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Towards new web service based supervisory systems in complex industrial organizations: basic principles and case study

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ABSTRACT

Mobility, cooperation and the information access of the different human actors within a complex industrial organization are some of the concerns of web-based HMI design. In this paper we highlight the application of some key concepts of web services for the specification and design of a complex supervisory web-based HMI. Hence, a novel approach based on a service oriented architecture and web services allowing flexible and transparent interaction between the field devices and human operators currently being considered is now possible. An overall design framework is presented and discussed. A real representative case study illustrating this approach is described and discussed from the human-machine interaction point of view, as well as further work.

KEY WORDS: Supervision, Human-Machine Interaction (HMI), Web Services, Service Oriented Architecture, Mobility, Design, Specification.

1. INTRODUCTION

Industrial supervisory systems are extremely demanding as regards the human-machine interface to be provided for the various actors or stakeholders involved. The relevant supervised data can be acquired from different sources and structures within the dynamic and evolving organization context as well. The current trend in industry is to integrate process supervision systems, qualified as traditional, along with new inherent functions to the underlying global information system of the organization. Thus, integrating people, process (es) and information, it can be accessed from outside the control room using web technologies [1]. This enables, for instance, members of an organization, such as operators on call, to work from remote locations, or commercial staff to send orders remotely or check the warehouse status. Moreover, this may also concern technicians in charge of the maintenance of several geographically separated IT infrastructures or installations.

Consequently, the information visualisation requires adaptations due not only to the diversity of the access devices used but also to the pertinence of the data provided on such devices [2]. So how would it be possible to provide the various human actors with rapid and efficient access, which is adequate and adapted to the various tasks they perform?

We believe that the service oriented architecture (SOA) model and its underlying web service technology offer a promising approach for the creation of new human actors' interaction models within a complex organization. Indeed, every human actor within that complex organization, whatever his/her hierarchical level or work location (inside or outside the organization), may have different needs from the underlying interactive systems. Moreover, the evolution of the global information system federating the different interoperable, integrated and heterogeneous business processes of the complex organization may also lead to newer interaction possibilities.

In section 2, we present the main design issues of a related work on the traditional supervisory HMI's and we argue that it is possible to move towards a more global and wider type of supervision.

Section 3 presents the motivations and foundations of the service oriented approach through the basic concepts of web services which are relevant in the design of the service-based HMI development model dealt with in our proposal.

Section 4 presents our contribution which consists of a global methodological framework aiming to integrate the development of service oriented interactive applications from software engineering and HMI points of view with a business oriented vision. In this section, we highlight the first steps of the framework towards the HMI specification and consider the specificities of the web services as well.

Section 5 shows the feasibility of such a novel approach applied to a real case study: a sugar refinery supervisory HMI. We will illustrate the approach through a typical supervisory scenario along with preliminary HMI mock-ups. Finally we will give some elements of interest seen from the user's point of view, whilst concluding and suggesting some research perspectives.

2. RELATED WORK AND NEW MOTIVATIONS

In this section, we present the main design issues taken from related work in the industrial supervision domain. Due to the newest and highest technological environment in which the supervision is evolving, newer functional and organizational issues appeared and are highlighted, leading therefore to new motivations regarding the supervisory HMI design. We recall the basic missions of traditional supervision and argue that it is possible to move towards a more global and wider supervision. We focus on the mobility and the cooperative task aspects of those motivations due to new peripheral devices and communications means and their impact on the supervision context as well.

2.1. From traditional to more global and wider supervision

The human-machine supervisory system as defined by [3], integrating various actors and stakeholders within the complex organization (including the supervision operators), has to consider the main missions of supervision representing a set of high-level tasks [4]. These tasks may include: planning, transmission of orders, supervision and learning, along with alarm management, data analysis, improvement of maintenance, process optimisation, etc.

With the advent of communication means, processing functions and computing resources are made available on different work stations to different users at different locations and sites. Consequently, different business applications as well as the supervisory application cooperate with each other in order to accomplish various tasks. Therefore, the necessary information for a supervision function has become distributed. The information access and retrieval along with its processing may be carried out in different organization sites (inside or outside). Moreover, the information support has also become heterogeneous. Hence, industrial systems in general and process supervision systems in particular have become highly automated and information based technologies. All the issues raised show that the interoperable, heterogeneous and distributed environments represent the new technological environment context of supervision with a potentially increased number of actors involved as well as their need for mobility and a high degree of task cooperation [5].

In addition, thanks to new Information Technologies, various information devices (PDAs, Pocket PCs, cell phones, etc.) are already being used for many new purposes in the process industries. This results in different and new human-machine interactions, requiring not only the development of specific human-machine interfaces but also the identification of the different human actor profiles involved and their various tasks dependent on these new means.

Moreover, the current trend is to place the supervision process at the core of the complex organization, by enabling various human actors to interact with the many different automated processes (figure 1); it must be possible to provide them with adapted possibilities for information visualisation and access. The needs and objectives of each human actor in a web environment favour a unified view of the supervision HMI [6]. Figure 1 shows the opening of company business processes to its partners and suppliers as well as to various (nomadic or not) human actors (within or outside the organization) in order to carry out their relevant cooperative tasks.

Consequently, considering the HMI which is almost dedicated to supervision in the control room may not be appropriate for the reasons highlighted above. Therefore, our contribution is intended to compensate for this and go further by investigating and studying the complementary aspects of the classic supervision HMI.

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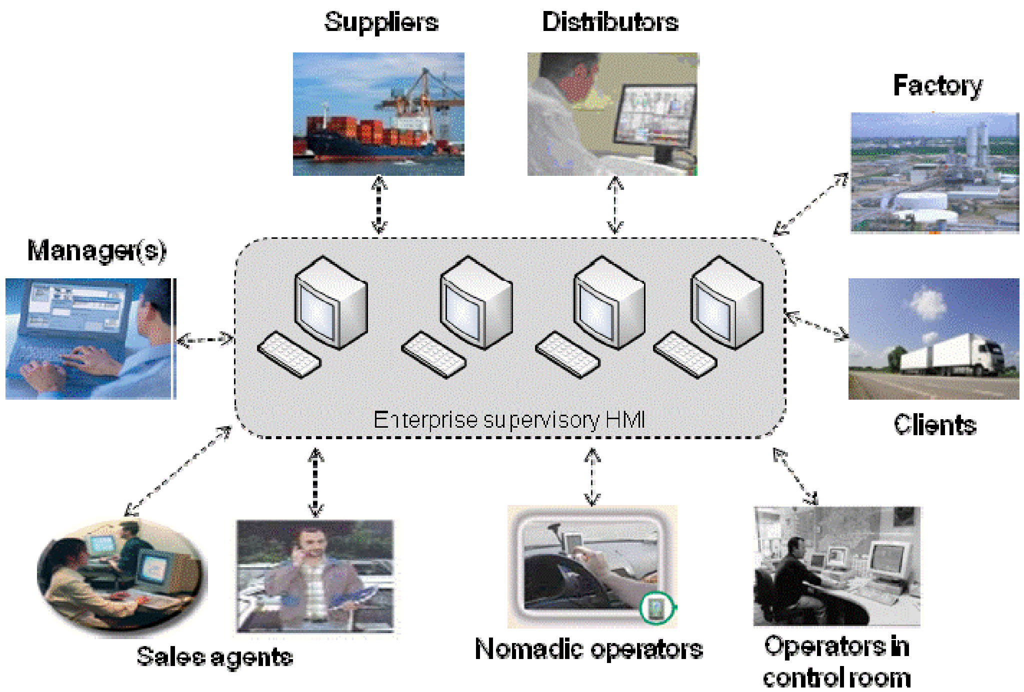

Figure 1. The supervision core of the complex organization

2.2. Availability of new technological supervision means

The supervision field covers several realities within a modern company. There are several human operator profiles (nomadic or not) with different needs and which may be alongside each other. There is an intra-organization mobility with employees who often move around inside the company site. At the same time, the extra-company mobility involves operators who need access to the company's system from the outside. The main preoccupation of the mobile operators is therefore the real-time nature of the supervision information they deal with, either locally or remotely using various communication means and media.

Mobile or remote peripheral device elementary functions, such as electronic diaries, contact management and electronic mail, still represent the main usage in the business world, but it is possible to go far beyond these basic uses. The scenarios of use of fully connected equipped mobile peripheral devices may enable various supervisory applications or functionalities that can be fulfilled by the mobile HMI. The nomadic operators may have to collect measurements and control data from the field device location itself. They can also synchronise their electronic diary with a central PC and thus update a centralized data-base in order to optimise production monitoring.

A mobility based application in a supervision context must be an extension either of several business applications (back office applications) or of future applications, which take into account some relevant mobility constraints. Mobility therefore implies remote supervision, or tele-supervision of an installation or a process using a web browser or any other access device through a communication infrastructure. Consequently, new functionalities based on some contexts may be envisaged in the supervisory HMI.

2.3. Taking the context of the supervisory HMI into account

The notion of context represents one of the main mobility design issues [7, 8]. Broadly speaking, the context includes the location, the identity of the people and the nearby objects, along with the modifications which may occur regarding these objects [9, 10]. Moreover, the use and the context in a mobile application represent a combination of the task and the environment in which it is performed [11].

[12, 13] have mainly considered those issues in the design of some types of simpler systems with traditional HMIs such as systems giving assistance during displacement in tourist places. The context is also useful at different levels as regards mobility [14, 15]. At the level of the user interface, the use of the context can help the change of an explicit human-machine interaction to an implicit interaction, leading towards a transparent user interface [16, 17]; this becomes possible if one manages to capture the pertinent elements which are relevant to the user tasks [18] using some communication means that enable the transfer of the contextual information between the context sensors and the mobile applications [19].

All the previously emphasized related design issues are relevant in the design or the construction of information systems in complex environments with traditional HMI's. When considering the design of more complex systems with complex HMI's, those issues are still relevant. However, there is little research undertaken in the supervision field that is characterized by a dynamic and evolutionary context in which various types of nomadic actors work. Hence there was no methodology or framework as such that could guide the designer in considering them. Therefore, the new complex and highly technological supervision environment leads to new motivations regarding the supervisory HMI design.

Thus, our contribution considers the main features of those issues in the early stages of the design process. The service oriented approach provides promising solutions regarding such design requirements.

3. SERVICE ORIENTED APPROACH FOR THE HMI DESIGN

This section presents some basic concepts and requirements of a service oriented design approach that can be used as a foundation for our proposal.

3.1. Concept of service orientation and service oriented architecture (SOA)

The service oriented architecture (SOA) is an approach for software design which breaks everything down into agile services dealing with one specific need [20]. It also defines the use of services to support the requirements of software users, making them available as independent services accessible in a standardized way [21]. Reusability, simplicity and interoperability are some design objectives of those services. The services are characterized to be: *loosely coupled*, *distributed*, *invocable*, *publishable* and *business oriented*. Unlike the traditional development of interactive applications, in this approach the business processes, the presentation of information and content (page-screens), and the applicative logic and data are separated into distinct interfaced layers of services (figure 2). Moreover, SOA is like a paradigm for integrating applications within and across organizational boundaries [22].

In a traditional HMI development project, the HMI designers often consider separately the design of the various HMI of the underlying applications. However, in an oriented approach, the designers only concentrate once on the HMI for all the applications involved (figure 3). The main benefits of the approach consist in reducing the development costs and complexity, as well as enabling complex organizations to make their business processes and business logic seamlessly accessible via some relevant web technologies such as WSUI [23] providing the interface through which a user can make use of a Web service directly, WSRP [24] which are visual user-facing web services that integrate content or applications from different sources, etc. Hence, our contribution concerns mainly the two upper layers (figure 2).

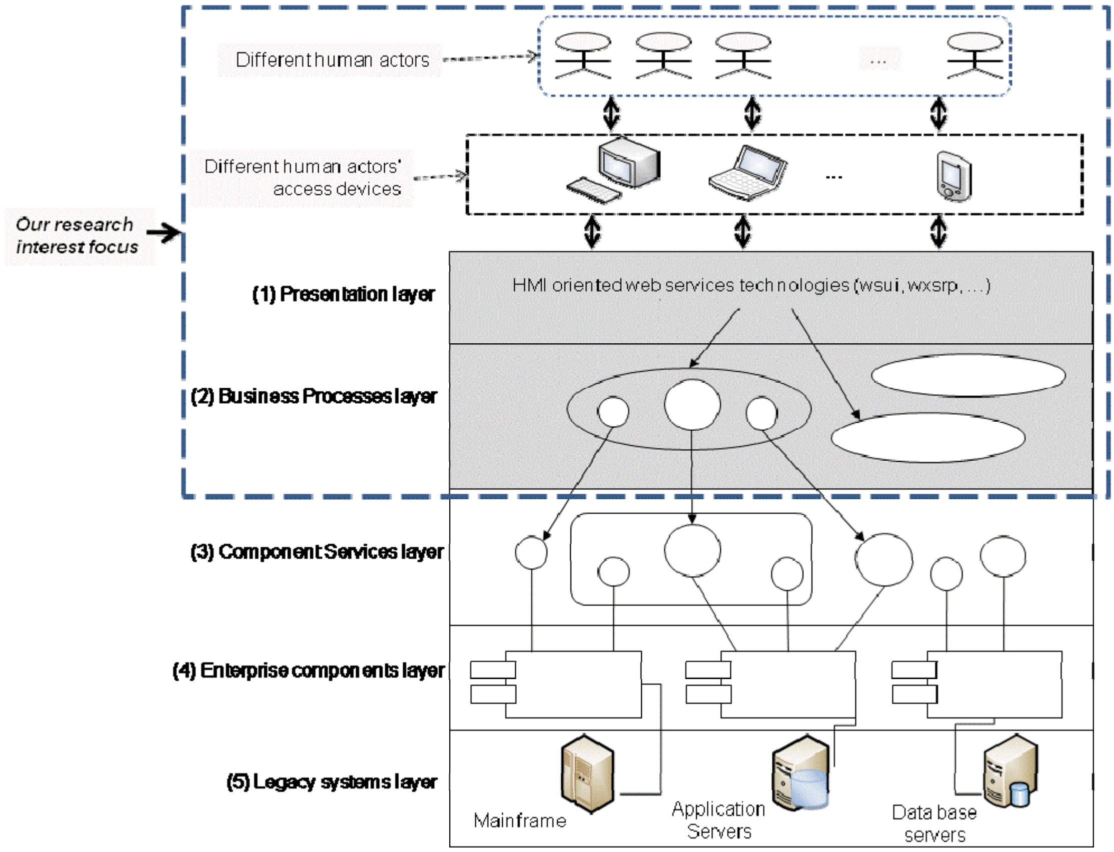

Figure 2. The layered service oriented architecture global view [25]

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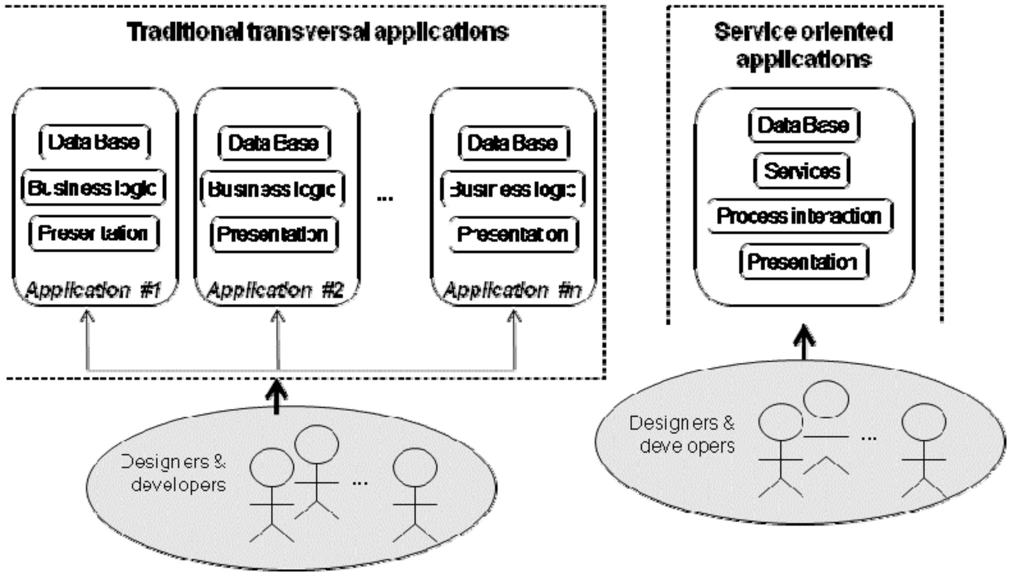

Figure 3. Different between traditional HMI and Web services based HM design [20]

3.2. Web services

Web services are auto descriptive, modular and loosely coupled applications. They can deliver functionalities such as simple requests or sophisticated business processes. They are software components of a web-based interaction system which can be deployed over multiple distribution channels (figure 3). This enables the creation of interaction between applications, computers and business processes and makes it possible to give access in a uniform manner to a set of remote application services adapting the information presentation to the distribution channel [26].

Web services are based on an interaction model which carries out three functions: (1) services supplier, (2) services directory, (3) services requesters. These can be performed according to the three following types of operation: (1) the publication of the service description (*publish*), (2) the search or lookup and discovery of the correct service description (*find*), (3) the association or invocation of services based on the description (*bind*), and also on a set of standardized protocols such as: HTTP, SOAP, WSDL (www.w3.org) and UDDI (www.uddi.org) which deal respectively with the transport, the invocation, the description and the search for web services.

When the targeted application is highly interactive such as supervision systems, user oriented web services or user interface oriented web services are used. Therefore, some relevant user interface specifications towards (1) Multi-channel user access to the web services, and (2) Aggregation of web services using a single presentation page via a distribution channel may be used.

A web service based application which is different to a traditional web-based one is defined as being an application in which one or several web services are used to adapt the information presentation to the distribution channel as well as to the user's profile. The user's goal is getting the pertinent or relevant information whatever his/her access means through somehow existing user oriented web service technology specifications such as: WSXL (IBM's Web Service Experience Language) [27], WSUI (Web Service User Interface; www.wsui.org), WSIA (Web Services for Interactive Applications; www.oasis-open.org)1 and WSRP (Web Service Remote Portal) (figure 2).

Finally, in the following section, we briefly describe the overall design framework along the first stages towards the HMI specification and consider the specificities of the web services expressing the new needs of the supervision operators as regards information access and visualization, mobility and cooperation. This will then be illustrated using a case study in which the service oriented based approach is applied.

4. OVERALL METHODOLOGICAL FRAMEWORK

This design process framework is based on the principles of a generic Unified Process (UP) [28] which are: iterative process, use-case driven and architecture centred. It highlights three main design activities which we refer to here as phases (different to the phases of the UP process). Moreover, it follows the general principles of a user centered design methodology as defined by [29, 30].

[1] OASIS : Organization for the Advancement of Structured Information Standards, www.oasis-open.org

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4.1. Global view of the framework

Figure 4 gives a global view of the framework proposed. We do not consider all the relevant phases in detail. Hence, we briefly outline the main characteristics [31].

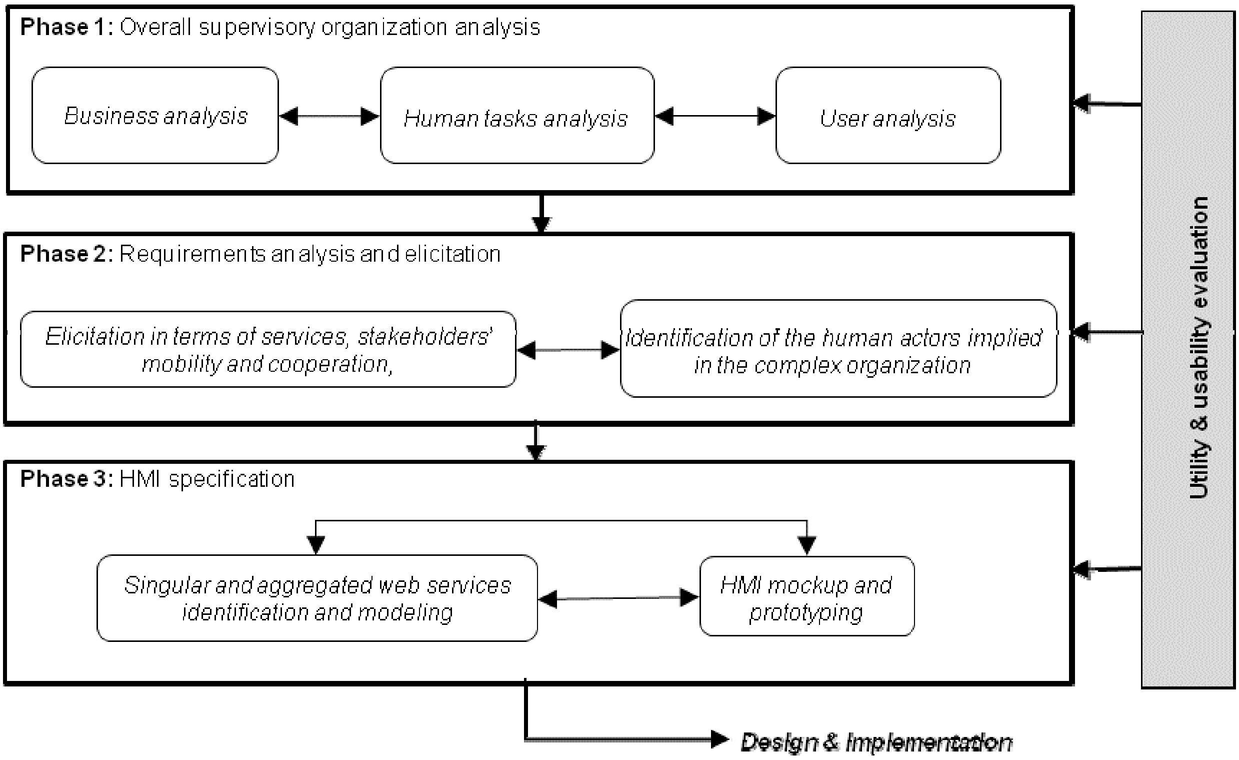

Figure 4. The service oriented HMI design framework global view

4.2. The web service based HMI framework design activities

The main phases of such a framework can be summarized as follows.

Phase 1: Overall supervisory organization analysis

This phase considers the preliminary study of the overall existing complex organization so as to identify the business problems and objectives of the global human-machine system. This stage is carried out according to the following predominant analyses. Each of them can be considered as essential in the Software Engineering and Human-Computer Interaction domains [32, 33].

Step 1 - Business analysis

The business analysis phase considers many aspects of the business carried out within a complex industrial organization, such as application domains, systems and technologies, contexts of use in which different types of users are involved [34]. This means that it consists of pinpointing the users' expectations and needs. This makes it possible to specify the users' applications from a utility point of view.

Step 2 – Human task analysis

The task analysis is about the study of how the users perform their different tasks within a given environment or context in order to achieve a given business goal [35]. It is one of the most efficient methodologies for the gathering of user data that makes it possible to understand the users' needs and their business processes [36]. Task analysis is also used in the requirements analysis for the user interface so as to identify which functionalities should be supplied by the user interface of the future system. Moreover, task analysis and user analysis can be carried out jointly and complementarily since several aspects of the task depend directly on the users' competence level.

Step 3 - User analysis

This consists in defining the users' profiles concerned by the use of the future HMI. It is carried out by gathering relevant data and information of those users so that it can be used for decisions in the design of the interactive system [37]. The user analysis can be undertaken jointly or based on other analyses considered to be predominant in the design of the HMI, such as domain and task analysis. Each typical profile identified and defined corresponds to a user model which can be taken into account by the design team.

Phase 2: Requirements analysis and elicitation

The aim of this phase is to capture, analyse and understand stakeholders' requirements, and translate them into different types of requirements such as (1) service requirements in terms of functions, tasks, sub-tasks and services. Consequently, it is possible to identify and derive a web service categorization seen from a high level of abstraction (business oriented); (2) the next aim is to understand how the stakeholders (users) are involved regarding those identified services and the task analysis outcome so as to derive their requirements from their mobility and cooperative task issues. This can be derived from different scenarios that can be drawn up. Scenarios are considered to be an efficient way of capturing the users' requirements and the structuring of the tasks and activities [5, 38], thus helping with the understanding of the use of the future system.

Step 1a - Elicitation in terms of services

This consists in defining the components of the supervisory system where access is done by Web services. The user can be either an application, and thus an automated Web service, or an operator requesting a function (task) through a server of services. The scenario of a supervisory task corresponds to the invocation of one or more Web services giving rise to one or more Workflows defining a composed service [39].

An industrial process seen from the business or user point of view can be modelled using a UML use case. The business process is then modelled in the form of services with a high level of abstraction. It is a compound service. The business process is broken down into several tasks (human and automated) which are themselves modelled in the form of services. By breaking down the tasks with a high level of abstraction into sub-tasks, we can model them with fine grain services. On the other hand, the business process and the high level tasks are modelled using coarse grain services. This is a service composition and service aggregation [40].

The various categories or classes of the supervision dedicated Web services may be targeted not only towards the human operators in the control room, but also towards many other members of the organization as well. These Web services enable them to interact with the process or other actors using adequate and appropriate HMI devices. All these categories of web services are specified according to the stakeholders' needs expressed as follows.

Step 1b - In terms of stakeholders' mobility

Mobile supervision HMI consists of several Web services devoted to the remote supervision and the communication (interaction) between various human actors (operators in a control room, maintenance teams, production engineers, decision makers, managers, experts, etc.) constituting the organization stakeholders independently in their geographical location (inside or outside the organization site) and their access means. The users can access the information provided by the Web services anytime, anywhere and whatever the physical access device is. Broadly, this step is about considering new scenarios, expressing new needs and giving rise to new mobile supervisory functionalities. Figure 5 illustrates the global process of web service expressed mobility functionalities.

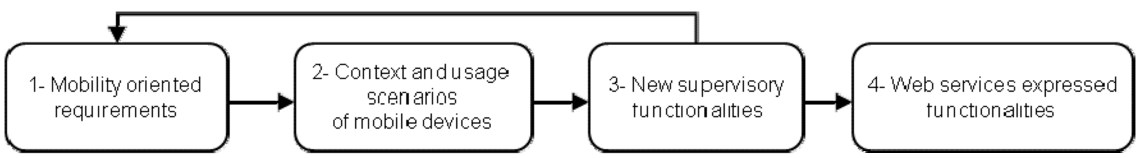

Figure 5. Global process of expressing mobility dedicated requirements

Finally, the web service expressed mobility dedicated functionalities have to consider mainly the relevant human actors' mobility features, as is illustrated by the class diagram in figure 6. This figure illustrates that for each service, a usage context is attached or corresponds, that is to say when would it be invoked?, how would it be invoked?, who would invoke it?, and what device would be used to invoke the service?. For instance, the usage context of a service may be allowed for all the actors with some static characteristics (names, position …), and some dynamic ones (competence, knowledge, experience…), along with some preferences (for instance English language) as well as using some particular access devices (PDA, laptops…).

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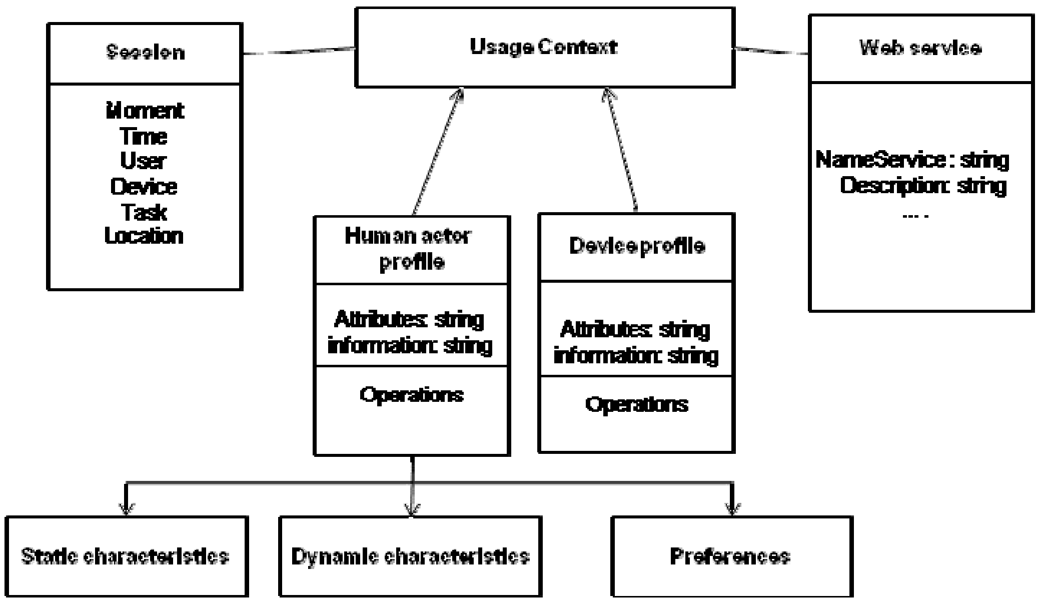

Figure 6. Web service based usage context class diagram

Step 1c - In terms of stakeholders' cooperation

There are many supervision tasks (classical and advanced tasks) that can be carried out within a complex industrial organization. Therefore, this phase concerns the task and function allocation to the different stakeholders as well as how these different tasks (cooperative or not) are expressed or specified by web services.

This step can also be conducted in a similar manner to that for mobility requirements. Figure 7 illustrates the web service expressed supervisory cooperative task global process, whereas figure 8 shows how these cooperative tasks can be expressed in terms of web services. A high level cooperative task can be expressed as a coarse grained composite web service, whereas the underlying sub-tasks can be expressed as elementary or singular fine grained web services which can be carried out separately by a particular human actor profile. That is to say, for example, many human actors (actor 1, actor 2 ...) may be implied in each, invoking a particular service independently to have finally the composite service fully completed.

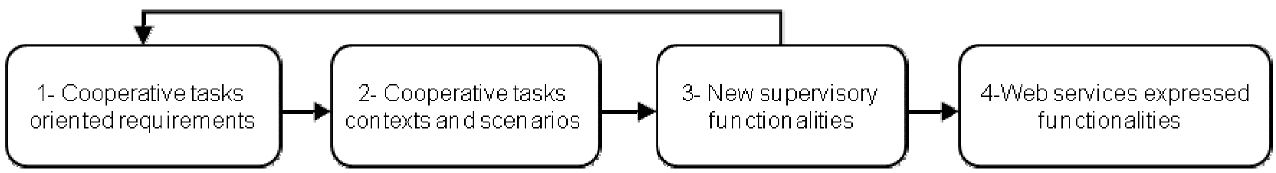

Figure 7. Global process of expressing supervisory cooperative task requirements

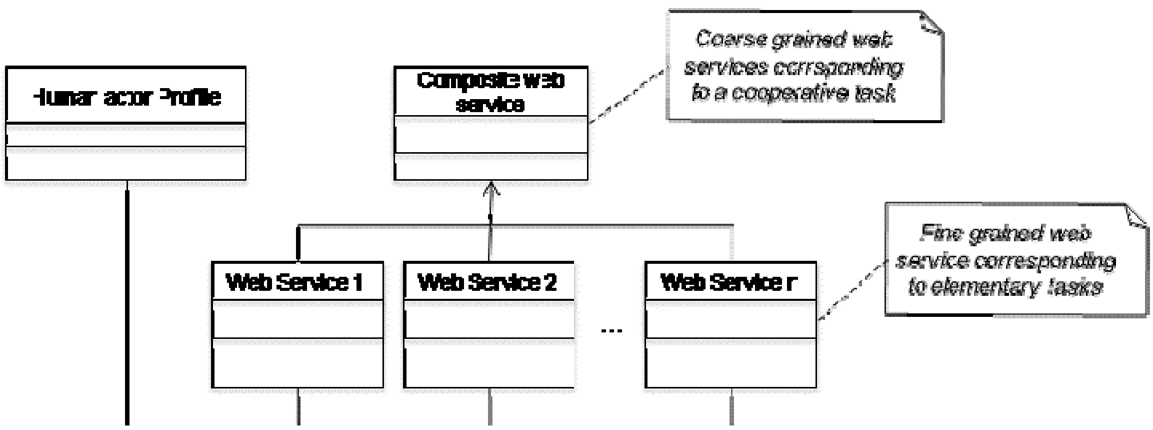

Figure 8. Expression of supervisory cooperative tasks in terms of web services

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Step 2 - Definition of the human actors implied in the complex organization

This is about defining the human actors within the complex organization that should have been mostly identified during the requirements elicitation in terms of mobility and cooperative tasks process. That is identifying who the nomadic operators are, who are not nomadic operators, who it would be if some adequate devices were provided, and so on. All the identified human actors may be broadly defined by the class diagram below (figure 9). The figure illustrates that the human actor may have an internal or external profile working in a particular supervisory environment and invoking some services under some service conditions of usage or requirements (Input: information that should be provided to invoke the service, Output: information expected after the interaction with the service, preconditions: set of conditions that holds prior to the service being invoked, Post conditions; set of statements that should hold true if the service is invoked successfully) [41].

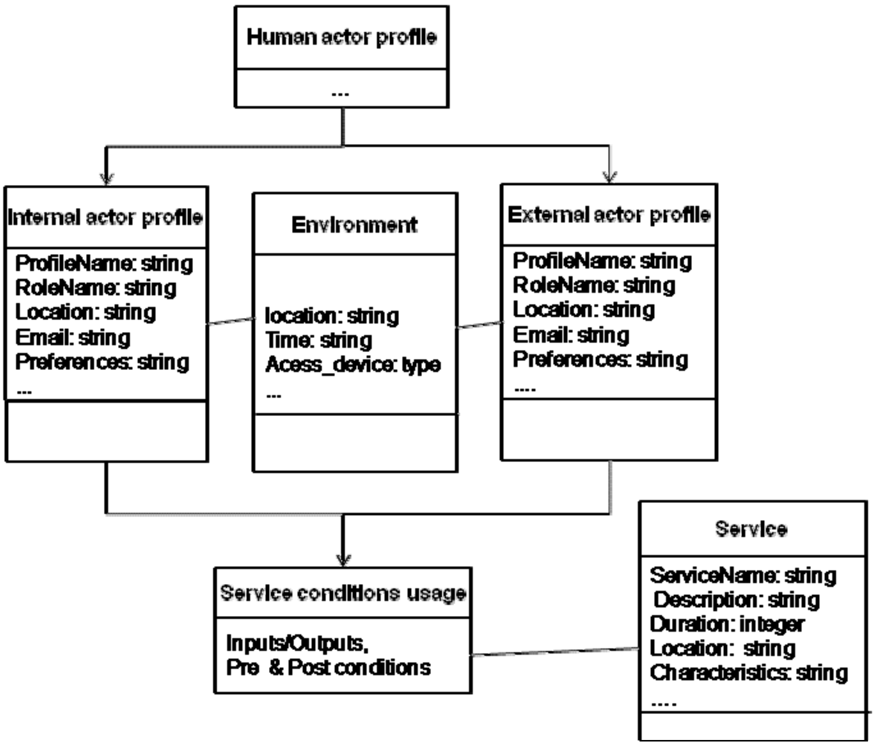

Figure 9. A class diagram representing the implied human actors in the complex organization.

Phase 3: HMI specification

This phase is about conducting the HMI specification by constructing and designing the HMI mock-ups and prototypes [42] which perform the web service based user task model as described above. This consists in deducing the user interaction objects for all the requirement needs identified, in terms of information, mobility and cooperation issues (figure 10). The HMI components which are exchanged between the user and the service managing the supervision HMI are XML-based message descriptions, processed by a presentation engine and finally presented to the user. This phase can be conducted following the two main steps shown below.

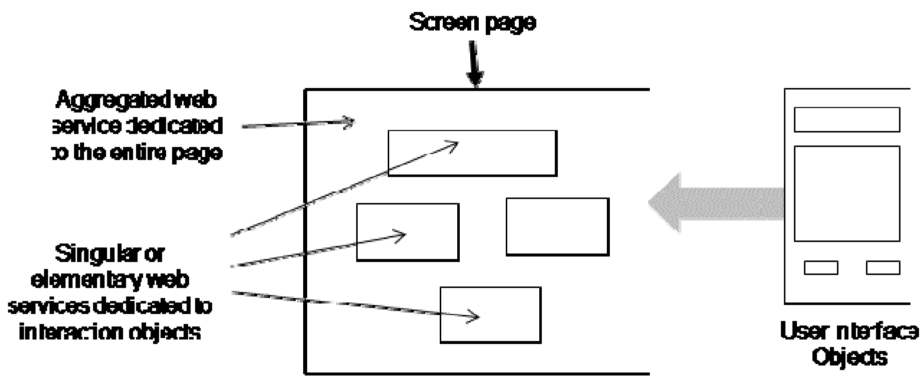

Figure 10. Web service dedicated User Interface interaction objects

Step 1 - Singular and aggregated web services identification and modelling

Here it is mainly a question of specifying the HMI components corresponding to the presentation model. This consists of a description of the interface objects as the user perceives and manipulates them as suggested in figure 10.

We can use different techniques to decompose the interactive interface objects hierarchically. We start from the most aggregated objects which therefore can be specified as aggregated web services and the elementary ones which can be specified by singular web services as illustrated in figure 10.

This step is also about the identification of the presentation units which correspond to the underlying interaction aspects (input, dialogue and display) of a sub-task of an interactive task. A presentation unit can be broken down into one or several logical windows (views). Singular and aggregated web services can then be used to specify all the presentation aspects (presentation layer of a service oriented application – see figure 2 above) of the HMI.

Therefore, the visual aspects of the underlying singular and aggregated web services components can be specified in an abstract manner without bothering about the technical or implementation issues relative to the final HMI rendering.

The next step considers this from the mock-up and prototyping points of view which are more appropriate for evaluation means (not considered in this paper).

User participation in the design and evaluation of the interface during the mock-up and prototyping phase enables the ergonomic evaluation process to reduce the risks. Ergonomic guidelines and principles guide the software or service component specification [43]. The evaluation phase consists in measuring the application usability which can be carried out by different methods [44].

A mock-up can be used as a support for user testing so as to validate the understanding and the visibility of the different screen zones or areas.

Step 2 - HMI mock-up and prototyping

This step consists in deducing, for all the information needs identified during the previously conducted user and task analyses, and for the underlying web service expressed interaction objects, the different HMI mock-ups that might help to visualize, test, simulate and validate the user interface according to user supervisory scenarios.

Figure 11 shows an example of a mock-up that illustrates access to web service specified user interface objects and mobile human actors who are dedicated depending on their respective profiles. It illustrates a mock-up consisting of six main zones or areas. Each zone is used as a visualization area for the categories of service. Each service category can be accessed by appropriate actor profiles. For instance, the human actors corresponding to the shift operators' profile (profile 1) should have access only to zone 1 with its relevant dedicated services, whereas the operators in the control room (profile 3) may have access to zone 2 and zone 1 as well.

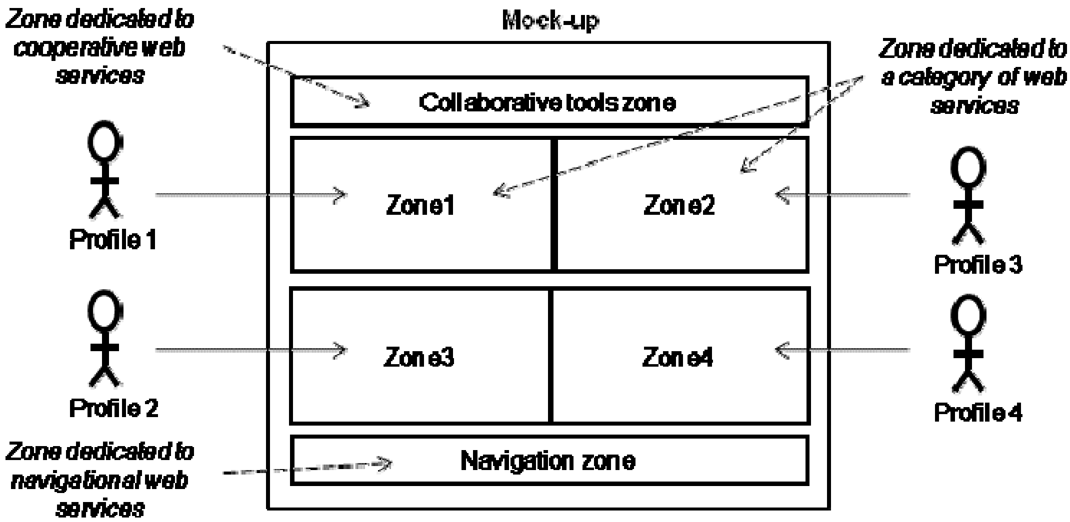

Figure 11. Example of a web service based HMI mock-up

It should be noted that this stage can also be led by ergonomic knowledge and recommendations. In this way, the mock-up design can lead to the creation of a prototype which can undergo an early assessment in order to guarantee the ergonomic quality of the interface [45, 46], whether the assessment is performed by specialists in human-machine interaction, or during user tests or by using automatic tools. However, assessment aspects are not to be dealt with in this paper. Finally, after this phase, we then proceed towards the development and deployment phase which is not included in the scope of this paper.

4.3. Conclusion on the overall methodological framework

We have broadly described a novel approach intended to define a reference framework relative to the design of service oriented supervisory HMI. This approach is based mainly on principles taken from methodologies and techniques in the areas of software engineering, human-machine interaction and web technology.

This framework uses the main phases of a user-centered approach to creating a web service based HMI. It also takes into account the increasing diversity of technologies, means of communication and contexts of use. It enables us to move towards a service oriented model seen from the human-machine interaction viewpoint. Therefore, the approach can be considered as being a preliminary attempt going in this direction. Indeed, at the moment, there is practically no methodology as such which considers the development of software components corresponding to a specific layer of service oriented HMI, and which exposes in web service form the dedicated functions for the business processing of different supervisory modules.

The briefly described overall methodological framework has been used as a basis for a project involving the design of a sugar refinery supervisory HMI for a multi-site industrial organization as described in the following section.

5. CASE STUDY: SUPERVISION OF A SUGAR REFINERY

The case study is based on the supervision of a sugar refinery. It belongs to a company which is part of a food-processing group with a multi-site organization and independent, geographically distributed and heterogeneous information systems. It consists of the analysis and mock-up of a web service based human-machine interface for the supervision of the sugar refinery in question.

The scope of the paper in the context of this case study deals mainly with the mobility and cooperative task issues raised in the first two phases of the proposed framework. We present just a summary of the main results and therefore only some stages have been broadly described.

5.1. Phase 1: Overall supervisory organization analysis

We will present the study context by concentrating essentially on the relevant supervisory elements seen from the HMI viewpoint2.

The main site of the organization is composed of three production units: (1) oil unit; (2) sugar unit and (3) margarine and vegetable oil unit. The sugar unit, also called the sugar refinery, which is the subject of the study, needed to find a new supervision HMI solution using web technologies. It is composed of ten section areas which are physically adjacent but functionally different. In the following paragraphs, we describe the main outcomes of the three steps of this phase.

Global business, task and user analysis

The business analysis allowed us to identify a set of supervisory business processes, where a sub set is visible in figure 12. These supervisory business processes have been modelled using UML models (use case, activity diagrams, etc.). The task analysis made it possible to decompose the global human-machine system into simpler and easier sub-systems and processes. The user analysis enabled the identification of the main human actors implied in the different business processes. In addition, the business services (1st level of analysis) were identified independently from technical and physical constraint issues.

Figure 12 shows in particular the complex work situation of the organization and the many different human actor profiles with their different needs as regards the different HMI's.

[2] In this paper, we do not deal with the safety of the installation, of personnel and of the environment, which, although they are very important aspects, do not come into the scope of this study. We do not look at the physical and cognitive ergonomic aspects either. In fact, we remain at a global level in relation to human-machine interaction.

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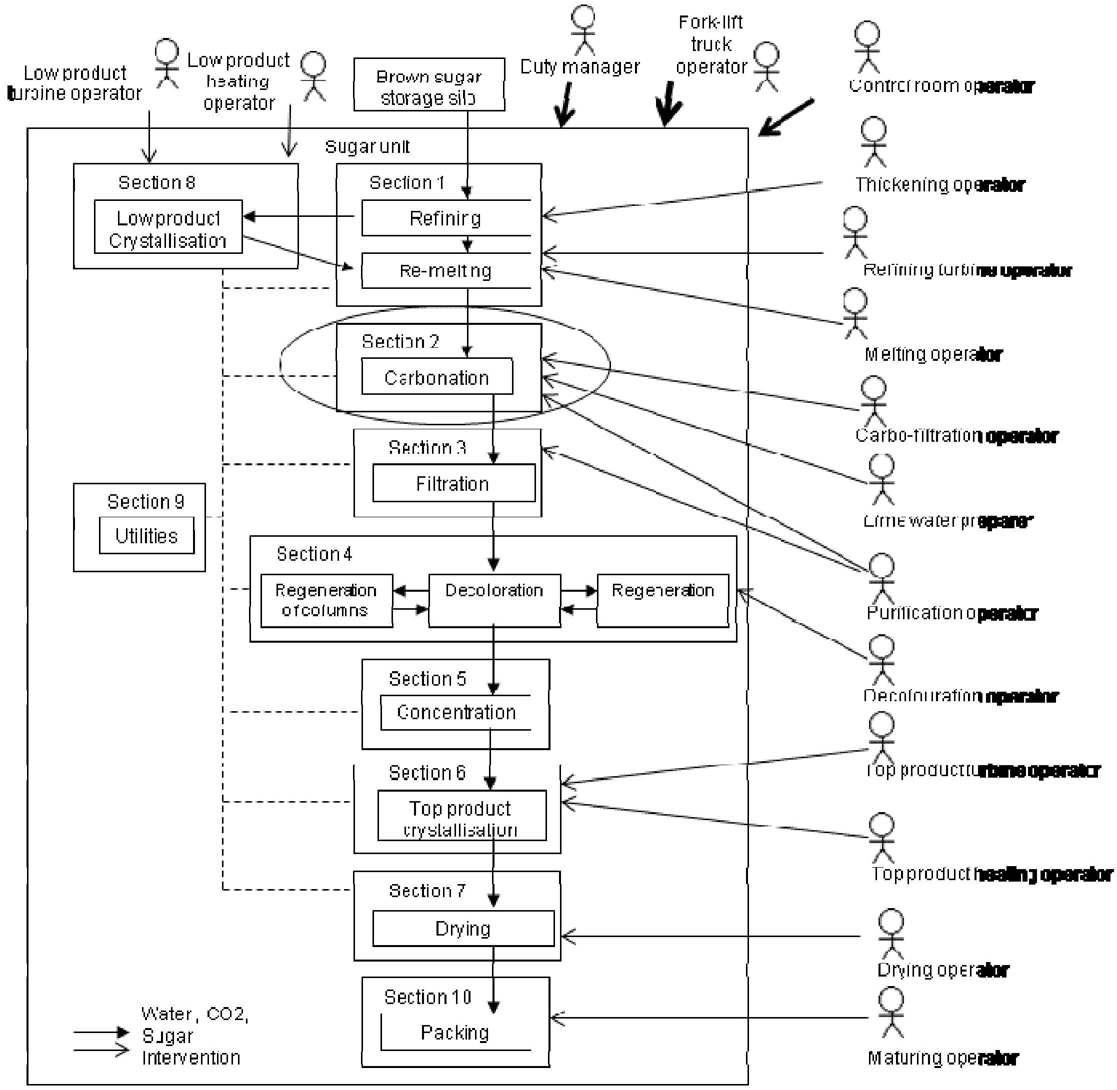

Figure 12. A global view of the current complex supervision context

5.2. Phase 2: Requirements analysis and elicitation

In this phase, we undertake a 2nd level of analysis. We elicit the new situation of the supervision requirements mainly in terms of services, mobility and cooperative tasks.

Elicitation in terms of services

The outcome of this step is the identification of a set of candidate web services expressing the supervision requirements derived from scenarios extracted from the study case (figure 12). An example of some services with their corresponding operations is given in figure 13 hereafter.

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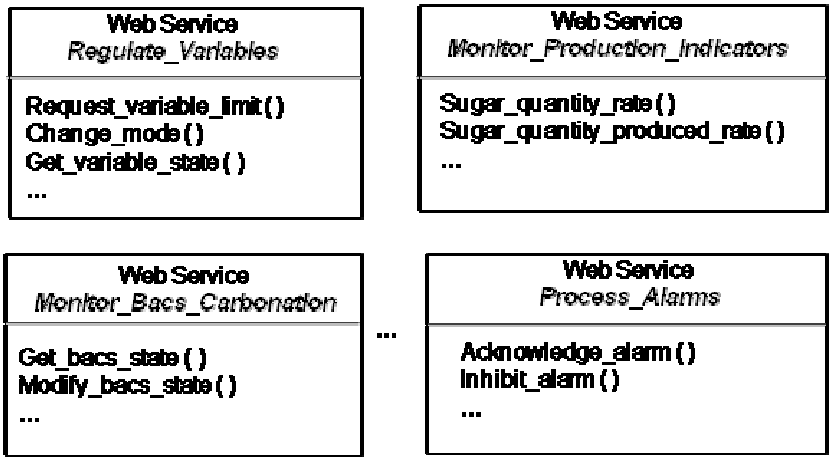

Figure 13. Example of candidate web services expressing user supervision requirements

In terms of stakeholders' mobility

In this section, the web service based mobility oriented functionalities are specified correspondingly to the potential identified nomadic human actors' scenarios, according to the process shown in figure 5 above.

In this way, we obtain major mobility dedicated scenario classes such as: alarm management, shift operator management, remote maintenance and intervention management...

For each major mobility dedicated scenario class, we specify the mobility dedicated features such as: the mobility dedicated web services, the implied human actor profiles, the targeted supervisory tasks, the conditions of usage of web services, the device access profiles used, the web service locations. Figure 14 shows a sequence diagram concerning four types of actor: supervisor, expert engineer, warehouse operator, field operator. Several web services aiming at supporting their activities are specified.

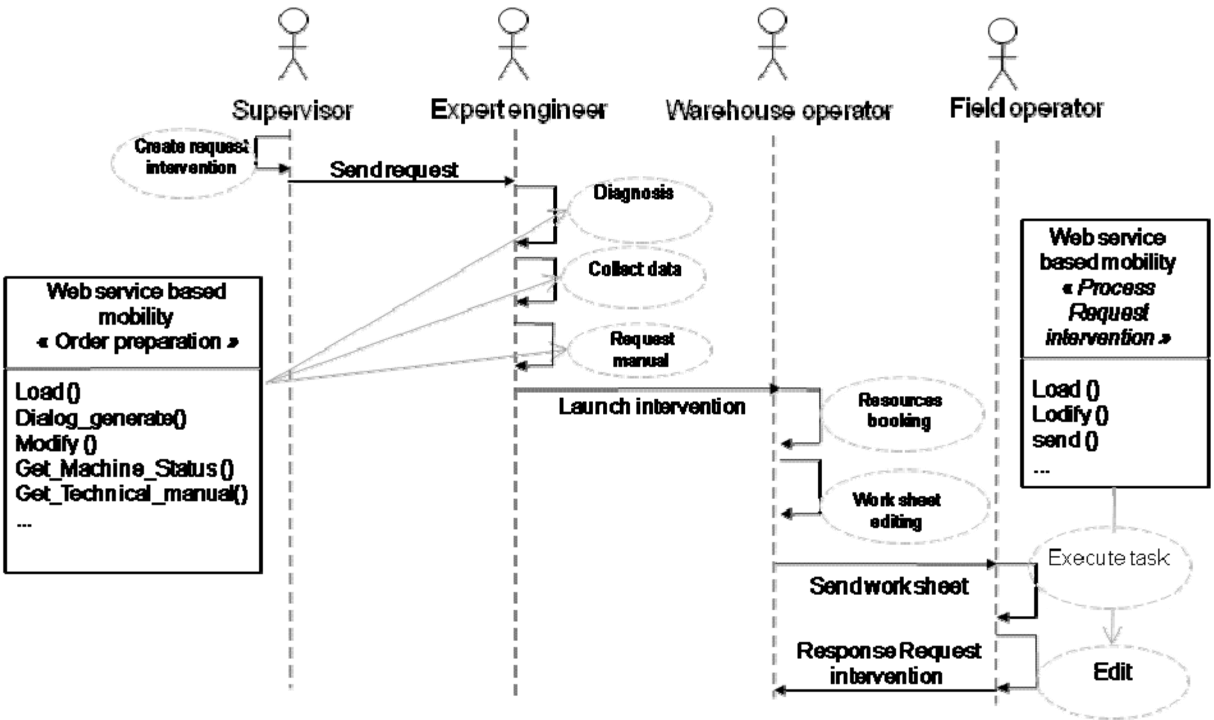

Figure 14. Example of Web service based mobility sequence diagram for the intervention management scenario

In terms of stakeholders' cooperation

This step is also conducted in a similar way to that used for mobility requirements. Therefore, we identify potential supervisory scenarios where the human actors might carry out their tasks in a cooperative manner.

The web services dedicated to cooperative tasks are considered to be of coarse granularity. They are decomposed into services dedicated to sub-tasks that can be of finer granularity as illustrated below.

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The figure 15 shows an example of expressing supervisory cooperative tasks in terms of elementary web services. The higher level of the cooperative task *Monitor_Critical_Variables* corresponds to a web service with a coarse granularity. However, the lower sub-tasks equating to elementary tasks correspond to elementary web services with finer granularities. It illustrates that the human actors (purification operator, refining turbine operator, etc.) have to access and invoke the corresponding elementary web services separately so as to invoke the *Monitor_Critical_Variables* web service according to some supervision logic (business rule).

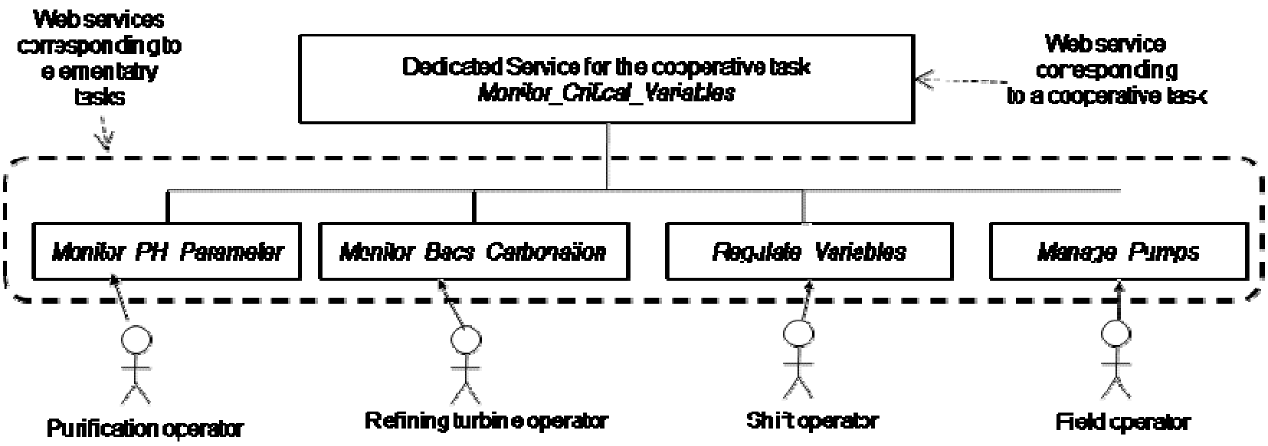

Figure 15. Example of web services expressed cooperative tasks

Definition of the human actors implied in the supervisory business process

During the requirements elicitation in terms of mobility and cooperative tasks process, more human actors were identified. However, they are not detailed here. Figure 16 shows an example of some human actors identified after web service dedicated mobility and task cooperative requirements elicitation.

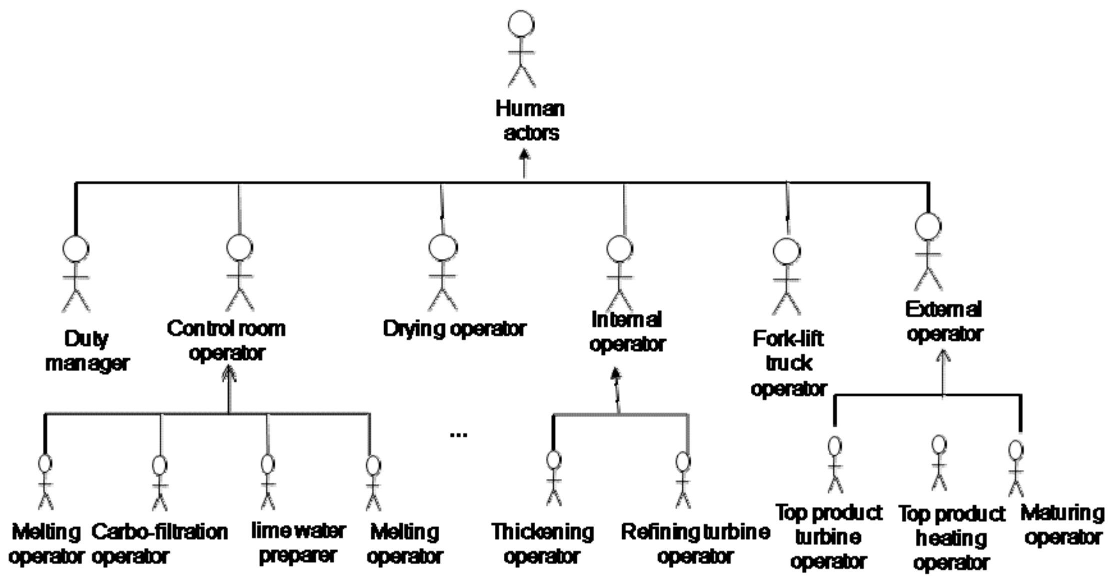

Figure 16. Some human actors identified relative to the dedicated mobility and cooperative task web services.

5.3. Phase 3: HMI specification

Based on the mobility and cooperative task oriented requirements identified previously and expressed in terms of web services, in this section, we identify the user interaction objects corresponding to those services that have to be specified as singular and aggregated.

Singular and aggregated web service identification and modelling

This consists of an abstracted description of the interface objects as the user perceives and manipulates them. Figure 17 shows a possible specification of the user interface elements of particular web services. This means that the whole screen page would be addressed by the composite web service "*Supervision of critical variables*" and each screen object zone (corresponding to Monitor_PH and Regulate_variables) would be addressed by the elementary web services *Monitor_PH_Parameter and Regulate_variables* as expressed below.

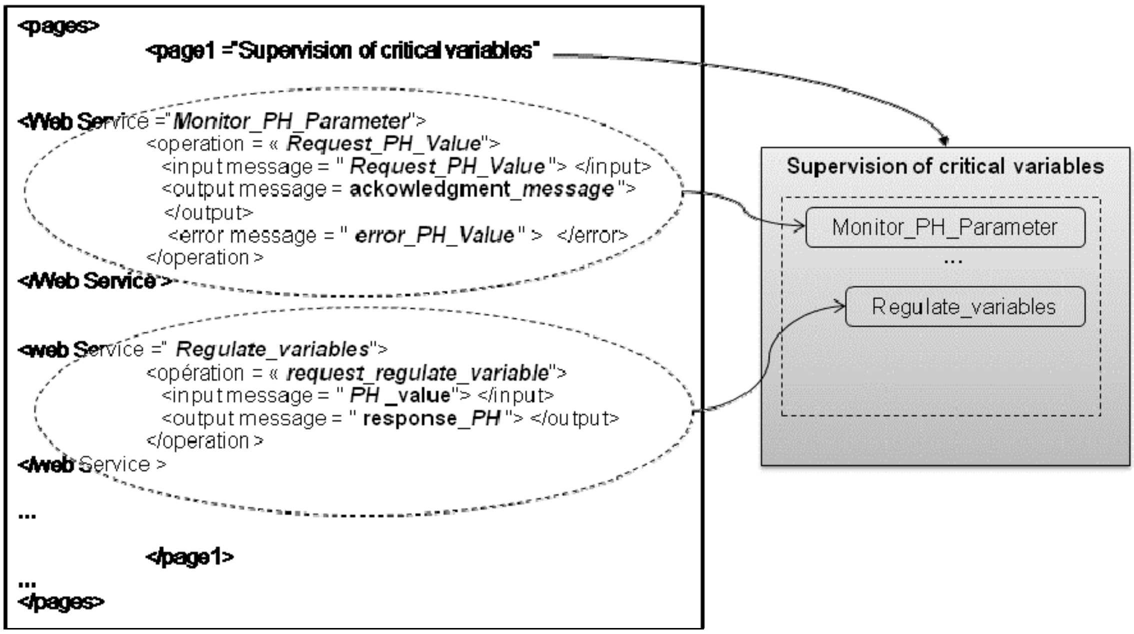

Figure 17. Abstract specification of the web service based user interface objects

HMI mock-up and prototyping

We will illustrate this phase very succinctly by a scenario corresponding to the specification visible in figure 18 through some representative mock-ups that could evolve to advanced prototypes. However, in order to limit the length of this paper, we only show an intermediate mock-up.

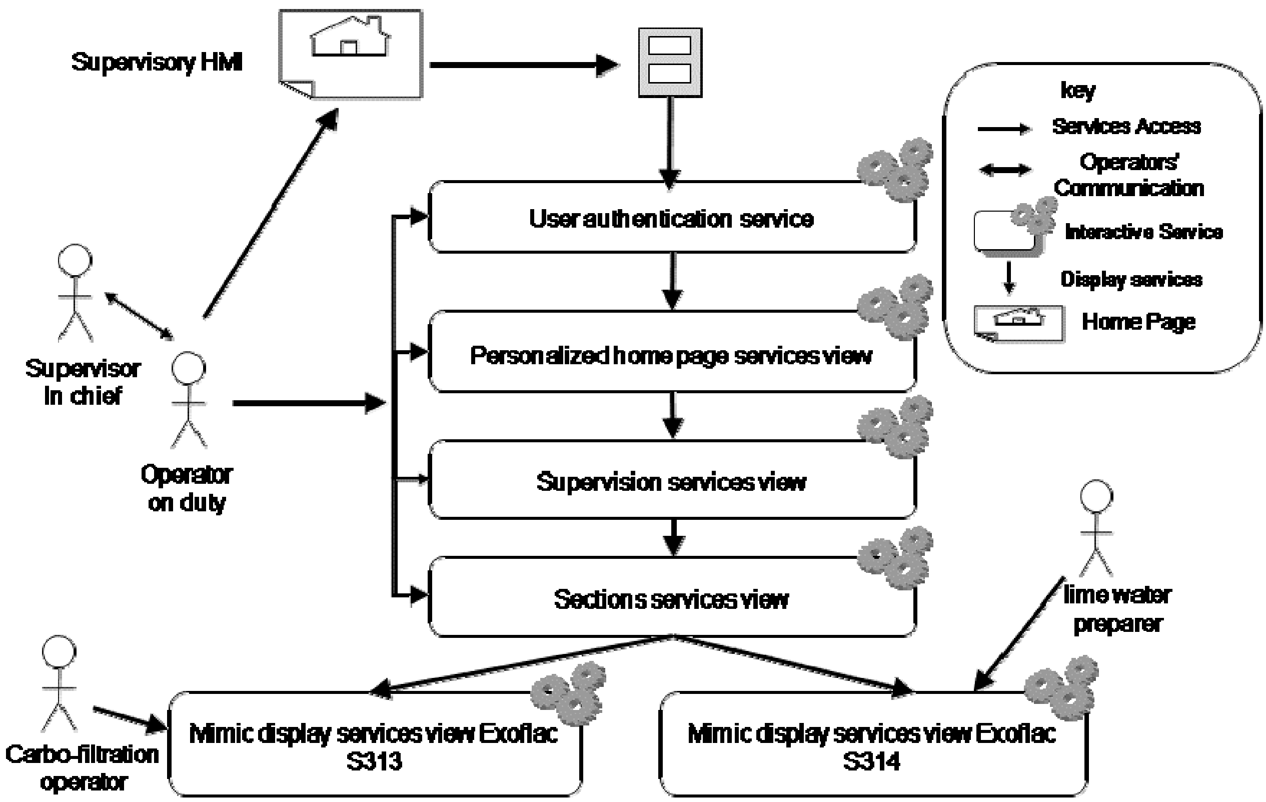

Figure 18. Illustration of the scenario from the HMI viewpoint

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Figure 19 shows an example of a sequence (Web services interaction) diagram that might be extracted from the scenario above. Therefore, the sequence may lead to an HMI mock-up as illustrated in figure 20.

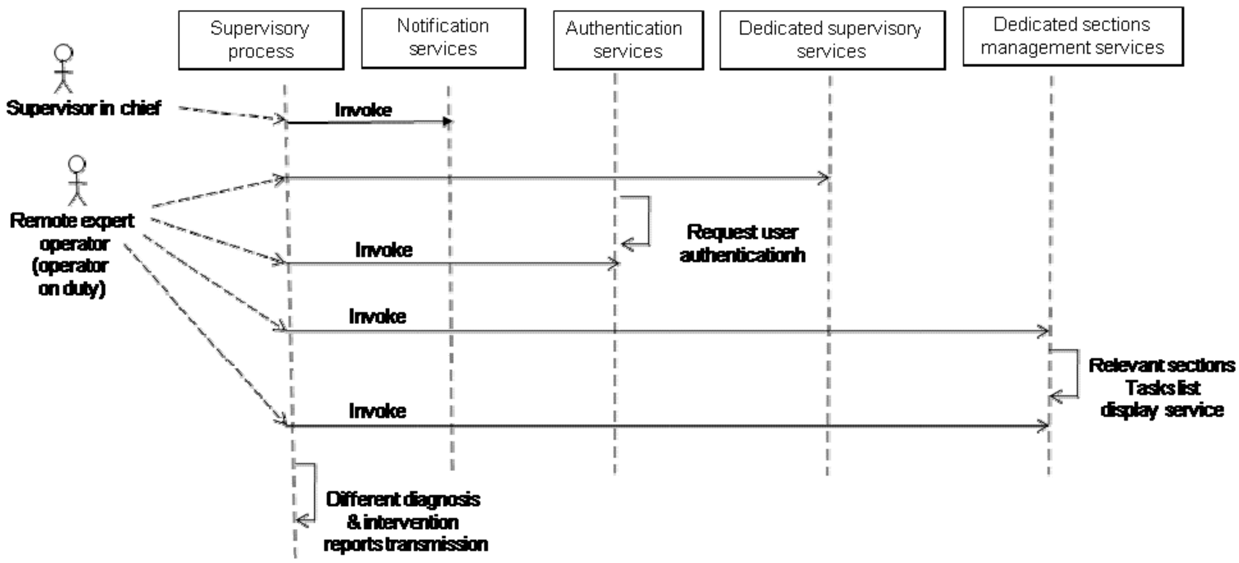

Figure 19. Example of a sequence (interaction services) diagram that might be extracted from the scenario

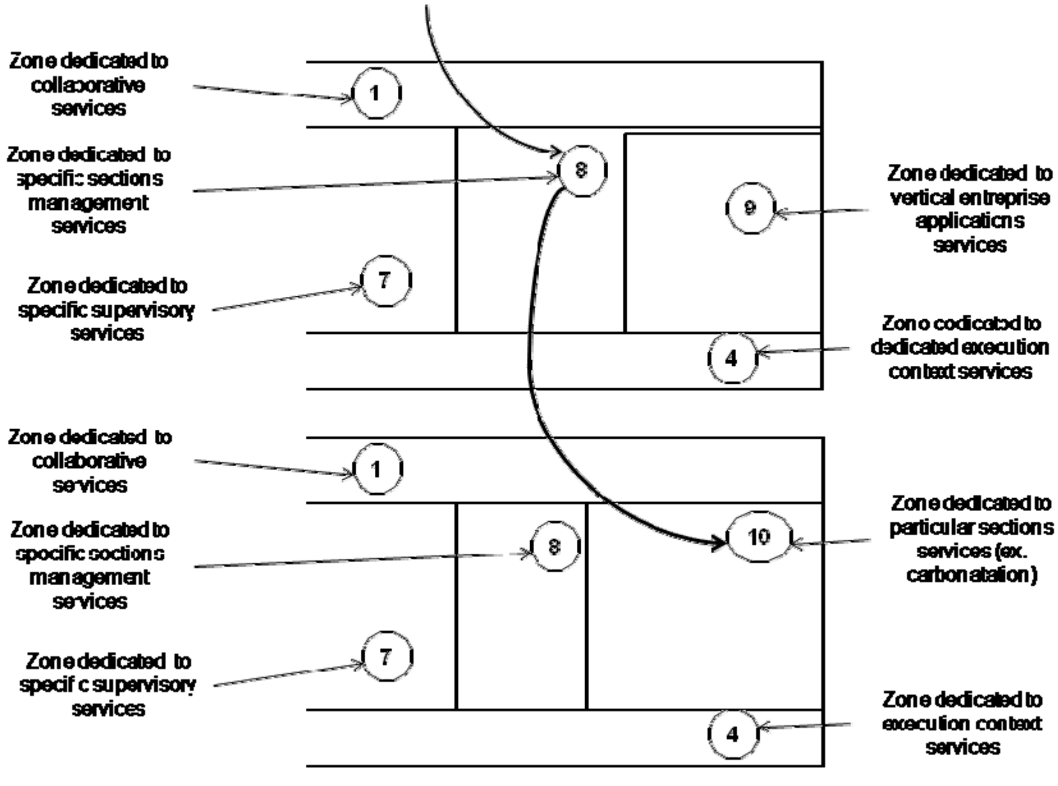

Figure 20. Authentication and remote operators' access to supervisory services (mock-ups)

Finally, the different mock-ups designed have to evolve progressively towards HMI prototypes through an iterative and incremental process and evaluation. Figure 21 represents possible interface prototypes for remote operators' access to dedicated supervisory services.

Figure 21 illustrates a remote maintenance management service. An operator on call is contacted by a head supervisor or supervisor in chief. After authentication, the operator accesses a set of dedicated supervisory interactive services. The operator on call first accesses a personalised view of all the services according to his/her user profile. He/she then accesses a view of supervision services through which he/she can directly access the view of the services related to the different sections, thus enabling access to the carbonation section for

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example (section focus) along with an intervention on this section. When the operator intervenes on this section, he/she has a set of tools and services available, allowing him/her to consult and collaborate with other actors outside the organization (external collaborators) and some authorized expert operators. Once the situation has been resolved, the operator gives an account to the head supervisor by transmitting various reports.

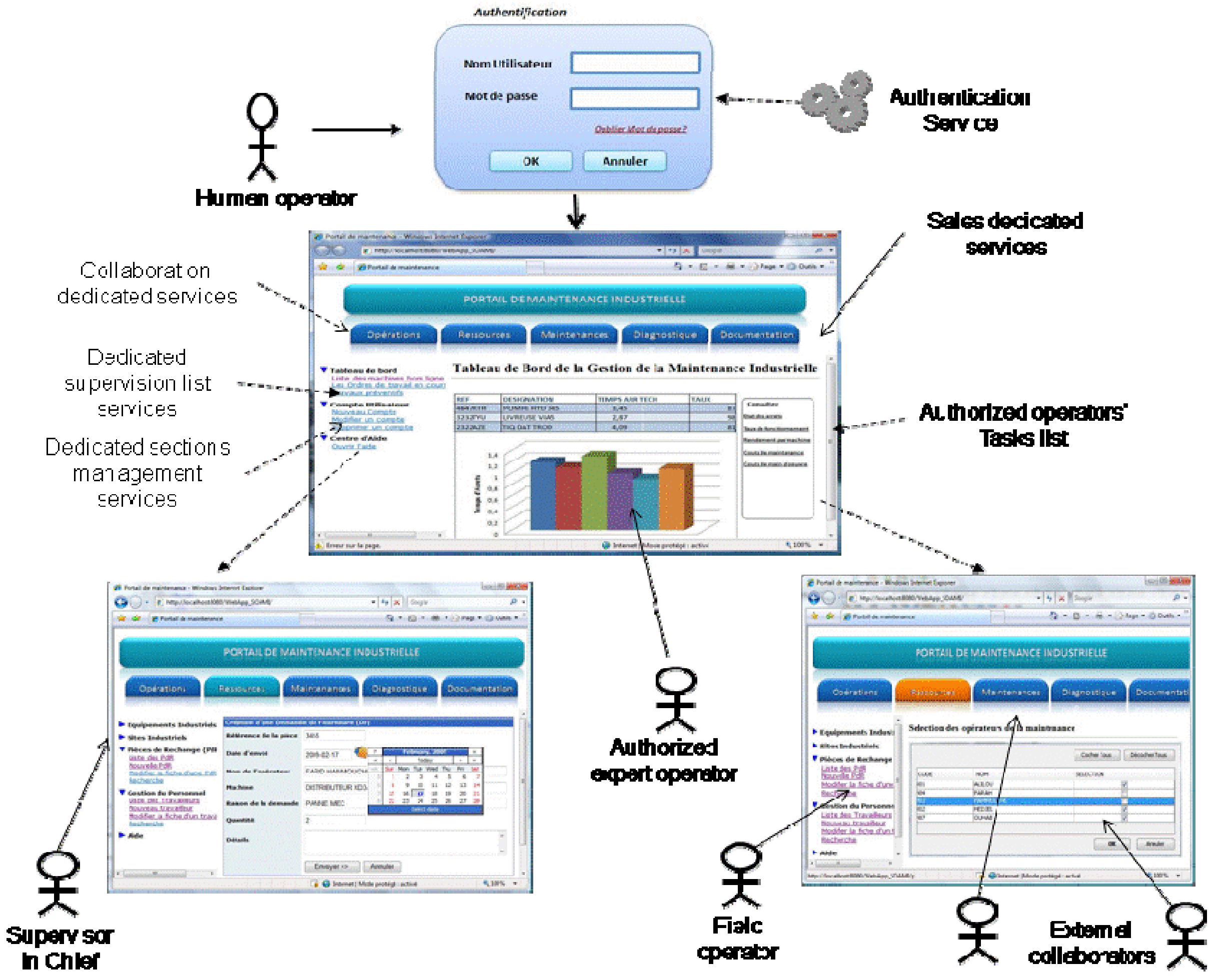

Figure 21. Example of User Interface prototypes of remote human actor access to dedicated supervisory services.

6. CONCLUSION & PERSPECTIVES

The application area of the case study can be considered as being new for the HMI design issues raised, and more complex than traditional supervision with classical HMI's. Therefore, this case study clearly shows how complex web based service HMI design issues may be approached. This has been done according to the main phases of the proposed framework through predominant analysis.

Throughout the case study, we have highlighted that the traditional industrial supervisory systems have many requirements as regards human-machine interfaces. It is possible to extend their basic functionalities such as moving towards a wider and more global supervision due to the availability of new technological means provided. This opens the way for new needs and scenarios, and thus new functionalities, especially those relating to operator mobility and cooperative tasks. Consequently, the case study has also shown that our research contribution intended to tackle newly related HMI design issues by investigating and studying complementary aspects of the classic supervisory HMI.

We have proposed a global service oriented supervisory HMI design framework. The proposal has focussed mainly on the first stages of a user centred interactive system design cycle following the main principles of a unified process. The paper has considered specifically the mobility and cooperative task dedicated supervisory web service design and mock-ups.

The service oriented architecture (SOA) is an approach for software design which breaks everything down into agile services dealing with one specific need. Unlike the traditional development of interactive applications, in this approach the business processes, the presentation of information and content (page-screens), and the applicative logic and data are separated into distinct interfaced layers of services. In a traditional HMI development project, the HMI designers often consider the design of the various HMI of the underlying applications separately. On the other hand, in an oriented approach, the designers only concentrate once on the HMI for all of the applications involved. The main benefits of the approach consist in reducing the development costs and complexity as well as the fact that it enables complex organizations to make their business processes and business logic seamlessly accessible via some relevant web technologies.

Therefore, further work and research perspectives need to be considered. Some research perspectives may concern the following issues: the validation of the approach on another application domain such as industrial maintenance for example, undertaking the evaluation process within the design phases or stages of the framework as highlighted, with different evaluation criteria; and finally proceeding beyond the three phases. We envisage to proceed beyond the HMI mock-ups to the design, implementation of the different supervisory services and testing of the supervisory web service based HMI.

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