. It was built from the ground up, with the intention of leveraging Siemens' development capabilities around the world including Scandinavia, Germany, the US and India.

As a discipline at SMedHS, the requirements engineering processes organize and guide the principal set of activities through which business needs and direction are discovered, understood, prioritized, and scheduled. These decisions and processes are then used to build effective health care-focused solutions that are implemented and delivered to the global health care marketplace. Performed well, this process provides resultant products and services that not only fulfill the needs of this marketplace and business, but also provide extra value and excitement in their delivery. The requirements engineering process spans the lifetime of the solution: from the inception of an idea throughout the effective life of the solution. The process is based on best practices derived from the Institute of Electrical and Electronics Engineers (IEEE) through their Software Engineering Body of Knowledge (SWEBOK) and from the Software Engineering Institute (SEI) through their Capability and Maturity Model (CMM). SMedHS created a proprietary model process that is integrated into the quality management system and solution life cycle practices. This model organizes information related to requirements into states and activities that allow identification of specific problem domain, business direction, fulfillment strategy, and detailed items that shall be included in a solution. It supports tracking, change management, verification, and validation activities throughout the development of the solution – in addition to solution enhancement requests after the solution is delivered and made generally available.

Related SMedHS global organizations and staff use state-of-the-art tools to store, organize, manage, and report all requirements related to specific solutions – Caliber RM which is a collaborative, web-based requirements management system that enables organizations to develop higher quality enterprise applications (39). This tool facilitates open communication and collaboration both within and between solutions provided by SMedHS to the health care marketplace. Siemens launched a company-wide business process model and quality management system including standardized processes for international requirement engineering. It has therefore been granted ISO 9001 certification (22).

Together with the cooperation partner ErlangenUMC, Siemens carried out a gap analysis to identify additional German country specific needs for Soarian. Topic specific workgroups from ErlangenUMC and Siemens Medical Solutions Product Management analyzed main functional areas like patient management, diagnosis and procedure encoding, DRG, charge capture, interfaces on base of current software releases and functional descriptions. Additional requests will be captured during the pilot phase based on the experiences of the clinicians as part of proof of the concept.

The data model and business logic for Soarian has been designed to achieve a high adaptability of the product to fit the needs of the different countries. The international challenging approach leads to the definition of invariant and variant functional areas of the clinical software. The invariant part in general is the relation and contact between a patient and a health care organization/clinician. The software Soarian reflects this relationship. A variation from country to country will be found for the different types of patient identifier. The term and definition of e.g. case/visit/encounter is different for each country. A similar situation can be found for catalogues for diagnosis/ procedure encoding. To reduce the implementation and administration expense of the different catalogue systems, a specific master file key administration has been developed. HL7 – master file transactions will be used, with the intention to facilitate the coordinated configuration of connected systems like laboratory or patient management.

3.6 Implementation and Support Strategy

The client migration strategy is another key aspect of the Soarian plans. Siemens has established a goal of a 50 percent reduction in client implementation times from the current industry average (18 months to two years) to a range of nine to 12 months. Soarian has been engineered with a deliberate focus on installability; which is inherent in the overall product design. Siemens' goal is to dramatically reduce the overall work-effort (both customer and Siemens) by deploying a product designed for workflow with special innovation in implementation tools and approach. Features embedded in Soarian, with its complete service portfolio including change management, process management and implementation, lead to a targeted reduced installation time of 12 months or less. An operational model, pre-populated files and installation wizards embedded in Soarian infrastructure are key factors to cut down implementation effort and duration.

Implementing Soarian starts with the assessment of the clinical, financial and administrative processes to ensure an effective and focused implementation. Prepopulated files are delivered in accordance with best practice workflows for each role and business line in health care. Tools to enable the implementation of specific customer modifications, 'focused-adaptation' will be delivered with the system. By direct assessment and planning activities, the anticipated workflow redesign for the customer's environment is part of the reduction in work effort. Automated implementation tools, the 'implementation toolkit', will support implementation of Soarian by the automation of key reference files, data conversions, and the deployment of model interfaces. Self-training guides and context-sensitive user assistance will be provided to decrease the end-user training time. With the addition of computer-based training and model training materials, the entire training cycle time will be reduced. Additionally, implementation services, key added-value services including applications service desk, ASP services, and re-engineering assistance are provided by Siemens.

3.7 Customer Base

Currently (April 2002) the following institutions form the customer base of Soarian:

- US: Chester County Hospital (beta), Carilion Health System (beta), Baptist Health System, Hamot Medical Center, Albany Medical Center, Health South, Susquehanna Health System, Meridian Health System, Ascension Health.
- UK: Dudley Group of Hospitals NHS Trust.
- Germany: Erlangen University Medical Center (beta).
- Sweden: Landstinget Gävleburg Hospital (beta). A lot of the existing Melior 1.5 customers have upgrade contracts.
- Norway: Ullevål University Hospital Oslo (beta). All University hospitals have upgrade contracts from their existing DocuLive system.

4. Comments and Conclusions

Huge investments have been made by Siemens to develop and design a completely new software product to support the work of health care professionals. For a long time Siemens has been criticized for not having such a product of its own in one of its key markets. As part of a globally acting technology enterprise with related systems e.g. in the field of picture archiving and communication systems, diagnostic and therapeutic modalities, hardware systems including mobile tools, Soarian is well embedded. As a functionally comprehensive, clinically oriented software product, Soarian Clinicals has a good prognosis to become one of the major products on the international market. With its functionality and its architecture, Soarian has good chances to support patient-centered, shared care. Its global design may help to better support and maintain national or language specific versions.

Nevertheless the first installations of Soarian's full Version 2.0 will be critical, as they will show, how the system will be accepted by the users and by the decision makers of the health care enterprises. In particular for the latter group, the investment and maintenance cost will be critical, also whether the reduced implementation time can be proven in practice. Siemens will have to show that the goals for Soarian are actually achieved by the product and achievable by the customers. The users and decision makers of health care enterprises will decide if Soarian will help them to accomplish their goals. These decisions will be based on the actually delivered product by Siemens.

It can be expected that competitors on the market for health care software will react on the announcement of Soarian. It will remain to be observed in the near future, how many health software enterprises will be able to offer such functional comprehensive software (not only independently developed, interfaced components) for patient-centered, shared care (not only for use inside one health care institution), and dedicated to support clinical work (not only organizational and administrative tasks). However, it could be seen at this IMIA WG10 working conference on health information systems and in the papers published in this issue that different opinions exist, which type of architecture should be preferred.

We are now on the way to having globally developed software with national or local instances. What still needs to be done – not only for this software product – is to achieve a language independent 'global' representation of patient data with local instances in certain languages (as it has to be done with medical and health knowledge). This would support patient-centered care in a global way even more.

New and better software will by no means solve the information processing problems of health care institutions by itself. Within health care institutions and for health politicians, the framework for the efficient use of such systems still has to be laid. This ranges from ethical questions (40), to the systematic planning of how to record patient data for its multiple use later on (41), via the controlled use of medical terminologies (42-44), the online access to medical knowledge (45), and last, but not least the strategic IT planning in hospitals (46).

Let us continue to work on Morris Collen's vision of patient-centered, computer-supported health/medical information systems. And do not let us forget the general aims for hospital/health information systems that have already been described by Peter Reichertz (e.g. in accordance with (47, 48):

- to present information suitably (*information presentation*)
- to record and to distribute information suitably so that the needed information is available at the right place and at the right time (*information logistics*), and
- if necessary, to provide support for decisions - a support, more than a pure information presentation does *(decision support)*.

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