	HoliDes **Holi**stic Human Factors **Des**ign of Adaptive Cooperative Human-Machine Systems	

D6.2 – Tailored HF-RTP and Methodology Vs0.5 for the Health Domain

Project Number:	332933
Classification:	Public
Work Package(s):	WP6
Milestone:	M2
Document Version:	V1.0
Issue Date:	12.09.2014
Document Timescale:	Project Start Date: October 1, 2013
Start of the Document:	Month 10
Final version due:	Month 10
Deliverable Overview:	**Main document:** D6.2 Tailored HF-RTP and Methodology Vs0.5 for the Health Domain - Public
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RECORD OF REVISION		
Date (DD.MM.JJ)	Status Description	Author
18.07.14	Template distributed to healthcare partners	Robert Hofsink
02.09.14	Version 0.2: Reworked after internal review	Robert Hofsink
05.09.14	Version 1.0: Updated sections according to review comments	Robert Hofsink

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2 Introduction

Within the Holides project a number of tools and services is available or will be developed. The integration of these tools leads to the Reference Technology Platform (RTP). In this context the tools and services are also referred to as RTP-components. The RTP-components become useful when they are tailored into an RTP instance. Tailoring here means the selection of tools and services that match the needs of a specific application use case.

In this document a first step is made towards a tailored RTP. Given the fact that there are multiple AdCos's, likely multiple instances of RTP's will be required. The listing of tools, as described in D1.3 is taken as a basis and for each healthcare use case the tools are identified that may be used as part of a tool chain for that specific use case.

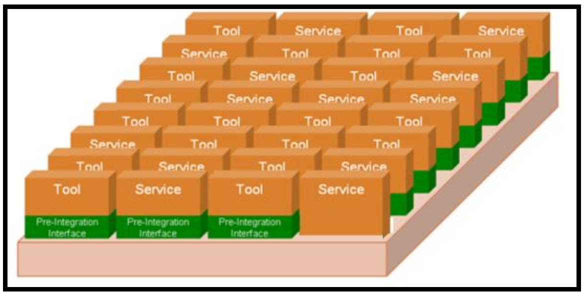

Figure 1 Set of tools and services forming the RTP

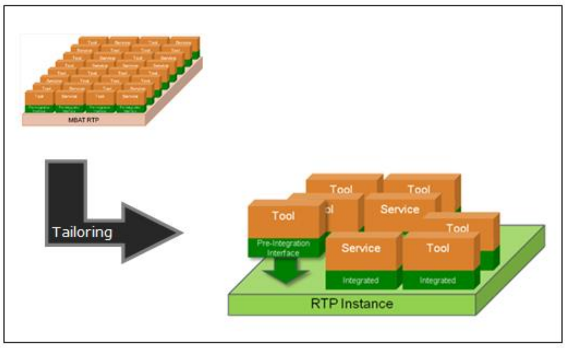

Figure 2 Tailoring to an RTP instance

3 Tools and Services available for the HF-RTP

The table below shows a list of all tools available within the Holides consortium. This table is taken from deliverable D1.3, in this document also a short description and potential usage in application use cases is provided.

Tool name	Tool type	Tool provider
HGRAPH:	**interaction modeling**	**Airbus group**
APA:	data mining	Airbus group
LEA:	machine learning prototype	Airbus group
EvolvGRN:	machine learning prototype	Airbus group
SearchBestie	Software analysis	Brno University of Technology
Race Detector & Healer for Java	Software analysis	Brno University of Technology
AnaConDA	Software analysis	Brno University of Technology
Predator	Software analysis	Brno University of Technology
ProSIVIC	Simulator	CIVITEC
Djnn	GUI programming toolkit	ENAC
D-Lab	Software	Ergoneers
Sim-Lab	Hardware	Ergoneers
Dikablis	Hardware	Ergoneers
Dominion	computer science	
Flight Log Database	Data analysis	Honeywell
EFB SDK	Software SDK	Honeywell
COSMO-SIVIC	Driver model and virtual simulation tool, to support a Human Centred Design approach of Driving Aids	IFSTTAR
	human monitoring function developpement and interaction modelling	IFSTTAR
RTMaps	Software framework	INTEMPORA
PED	Task Model and Specification	OFFIS
CASCaS	System/HMI evaluation	OFFIS
CoSimECS	Simulation framework	OFFIS
Bayesian Autonomous Driver Mixture-of-Behaviors (BAD MoB) models	Probabilistic Model	OFFIS

Human Efficency Evaluator	Software	OFFIS
"TrainingsManager"	Adaption of Training Syllabi	OFFIS
Tobii glasses	human monitoring tool	Tobii
FaceLab 5 + Eyeworks software	human monitoring tool	Seeingmachines
Captiv T-sens sensors + Analysis software	human monitoring tool	TEA - Technologie Ergonomie Applications
Enobio	human monitoring tool	Starlab
HS-SEARCHOPT	Software	Search strategy inference approach
Mommy	Software	Tecnalia
Prossurance	Methodology	Tecnalia
GreatSPN	Software framework	University of Turin - Department Computer Science
AudioDistraction	Algorithms / Tool	TWT

4 Tool selection for the use cases

The tailoring process starts with the selection of tools from the RTP that could be used in an RTP instance.
In this section, the use cases for the Healthcare domain are described and the tools from the RTP that can be incorporated in the design processes of these application use case are described.

4.1 WP6_HEA_CON_UC01_Operator_task_schedule_and_guidance

Lead: Integrasys

4.1.1 State of the art

This use case is based on a distributed platform for hospital workers (operators and patients) that are immersed in changeable work environment, and that support them with real-time context aware tool for guiding them in daily tasks.
The workflow for operators in medical environment (nurses, physicians…) comprises very complex procedures with many factors that influence the execution of tasks, such unexpected events that make difficult to accomplish a pre-organized plan. Informal process at hospital is very common. For instance small interruption of nurse works are usual in Hospital. When the number of small interruptions outweighs the amount of planned work done in a given hour, that impact is felt in slower progress, lower job satisfaction, and potentially lower quality of care.

Current workflow approach in Hospital are getting obsolete and have a large room of improvement. Our application focused on a prototype implementation of the a dynamic workflow system that help to care personnel to carry out their daily tasks.

The research findings for research studies of operational workflows have practice implications for operators and researchers. Throughout the literature, the importance of bringing multiple parties to the table was emphasized. Because organizational workflows often cross the lines of professional disciplines, workflow design from any single perspective runs the risk of sub-optimizing against other constraints, priorities, and schedules.

System architecture

The following picture depicts a high level architecture of the system to be tested:

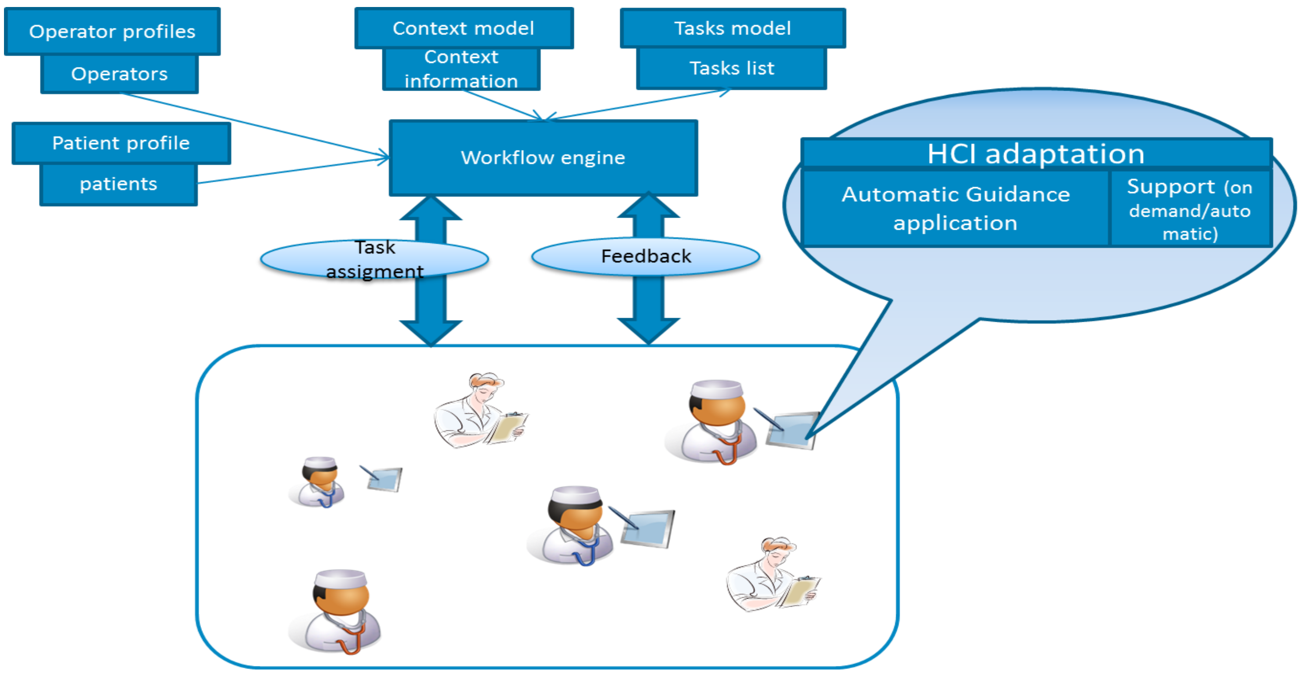

Figure 3 High level architecture

The intention of our AdCoS system is to ease the development of workflow solution for hospital focused on the following aspect:

- Help to proper staff assignment to tasks
- To provide real time instructions
- To optimize the workflow and cooperation with rest of operators.
- To provide feedback to the platform for further refinement (workflow mining technique)

Given the broad scope of workflow, we will focus on a subset of casuistic: Our application focused on a **prototype implementation** of a dynamic workflow system that helps to care personnel to carry out their daily tasks.

The technical infrastructure foreseen is composed by:

- Server infrastructure: Where the information is stored and workflow is created.
- Mobile platforms: Tablet, smartphone, smartwatch
- Communication network: To ease the monitoring and exchange of information

Applied technologies in the system

General

- Eclipse IDE
- Java
- HTML5
- AJAX
- JavaScript
- Service Oriented tools (java based)

Specific

- YAWL. It includes:
  - Language for capturing control-flow dependencies and resourcing requirements.
  - Native data handling using XML Schema, XPath and XQuery
  - Service-oriented architecture compliance
  - Dynamic workflow through the Worklets approach
  - Compliance with Business Process Management Notation (BPMN)

Applied design tooling

This platform is a software tool whose development cycle involves typical software development cycle stage: Requirement elicitation and analysis, modelling, design, implementation, pre-testing, deployment and testing. For the purpose of this project, we do not plan to make a real deployment, but use Holides tools to maximize user experience and ease the development based in simulation tools. So, the steps we will follow for the prototype implementation of this AdCoS system are:

- For the requirement phase we involve the end users. It is based on free meeting and targeted questionnaires.
- The analysis of requirements involve multiple tasks: categorization, use case model, initial design of mock-ups, functional and non-

funtional requirements, system and technical requirements, identification of standards and constrain.

- For the modelling stage and design stage we usually uses formal language, namely UML. In order to model the workflow We also plan to use *YAWL* (http://www.yawlfoundation.org/), which offer comprehensive support for the control-flow patterns and is based on a modelling language that allow to handle complex data transformations, and full integration with organizational resources and external Web Services.
- The modelling of user interfaces are based on mockup, wireframes, user interfaces
- The prototype development stage depends on the platform we deploy the system. Not support from HOLIDES tools is foreseen here.
- Testing and validation: The testing is based on high fidelity simulation environment, where we are able to create scenarios that automatically are executed although also allow manual inputs to stimulate the system. Holides plays an essential role in this stage.

Analysis & feedback tooling

- Usability analysis tooling: questionnaires, interviews, observations
- Functional and non-functional test: JUNIT, Fault injection
- Logging tools(such as log4j)

4.1.2 Unmet needs

One of the problems for the development of this system, is the testing, since experimenting in real scenarios is a complicated task in health domain. There are many strategies to overcome this problem. The gradual introduction of the new IT solution is essential for the adoption of the solution. First less safety critical functions are introduced, normally in a limited number of users and department.

Early testing of system designs is important to reduce the risk of inefficient development

Our intention is to implement a simulation tool that helps us to pre-validate the implementation of a AdCos System, before the full implementation on real hospital are carried out.

4.1.3 Tool selection

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	No tools required
Modelling of tasks, agents, UI and interaction	**YAWL**: This tool is not provided by Holides project, but will be evaluated as a promising open source tool for workflow modelling and execution **GreatSPN**: It is also a candidate tool to be used. It could be used to capture the Clinical Guidelines dynamics, its execution environment, based on the idea of representing a set of processes, whose interaction models in a more realistic way the Clinical Guidelines execution itself. The Petri Net approach allows for performance analysis and resource allocation optimization. This facility can become even more helpful by shifting the perspective from the one of executing a single GL on a single patient, to the one of dealing a real healthcare setting, in which different agents (physicians, nurses, labs) cooperate, and several, different GLs have to be executed, in order to care a set of patients. However more detail study are needed to evaluate the usefulness of this tool.
HMI	**Human Efficient Evaluator**: The HEE could be applied to compare the task performance of the current design of the guidance system with the context-based guidance adaptations for different user profiles. Interesting specific targets of the performance analysis could be an inspection of the user interface navigation options of the mobile device, to figure out how they affect the overall task performance **Djnn:** To be assessed if it is useful as a Multiinterface evaluator

Implementation and integration	No tools requred
Simulation and evaluation of user related aspects	**RTMaps** for Simulating stream of different information (sensors) and decision making algorithms.Potentially use in real time. It will be use a "context management" by allowing to add inputs/stimulus to the system, synchronizing and distributing it. Decision algorithms will be also implemented within RTMAPS platform. The output of RTMAP will feed the prototype application implemented in previous stage.

4.2 WP6_HEA_CON_UC02_Querying_openEHR_data

Lead: ATOS

4.2.1 State of the art

There are two big issues; (1) speed to access to DICOM images and (2) interoperability problems. To deal with DICOM images access, which the system can retrieve earlier acquired, it has been decided via WADO (Web access to DICOM images), but still, it has to be carried out some tests to ensure usability, speed and efficiency on different devices (PC and android systems like tablets or mobiles). About interoperability, the solution integrates the data from heterogeneous and fragmented healthcare information systems and devices based on generic information models, which conform to openEHR/EN13606 archetypes and besides offers the possibility to exchange information with other Hospital Information Systems (HIS) using Health Level 7 (HL7) Clinical Data Architecture (CDA), Continuity of Care Record (CCR), Continuity of Care Document (CCD) or virtual Medical Record (vMR) as the payload: yourEHRM, standard-based management of your personal healthcare information.

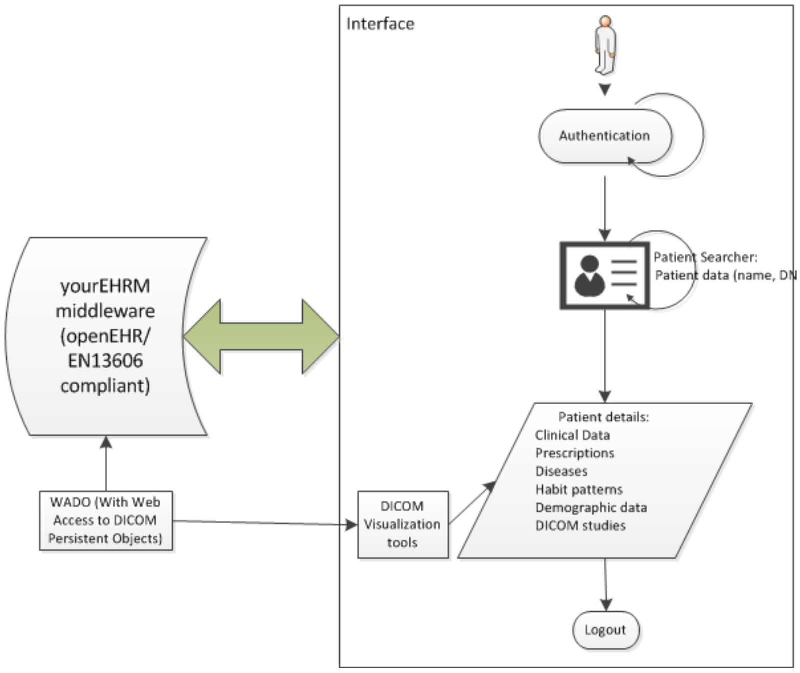

Figure 4 Interaction in the AdCos

System Architecture

The querying EHR data is integrated into ATOS Software.

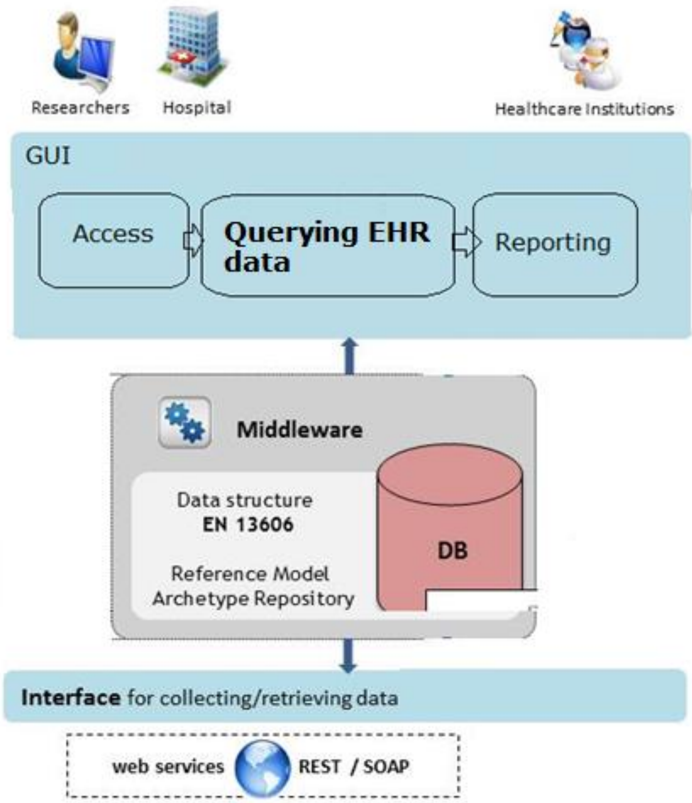

Figure 5 General EHR architecture

<u>Security and privacy:</u>

- The system can only be accessed by authorized physician using their credentials (at least user and password).
- The system MUST have a logout option and session time out.
- Other security mechanisms must be studied due to the sensitive information treated.
- The system must use secure protocols (e.g. https)

Applied technology in the system

General
- Eclipse IDE

- GWT framework
- HTML5
- C#
- JavaScript

Specific
- Open source libraries for manipulating the OpenEHR Reference Model and archetypes
- Open source repository of archetypes Clinical Knowledge Management (CKM)
- Open source libraries for WADO access

Applied design tooling
- Html5 DICOM viewer

Analysis & feedback tooling
- Usability analysis tooling: questionnaires, interviews, observations
- Continuous Integration (CI) tools: GitLab
- Issue tracking: Trac & GitLab

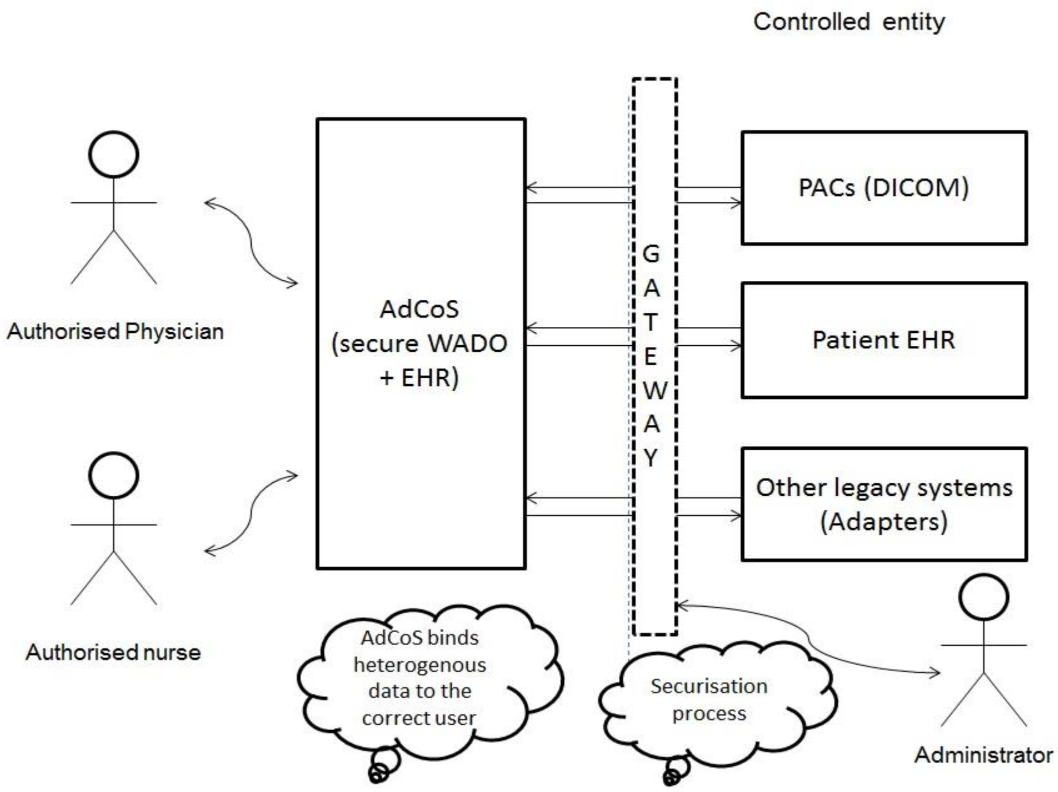

Figure 6 AdCos analysis

4.2.2 Unmet needs

To access data like MRI exam (for example), these data have had to be previously stored from acquisition of physiology signals; the system must have access to them.

As it is mentioned before, to deal with DICOM images access it has to be carried out some tests to ensure usability, speed, efficiency and visualization on different devices.

In the clinical environment it is hard to include new modelling and simulation tools. Some HF-RTP available with the corresponding IOS would facilitate the integration of new techniques to provide better tools for access and display; PED, CASCaS and CoSimECS will be considered.

4.2.3 Tool selection

We need further research to validate that the tools listed are suitable for this UC. The first list of tools and techniques identified needs to be filtered out once we analyse in depth the software provided.

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	N/A
Modelling of tasks, agents, UI and interaction	PED HGRAPH Human Efficiency Evaluator
HMI	CASCaS
Implementation and integration	ATOS monitoring system Java Race Detector & Healing SearchBestie Mommy HS-SEARCHOPT
Simulation and evaluation of user related aspects	CoSimECS

4.3 WP6_HEA_DAT_UC01_internal_analysis_and_reporting

Lead: ATOS

4.3.1 State of the art

This use case provides a tool which analyses and generates clinical reports based on data coming from heterogeneous and fragmented healthcare information systems. The system SHOULD be able to combine data from different sources and MAY be aware of different versions of archetypes.

The access to the system must be available anytime and anywhere, apart from the hospital environment, so it will provide a web Graphical User Interface (GUI). This interface MUST provide easier usage of the information and SHOULD present clinical information to the physician in an integrated way.

Two different clinical reports (PDF format) are provided:

- **Internal clinical report**: This report allows analysing possible causes that has brought a certain patient to the hospital by comparing and analysing data with other patients in order to avoid possible future illness. The professional selects a group of patients with similar diseases and generates an internal report with risks factors and predictions. This report is internal to the hospital and includes risk analysis, predictions, etc.

- **Patient report:** Besides the predictive report for the doctor the tool would permit to generate simple reports for the patients just to provide a general overview of his/her health status. This custom report pretends to avoid additional CDs or paper reports given to the patient nowadays. This report includes clinical patient data. MRI, Lab Tests, prescriptions, etc... Any EHR data that the professional considered desirable.

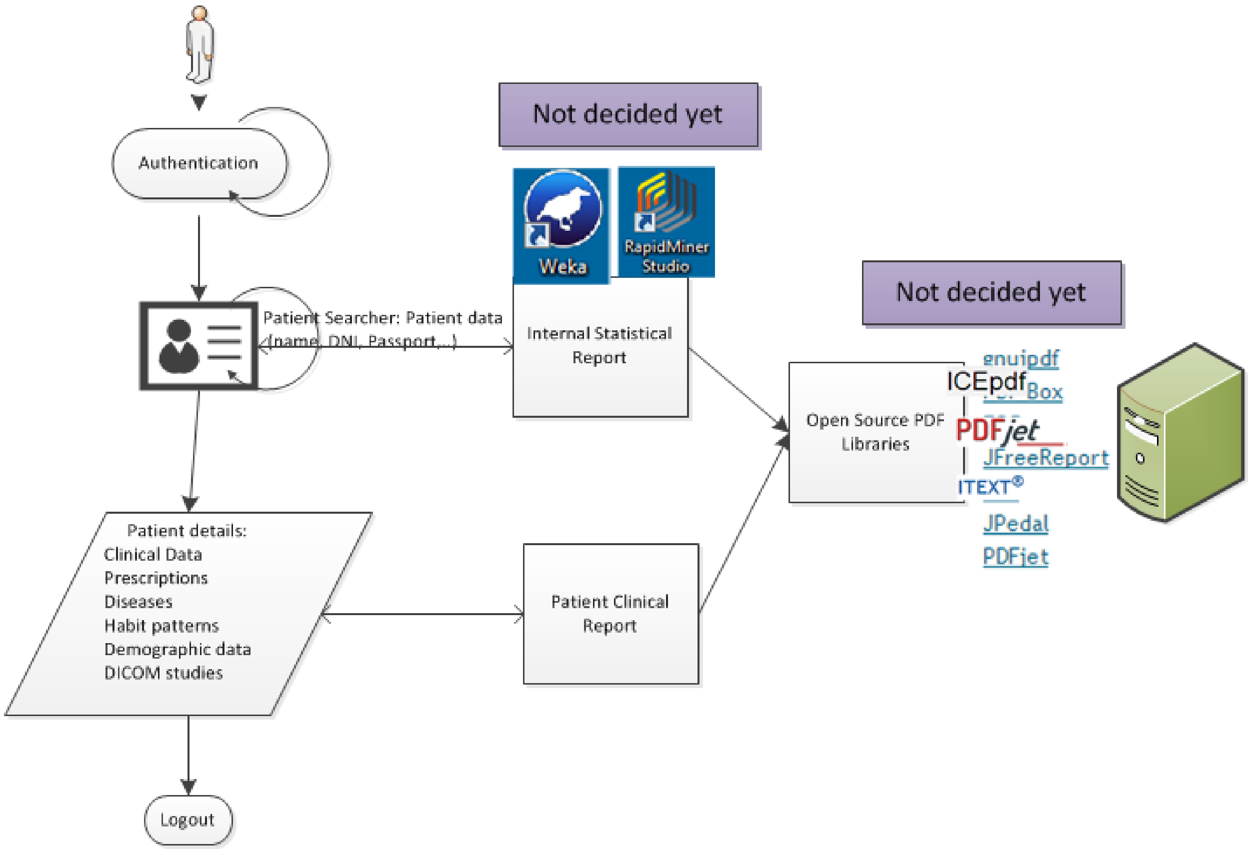

Figure 7 Interaction in the AdCos

System Architecture

The information MUST be anonymised before providing the results. The data coming from the hospitals due to the interoperability platform will help in the analysis of statistical values to improve the diagnostic and treatment of the patient finding similar cases already stored in the system.

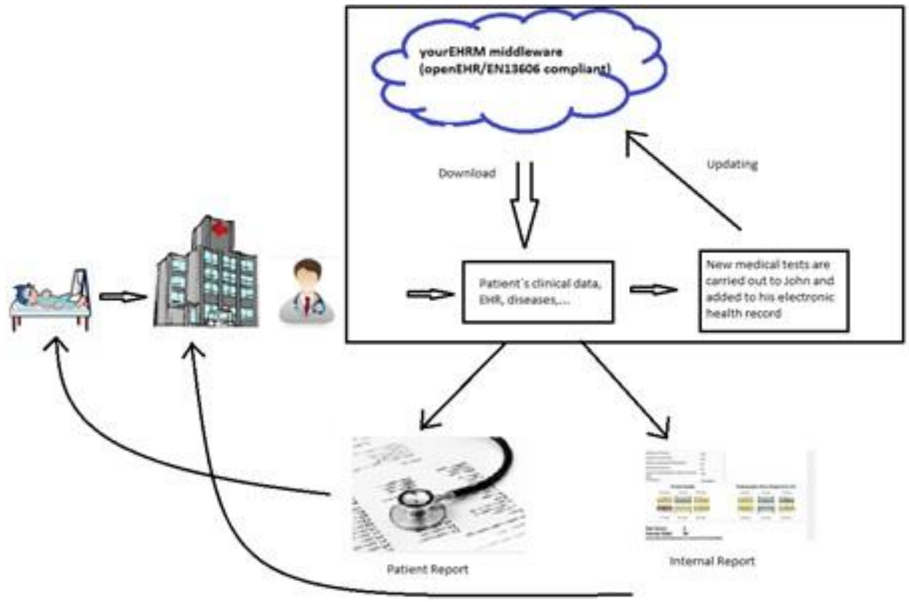

Figure 8 General reporting architecture

<u>Security and privacy:</u>

- The system can only be accessed by authorized people (researchers, medical specialists and so on) using their credentials (at least user and password).
- The system MUST have a logout option and session time out.
- Anonymisation of the information.
- Other security mechanisms must be studied due to the sensitive information treated.
- The system must use secure protocols (e.g. https)

Applied technology in the system

General

- Eclipse IDE
- GWT framework
- HTML5
- C#
- JavaScript

Specific

- Open source programs data mining; Probably Weka or RapidMiner
- Open source library that allows creating and manipulating PDF documents; Probably iText.

- Software to visualise the PDF reports

Applied design tooling

- Html5 DICOM viewer

Analysis & feedback tooling

- Usability analysis tooling: questionnaires, interviews, observations
- Continuous Integration (CI) tools: GitLab
- Issue tracking: Trac & GitLab

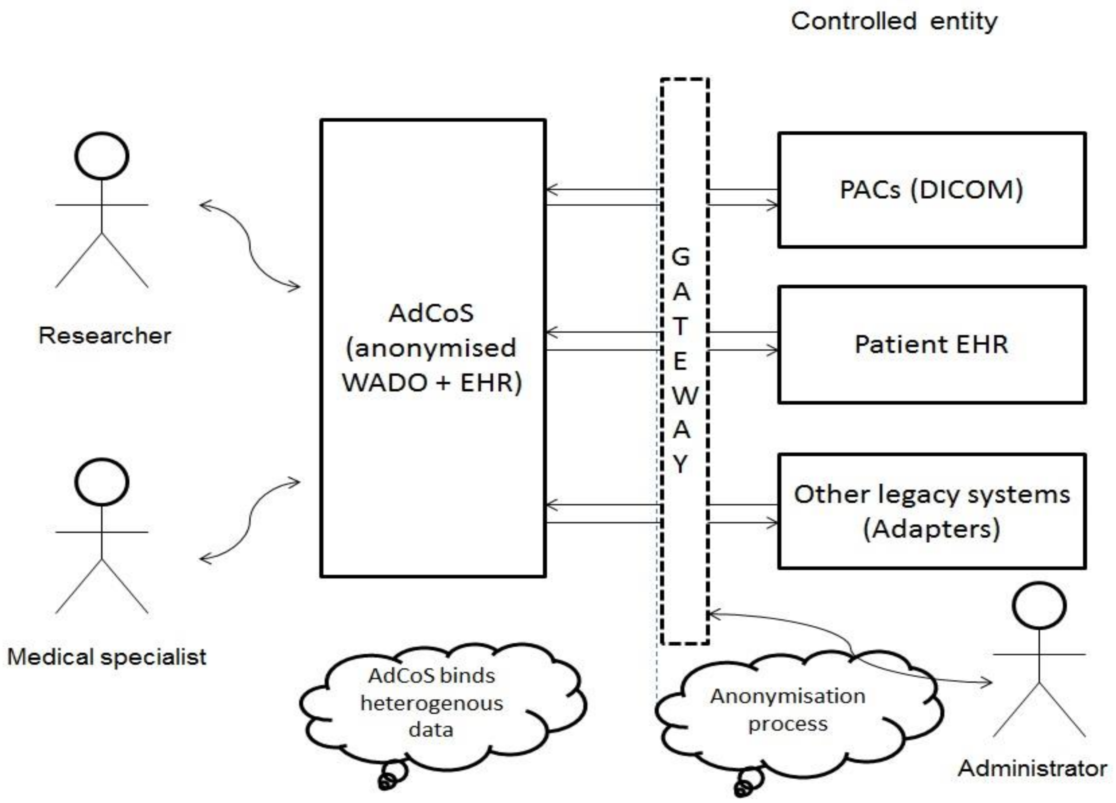

Figure 9 AdCos analysis

4.3.2 Unmet needs

In the clinical environment it is hard to include new modelling and simulation tools, especially in those reports which include statistical analysis and predictive results, it means that doctors will need to become familiar with decision making tools and the statistical principles underlying them.

In addition, it is important to mention, the data input; Since Data mining goal is to discover understandable useful hidden patterns and extraction of new knowledge; the system needs a large amount of data to analyse which is complicated to get in health environment (even anonymized). To deal with this issue the system will be trained with fake data and only when the relevant real data will be available the final modeling phase will be completed.

Some HF-RTP available with the corresponding IOS would facilitate the integration of new techniques to provide better tools for diagnostic and treatment. APA, LEA and EvolvGRN will be considered, all of them related to data mining and machine learning.

4.3.3 Tool selection

We need further research to validate that the tools listed are suitable for this UC. The first list of tools and techniques identified needs to be filtered out once we analyse in depth the software provided.

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	N/A
Modelling of tasks, agents, UI and interaction	PED HGRAPH Human Efficiency Evaluator
HMI	CASCaS
Implementation and integration	Java Race Detector & Healing SearchBestie EvolvGRN APA Mommy HS-SEARCHOPT
Simulation and evaluation of user related aspects	CoSimECS

4.4 WP6_HEA_DAT_UC02_patient_access_of_data

Lead: ATOS

4.4.1 State of the art

This use case provides an overview of workflow to access, patients to medical and clinical data, always in a secure way. The data to be displayed to the patient are demographic, habits patterns and personal details as well as clinical reports previously generated by his or her professional.

In addition, the patient is allowed to modify some data like demographic, habits or personal details in order to keep his or her information as updated as possible.

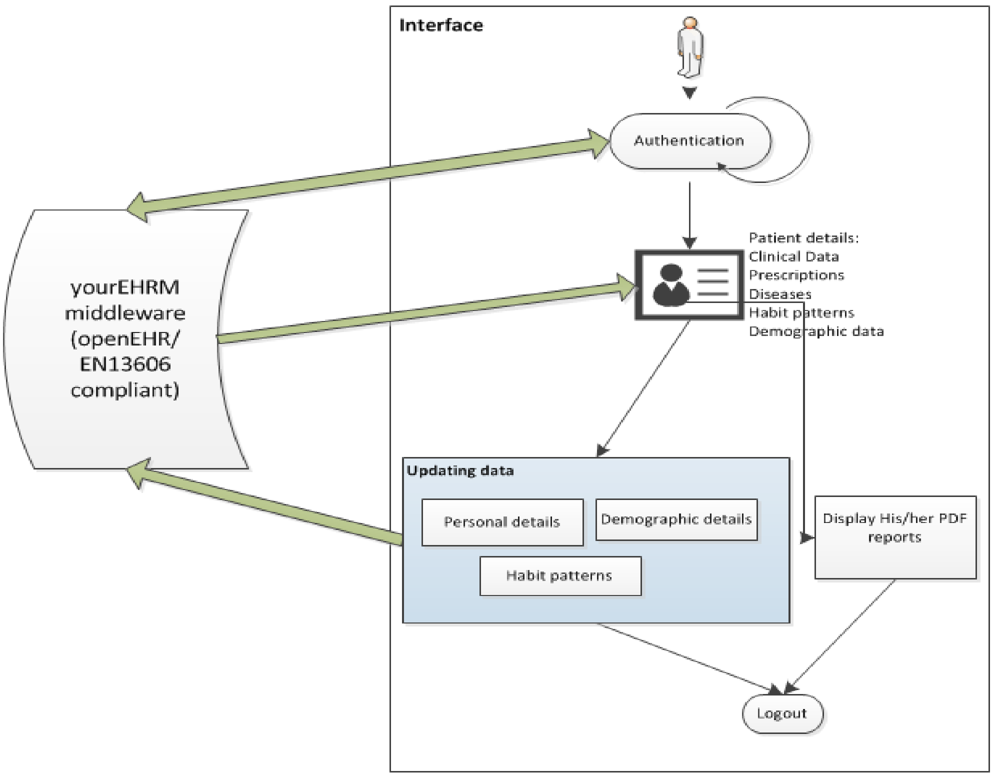

Figure 10 Interaction in the AdCos

System Architecture

The architecture used is the same than in the UC WP6_HEA_CON_UC02_Querying_openEHR_data.

Security and privacy:

Due to the patient may access to the system from wherever outside the hospital (Web development), this information needs to be safely accessible anytime anywhere. In addition, the patient is allowed to download or save his/her own clinical reports (previously generated on analysis and reporting system) which could contain very sensitive information, as a result of all this, privacy and security will be crucial aspects that will be considered during the entire workflow.

It is desirable that the protection of user patient will go further than authentication by username and password. Different technologies have to be studied (secure protocols, encryption, certificates…).

- The system can only be accessed by authorized patients using their credentials (at least user and password).
- The system MUST have a logout option and session time out.
- Other security mechanisms must be studied due to the sensitive information treated.
- The system must use secure protocols (e.g. https)

Applied technology in the system

General

- Eclipse IDE
- GWT framework
- HTML5
- C#
- JavaScript

Specific

- Open source libraries for manipulating the OpenEHR Reference Model and archetypes
- Open source repository of archetypes Clinical Knowledge Management (CKM)
- Software to visualise the PDF reports

Applied design tooling

- Html5 DICOM viewer

Analysis & feedback tooling

- Usability analysis tooling: questionnaires, interviews, observations
- Continuous Integration (CI) tools: GitLab
- Issue tracking: Trac & GitLab

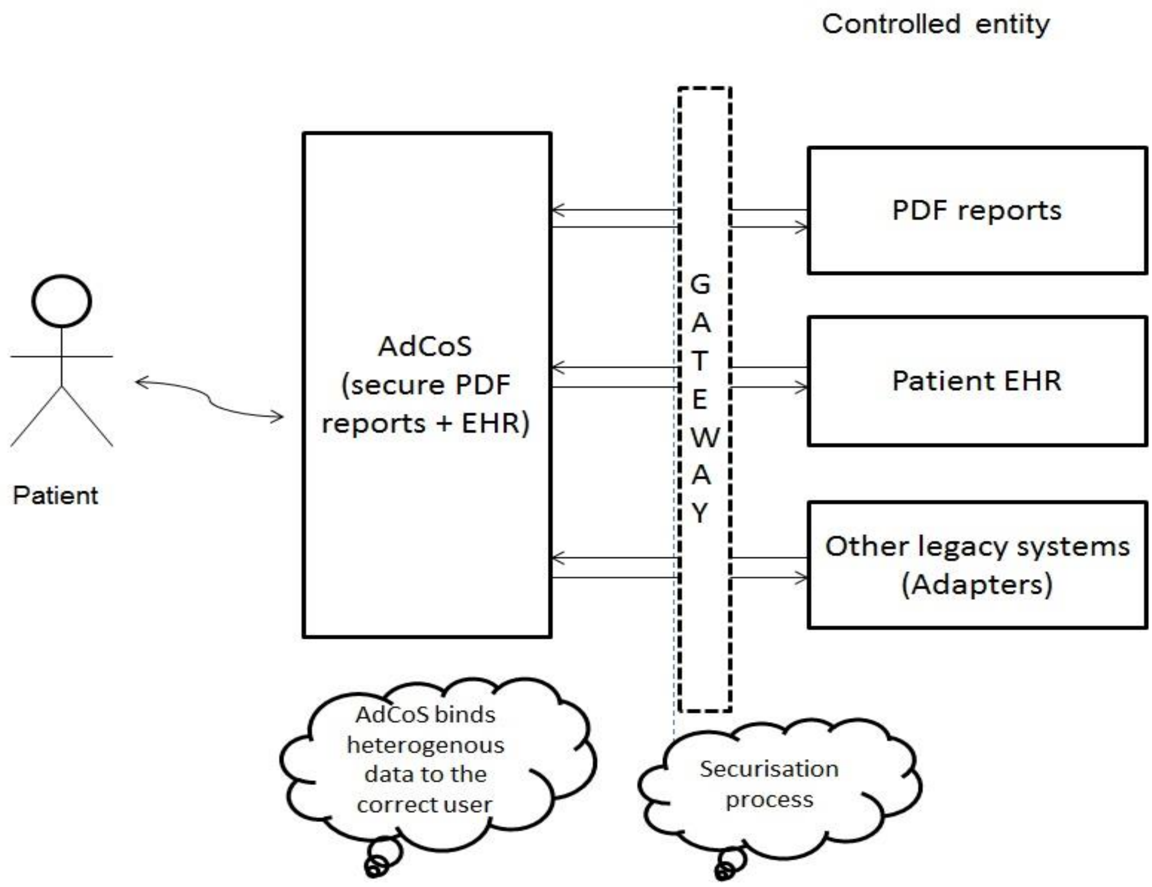

Figure 11 AdCos analysis

4.4.2 Unmet needs

In the clinical environment it is hard to include new modelling and simulation tools. Some HF-RTP available with the corresponding IOS would facilitate the integration of new techniques to provide better tools for patient access and deal with clinical information on his or her own EHR.

The full design process must take into account security and velocity at any time.

4.4.3 Tool selection

We need further research to validate that the tools listed are suitable for this UC. The first list of tools and techniques identified needs to be filtered out once we analyse in depth the software provided.

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	N/A
Modelling of tasks, agents, UI and interaction	PED HGRAPH Human Efficiency Evaluator
HMI	CASCaS
Implementation and integration	ATOS monitoring system Java Race Detector & Healing SearchBestie Mommy HS-SEARCHOPT
Simulation and evaluation of user related aspects	CoSimECS

4.5 WP6_HEA_MRI_UC02_safe_patient_transfer

Lead: Philips (MRI)

4.5.1 State of the art

4.5.1.1 System Architecture

The MRI Trolley is a separate component with clearly defined interfaces with:

- The MRI table top, which is placed on top of the trolley
- The Patient support (the static part in front of the magnet, that carries the table top when the patient is shifted into the magnet)

The AdCoS, so the tool to design and validate the MRI trolley, needs to interface with mechanical design tooling: ProEngineer.

4.5.1.2 Applied technology in the system

ProEngineer is applied for mechanical design

4.5.1.3 Applied design tooling

- Requirement management: HP Application Lifecycle Management
- Documentation archive: Agile
- Mechanical design tooling: ProEngineer

4.5.1.4 Analysis & feedback tooling

- Usability analysis tooling: questionnaires, interviews, observations
- Internal defect tracking (during development): ClearQuest
- External defect tracking (after release): TrackWise

4.5.1.5 Tool / design workflow relations

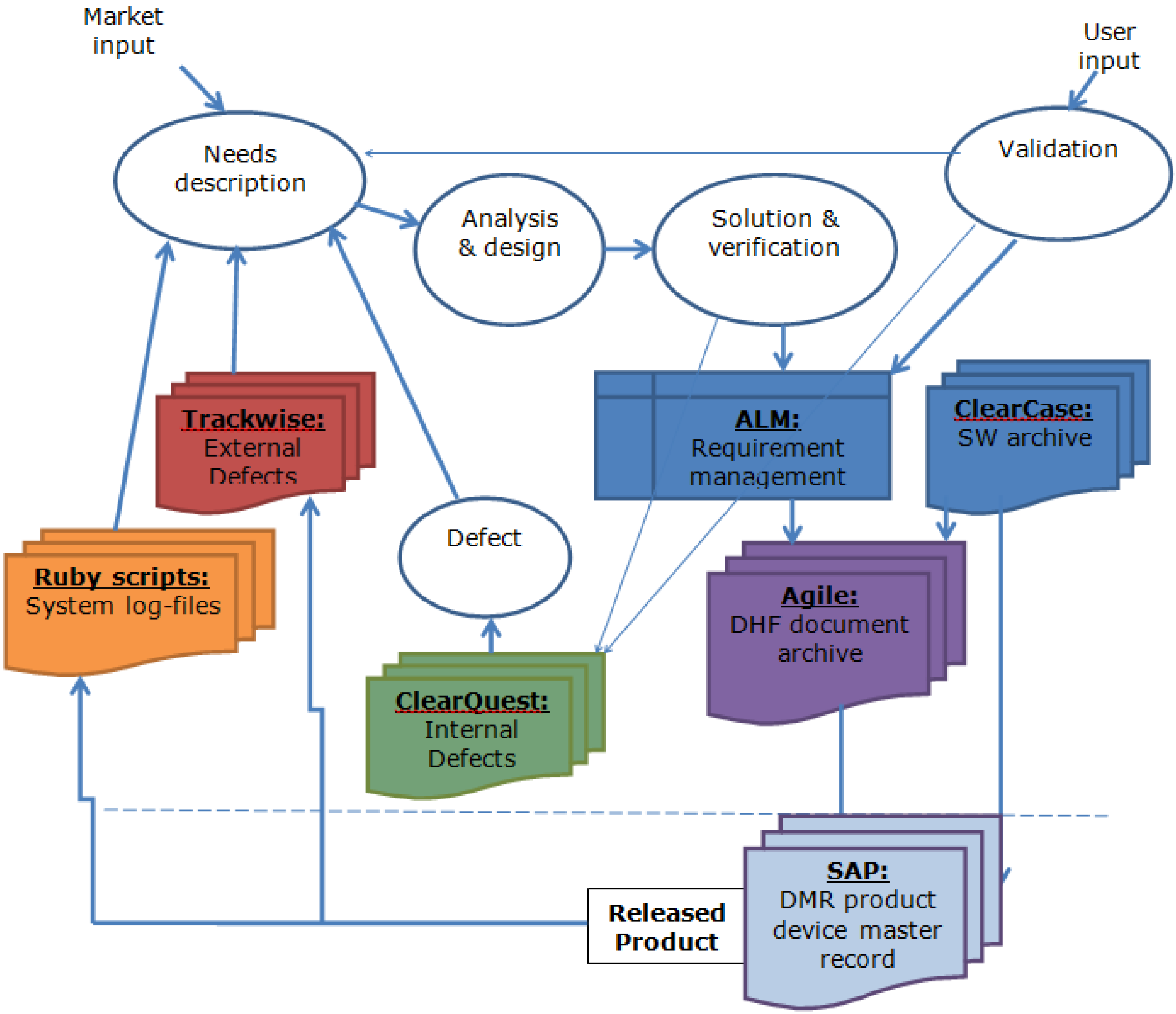

Figure 12 Design workflow and applied tools

4.5.1.6 AdCoS Description

The AdCoS is the system that enabled the design and validation of the Safe Patient Transfer System, also called the MRI Trolley.
This Trolley needs to be safe and easy to use for a broad range of operators and patients.

Anthropometric data:
MR operators with different stature will work with MR patient transportation and different patient sizes needs to be supported:
Patient weight: 0 – 250 kg.
Patient height: 0 – 2.20 m

The MRI Trolley is used to transport an immobile patient to and from the MRI scanner. The patient typically arrives in a non-MR compliant bed or wheel chair at the MRI facility. Outside the examination room the patient is put on the MRI table top, which is on the trolley. The operator wheels the trolley + patient into the examination room, and places this over the patient support, which is in lowered position. If the patient support is lifted the tabletop with patient will be automatically put on top, ready to be shifted inside the MRI scanner.

4.5.2 Unmet needs

The high level user need that requires a solution for patient transportation is:
Enable fast patient preparation, easy and safe patient transport, and comfort for immobile patients and flexibility in emergency situations

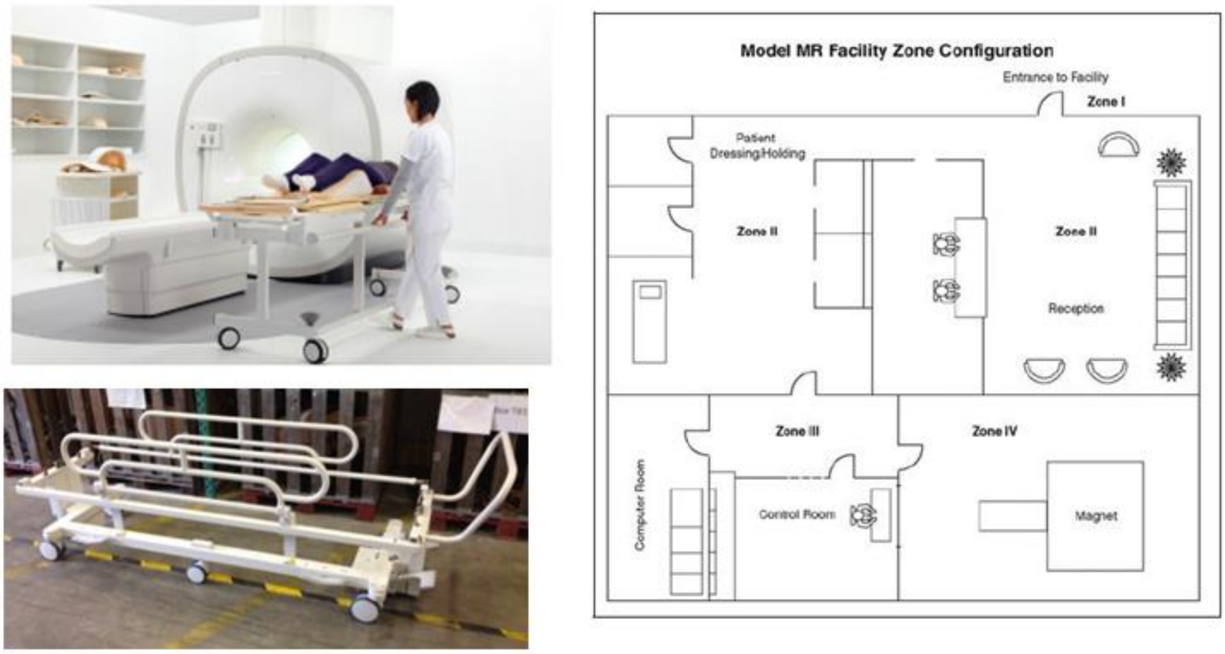

Figure 13 MRI trolley and system explanation

Explanation to Figure 13

- Left below: Picture of the MRI Trolley;
- Left above: Patient on trolley is wheeled to the MRI system.
- Right: typically lay-out of the radiology department.

The AdCoS needs to be able to model the variety of applications, operators, patients and physical properties of the radiology department.

4.5.2.1 Design & Validation Needs

The design process, including validation of intermediate and final solutions, is hardly supported by tooling. It is therefore very likely that some tooling in the HF-RTP can be applied and leads to a more structural and repeatable design process.

Currently optimization of the design of the trolley is very labor intensive and requires design, creation, and validation of various prototypes, including workflow tests and ergonomic reviews. No tooling is applied and there is a low coverage of all cases, patient- and operator groups, and applications.

Required MTT Support:

1. **to simulate functional aspects** of the trolley and related components for the full range of specified users, patients and applications
2. to allows **fast iteration to rapidly validate various concepts** interactively
3. to **systematically (if possible automatically) validate a series of concepts**, resulting in a summary with pro's and con's for the various options
4. to **smoothly interface with applied mechanical design tools** (Pro-E) for product validation

In the next paragraph the selection of methods, tools and techniques from the HF-RTP needs is discussed.

4.5.3 Tool selection

From the list of available methods, tools and techniques in the HF-RTP, as presented in chapter 2, the following preliminary selection is made. This selection is based on the needs as discussed in the previous paragraph. This is intended as the first estimate, based on available descriptions of the tools; the actually applicability of the MTT for this AdCoS needs to be explored in the next phases of the project. The table below refers to the *Required MTT Support* list in the previous paragraph.

Step of the tool-chain	Tools and techniques to be explored
Requirements definition and tracking	No support required
Modelling of tasks, agents, UI and interaction	Potential for the required MTT support 1 and 2: • OFFIS: Human Efficiency Evaluator. • CVT: Pro-SiVEC.
HMI	No design tools with HMI available
Implementation and integration	No tools available for required MTT support 4.
Simulation and evaluation of user related aspects	Potential for MTT support 3: • HFC: Task analysis; Human Factors and Safety regulations and guidelines for metrics; • HFC: Tests for Cognitive Task Models.

4.6 WP6_HEA_MRI_UC01_guided_patient_positioning

Lead: Philips (MRI)

4.6.1 State of the art

4.6.1.1 System Architecture

The Guided Patient Positioning System is integrated in the Philips MRI systems

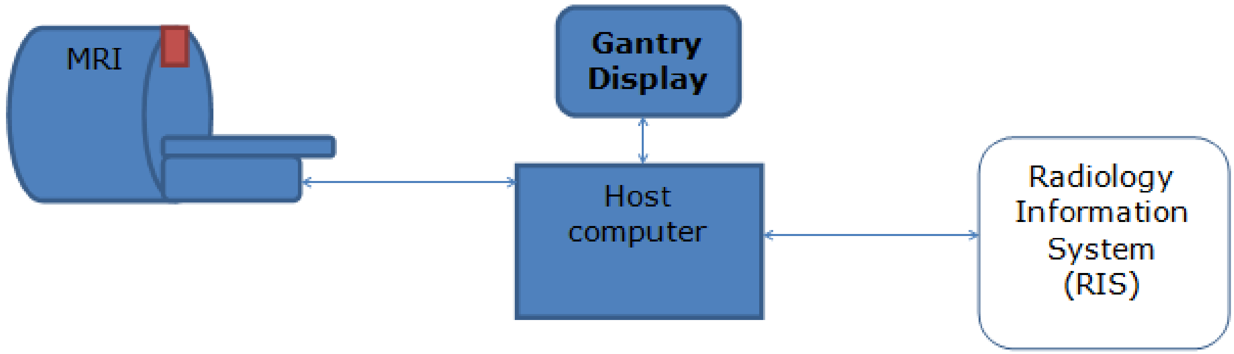

Figure 14 Simple diagram showing the connections of the Gantry display with the MRI system. Note that the display is physically on the front of the MRI magnet (indicated in red)

4.6.1.2 Applied technology in the system

General:
- Standard computer interfaces (Ethernet)
- HTML5
- C / C++ / C#

UI technology:
- Touch control on the Gantry Display (like on tablets).
- To be considered: Voice control, gesture control

4.6.1.3 Applied design tooling

- Requirement management: HP Application Lifecycle Management
- Documentation archive: Agile
- SW management system: ClearCase (Rational)
- No specific graphic design tooling

4.6.1.4 Analysis & feedback tooling

- Log-file analysis tooling: Ruby scripts

- Usability analysis tooling: questionnaires, interviews, observations
- Internal defect tracking (during development): ClearQuest
- External defect tracking (after release): TrackWise

4.6.1.5 Tool / design workflow relations

See figure 3.5.1 in the previous chapter.

4.6.1.6 AdCoS Description

The AdCoS is the system that provided guidance to the operators during preparing and positioning patient for MRI examinations.

Figure 15 Pictures of several actions during patient positioning

Correct positioning of the patient for the MRI examination and using the right coils and other devices is important to get good diagnostic quality images, but also important to avoid safety issues. Currently the operator is trained for this. The on-line guidance system intents improve usability and to reduce risks, also in case of novice, less experienced users.

<u>Input:</u>
The Guided Patient Positioning System has access to the on-line information from the MR system (patient characteristics, MRI examination procedure, actual system status, physiology signals and connected devices).

<u>Output:</u>
The Gantry Display, positioned at the front of the magnet at a fixed location, provides information and instructions for the operators. Additionally sound can be used to provide feedback to the operator.

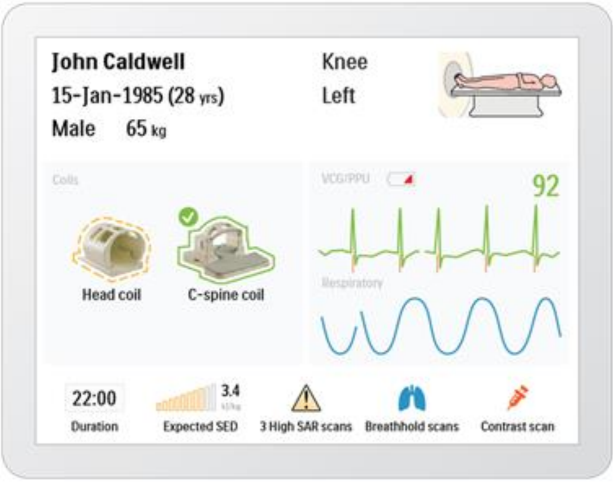

Figure 16 Example of the gantry display

<u>Operator control:</u>
The touch screen UI on the Gantry Display allows the operator to access various levels of information (e.g. more detailed instructions for novice users, more details of received physiology signals)

4.6.2 Unmet needs

The design process, including validation of intermediate and final solutions, is hardly supported by tooling. It is therefore very likely that some tooling in the HF-RTP can be applied and leads to a more structural and repeatable design process.

Required MTT Support:

1. **to model and simulate functional aspects** patient positioning for the full range of specified users, patients and applications
2. **to systematically validate a series of concepts**, resulting in a summary with pro's and con's for the various options

In the next paragraph the selection of methods, tools and techniques from the HF-RTP needs is discussed.

4.6.3 Tool selection

From the list of available methods, tools and techniques in the HF-RTP, as presented in chapter 2, the following preliminary selection is made. This selection is based on the needs as discussed in the previous paragraph. This is intended as the first estimate, based on available descriptions of the tools; the actually applicability of the MTT for this AdCoS needs to be explored in the next phases of the project. The table below refers to the *Required MTT Support* list in the previous paragraph.

Step of the tool-chain	Tools and techniques to be explored
Requirements definition and tracking	No support required
Modelling of tasks, agents, UI and interaction	Potential for MTT support 1: • OFFIS: Human Efficiency Evaluator. • EAD-FR: HGRAPH / Analysis of operator, patient and nominal interaction (based on patient characteristics and type of examination). Assess current operation and provide dynamic guidance according to the context • Anywi: Modelling of AdCoS data from a means-ends perspective
HMI	Potential for MTT support 1: • Anywi: HMI framework development
Implementation and integration	No support required
Simulation and evaluation of user related aspects	Potential for MTT support 2.: • HFC: Task analysis; Human Factors and Safety regulations and guidelines for metrics; • HFC: Tests for Cognitive Task Models. • ERG: Dikablis (Head-mounted eye tracking system) • RE:LAB: Empirical validation methods in simulators • SNV: Empirical analysis and validation methods of cognitive and communicative processes in automotive and control room domain

4.7 WP6_HEA_MRI_UC02b_robust_ECG_triggering

Lead: Philips (MRI)

4.7.1 State of the art

4.7.1.1 System Architecture

The Guided Patient Positioning System is integrated in the Philips MRI systems

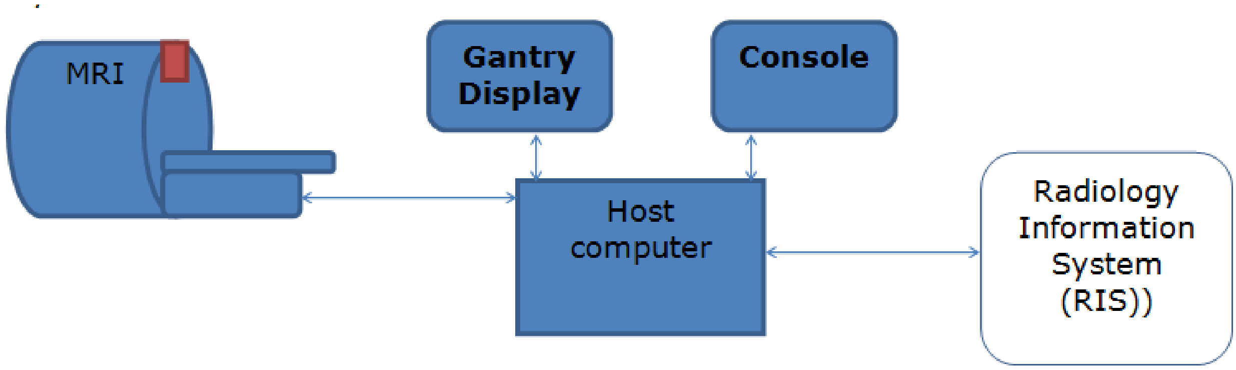

Figure 17 Simple diagram showing the connections of Console and the Gantry display with the MRI system.

Note that the display is physically on the front of the MRI magnet (indicated in red). The physiology traces can be displayed on both the Gantry Display and on the Console.

4.7.1.2 Applied technology in the system

General:
- Standard computer interfaces (Ethernet)
- HTML5
- C / C++ / C#

UI technology:
- Touch control on the Gantry Display (like on tablets).
- To be considered: Voice control, gesture control

Data processing:
- Home built real-time adaptive ECG filtering

4.7.1.3 Applied design tooling

- Requirement management: HP Application Lifecycle Management
- SW management system: ClearCase (Rational)
- No specific graphic design tooling
- No specific filter design tooling

4.7.1.4 Analysis & feedback tooling

- Log-file analysis tooling: Ruby scripts
- Usability analysis tooling: questionnaires, interviews, observations
- Internal defect tracking (during development): ClearQuest
- External defect tracking (after release): TrackWise

4.7.1.5 Tool / design workflow relations

See Figure 12.

4.7.1.6 AdCoS Description

System for real time acquisition of physiology signals from the patient to derive trigger signals required during MRI scanning.
Acquired signals:

- VCG (Vector Electro Cardiogram, via sensors on the chest)
- PPU (Peripheral Pulse Unit, typically via a finger clip)
- Respiratory (via sensor on the chest)

The system displays the signals, allowing the operator to judge the quality, and all data are logged for off-line analysis.

Many MRI scans require synchronization on the cardiac motion, either to minimize motion artefacts due to the motion of the heart itself or the pulsatile blood flow.
Two methods are available:

- VCG (Vector-ECG) signals, derived from electrodes on the patient's chest
- PPU, peripheral pulse unit, which measures the oxygen level in the fingertip.
-

The VCG signals are accurately linked to the cardiac motion and are needed if images are taken close to or of the heart. In that case trigger pulses are derived from the signal, either to directly synchronize the scans or to administer the timing together with the MR data collection, used to retrospectively align the MR data with the ECG signal.

Detection of the ECG signal during MR scanning is complicated because of the following effects:

- The ECG signal is distorted because blood flow in the presence of a strong magnetic field creates significant potential differences, which interferes with the normal ECG signal
- Fast gradient switching induced additional potential differences in the body, which easily can be much larger than the normal ECG signal

Filters are available to deal with these issues. However, positioning of the electrodes in relation to the physiology of the patient and respiratory motion are still important sources for distortion.

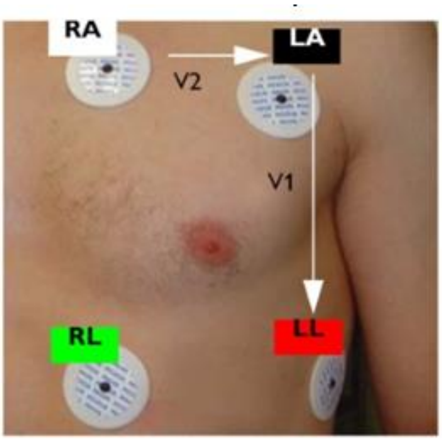

Figure 18 Placement of the ECG electrodes

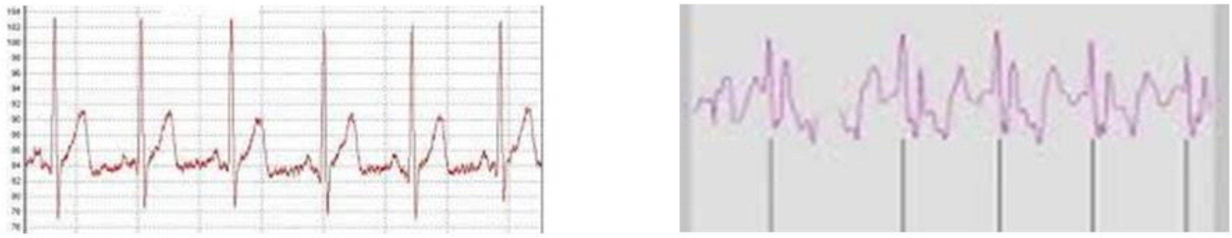

Figure 19 Left: Clean ECG signal outside the magnet, right distorted ECG signal in the magnet due to MHD effect in combination with blood flow

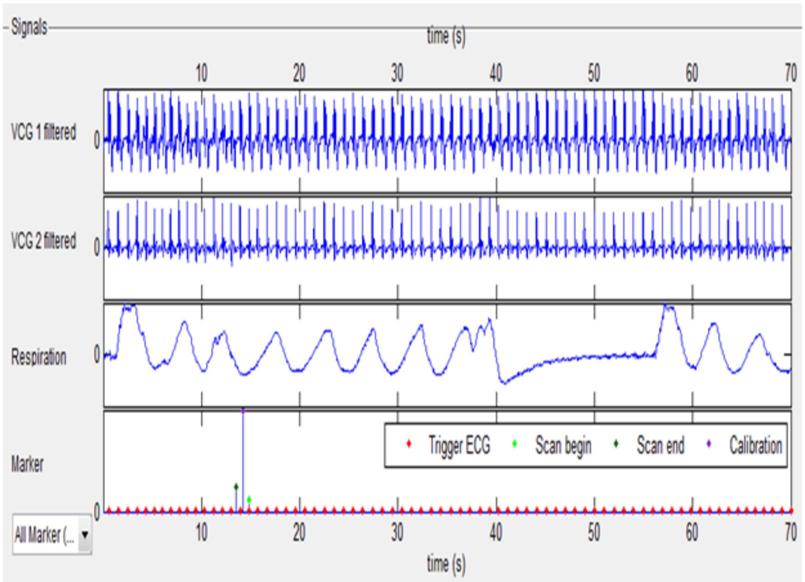

Figure 20 Example physiology display

Figure 20 shows the following: from top to bottom: two ECG traces, one respiratory trace, and the red trace with trigger signals. Note that this was a breathhold scan, as can be seen from the respiratory signal

4.7.2 Unmet needs

The design process, including validation of intermediate and final solutions, is hardly supported by tooling. It is therefore very likely that some tooling in the HF-RTP can be applied and can lead to a more structural and repeatable design process.

Required MTT Support:

1. **Improved operator guidance** based on analysis of acquired data during patient positioning and scanning.
2. **Off-line data analysis** to identify patterns in the acquired signals trying to relate this to the success or failure of successful triggering, and to patient characteristics (like weight).
3. **Simulation environment** to study the generation of trigger signals derived from all available input data (ECG signals, PPU signal, respiratory signal, patient characteristics, ..)

4. **Real time data analysis and system control**, including adequate feedback to the operator, based on all available input signals (ECG, PPU, respiratory, scan status, …)

In the next paragraph the selection of methods, tools and techniques from the HF-RTP needs is discussed.

4.7.3 Tool selection

From the list of available methods, tools and techniques in the HF-RTP, as presented in chapter 2, the following preliminary selection is made. This selection is based on the needs as discussed in the previous paragraph. This is intended as the first estimate, based on available descriptions of the tools; the actually applicability of the MTT for this AdCoS needs to be explored in the next phases of the project. The table below refers to the *Required MTT Support* list in the previous paragraph.

Step of the tool-chain	Tools and techniques to be explored
Requirements definition and tracking	No support required
Modelling of tasks, agents, UI and interaction	Potential for MTT support 1 and 4: • OFFIS: Human Efficiency Evaluator. • Anywi: Modelling of AdCoS data from a means-ends perspective
HMI	Potential for MTT support 1 and 4: • Anywi: HMI framework development
Implementation and integration	No support required
Simulation and evaluation of user related aspects	Potential for MTT support 1: • HFC: Task analysis • HFC: Tests for Cognitive Task Models. • SNV: Empirical analysis and validation methods of cognitive and communicative processes in automotive and control room domain Potential for MTT support 2 and 3: • UTO: data analysis

4.8 WP6_HEA_MRI_UC03_safe_parallel_transmit_scanning

4.8.1 State of the art

4.8.1.1 System Architecture

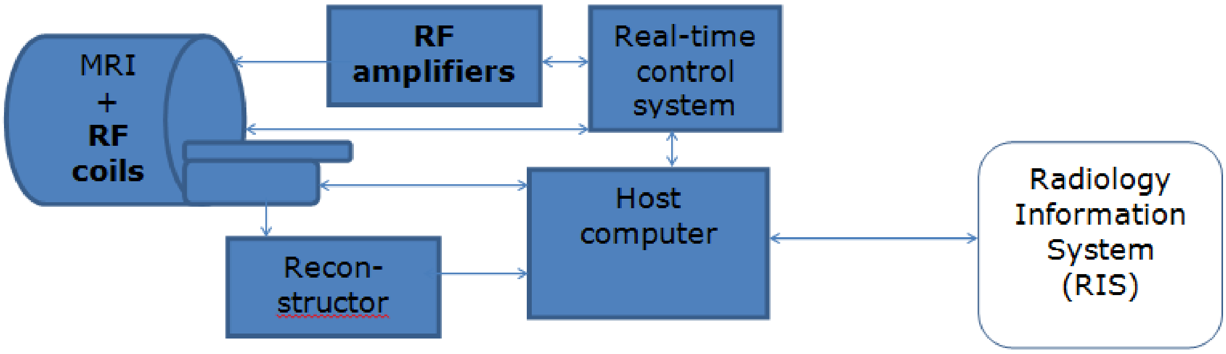

Figure 21 Simple diagram showing parallel transmit scanning system.

4.8.1.2 Applied technology in the system

- Standard computer interfaces (Ethernet)
- C / C++ / C#
- GPU cards
- IP/TCP
- Electromagnetic numerical solvers
- RF hardware

UI technology:
- UI elements on the console (e.g. pop-ups, dialogues, icons, …)

4.8.1.3 Analysis & feedback tooling

- Log-file analysis tooling: Ruby scripts
- Validation experiments using synthetic data sets allowing validation of system predictions.
- Experimental validation on a limited number of subjects/phantoms using EM field probes, MR thermometry to validate the RF heating predictions.

- Operator observation, questionnaires and interviews.

4.8.1.4 AdCoS Description

To optimize the MR image quality for certain anatomical regions, a so-called phased antenna array is used in 7T head imaging. A set of (e.g. 8) RF amplifiers each connected to a coil element (antenna) provides the transmit field to generate MR signal. Each channel is independently modulated: optimal phase, frequency and amplitude modulation should lead to the required excitation of part of the patient, e.g. homogeneous (same signal from all parts of the brain), or spatially focused (e.g. only signal from the spinal cord).

However, this temporal modulation of the RF signals alters also the spatial interference of the concomitant electric fields resulting potentially in unsafe RF induced tissue heating (microwave heating effect) at certain body location. The electric fields and heating cannot be detected directly with MRI and their spatial patterns are highly patient specific due to the complex electromagnetic interaction of RF signals with the human body. The RF power absorption can only be determined by means of electromagnetic simulations employing dielectric models of the scanned subject.

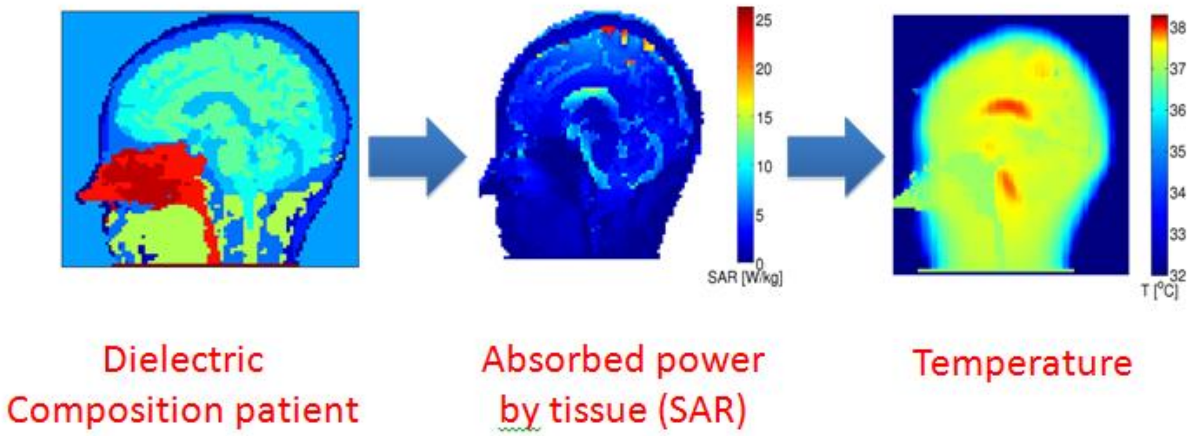

Figure 22 Relation between various calculated maps of field in the patient

The AdCoS consists of the following parts:
- Tool to calculate the dielectric composition of the patient
- Tool to calculate the local absorption of RF energy in the patient

- Tool to calculate the local temperature change in the patient
- Mechanism to adjust the RF transmit system based on calculated temperature map, taking safety limits into account
- UI elements to communicate the status and required actions to the operator
- Control elements to run-time monitor the status of all elements in the RF transmit chain
- Mechanism to generate an interlock followed by a scan abort if any malfunction is encountered

The AdCoS makes use of the general capabilities of the MRI system to calibrate average RF power and to scan a series of scans and real-time generate images.

4.8.2 Unmet needs

The design process, including validation of intermediate and final solutions, is hardly supported by tooling. It is therefore very likely that some tooling in the HF-RTP can be applied and can lead to a more structural and repeatable design process.

Required MTT Support:

1. **Modelling of physiology and human heating,** connecting measurements and theory.
2. **Analysis of operator actions and use patterns** to access the effectiveness of safety related user interaction
3. **Modelling of the AdCoS** to have a clear overview of the system and the user interaction

In the next paragraph the selection of methods, tools and techniques from the HF-RTP needs is discussed.

4.8.3 Tool selection

From the list of available methods, tools and techniques in the HF-RTP, as presented in chapter 2, the following preliminary selection is made. This selection is based on the needs as discussed in the previous paragraph. This is intended as the first estimate, based on available descriptions of the tools; the actually applicability of the MTT for this AdCoS needs to be explored in the next phases of the project. The table below refers to the *Required MTT Support* list in the previous paragraph.

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	Potential for MTT support 1: • UTO: greatSPN: physiology & human heating modelling & analysis
Modelling of tasks, agents, UI and interaction	Potential for MTT support 3: • SNV & TEC: Analysis of system and operator actions from log files • Anywi: Modelling of AdCoS data from a means-ends perspective •
HMI	Potential for MTT support 3: • Anywi: presentation of data in UI
Implementation and integration	No support required
Simulation and evaluation of user related aspects	No support required

4.9 WP6_HEA_iXR_UC01_3D_acquisition

Lead: Philips (iXR)

4.9.1 State of the art

System Architecture
The 3D acquisition tool is integrated in the Philips Angiography system. The acquired data is used by a connected 3D workstation that contains tools to render and process the data.

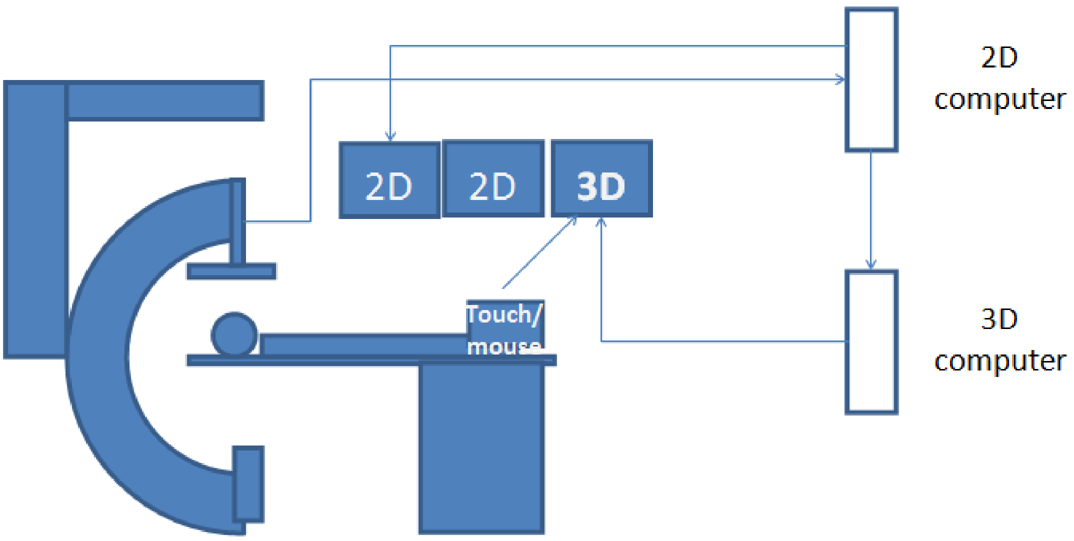

Figure 23 Overview of the product agents in the AdCos

Applied technology in the system

General:

- Standard computer interfaces (Ethernet)
- Proprietary interfaces
- C / C++ / C#

UI technology:

- Touch and mouse control at the patient table
- To be considered: Voice control, gesture control

Applied design tooling

- Document management: Agile

- SW management system: ClearCase (Rational)
- No specific graphic or hardware design tooling

Analysis & feedback tooling

- Log-file analysis tooling: RADAR
- Usability analysis tooling: questionnaires, interviews, observations
- Internal defect tracking (during development): ClearQuest
- External defect tracking (after release): TrackWise

Objective

With help of good design our objective is to make users become more confident and efficient in acquiring and using 3D data. An example of adaptability is to play with level of user guidance, target information to the right users concerned with the related task and remember repetitive actions/preferences.

As a consequence we define the 3D Acquisition AdCos as a variable system of acting agents that consists of user agents and the product agent. Variability is in the roles of different users, order in which they perform tasks, skills they have, the way they are organized to work with 3D acquisitions and feedback provided by the product agent based on detected events.

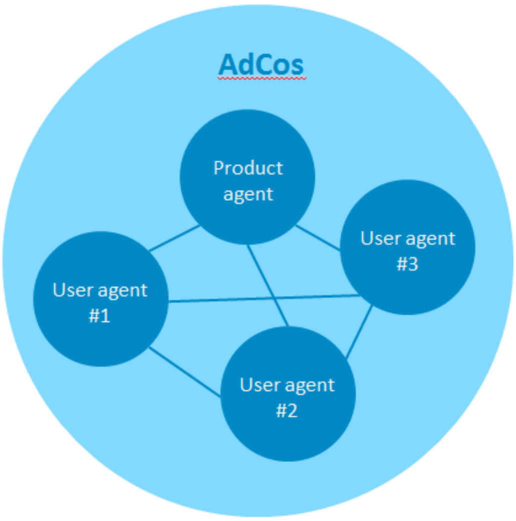

Figure 24 Overview of the AdCos

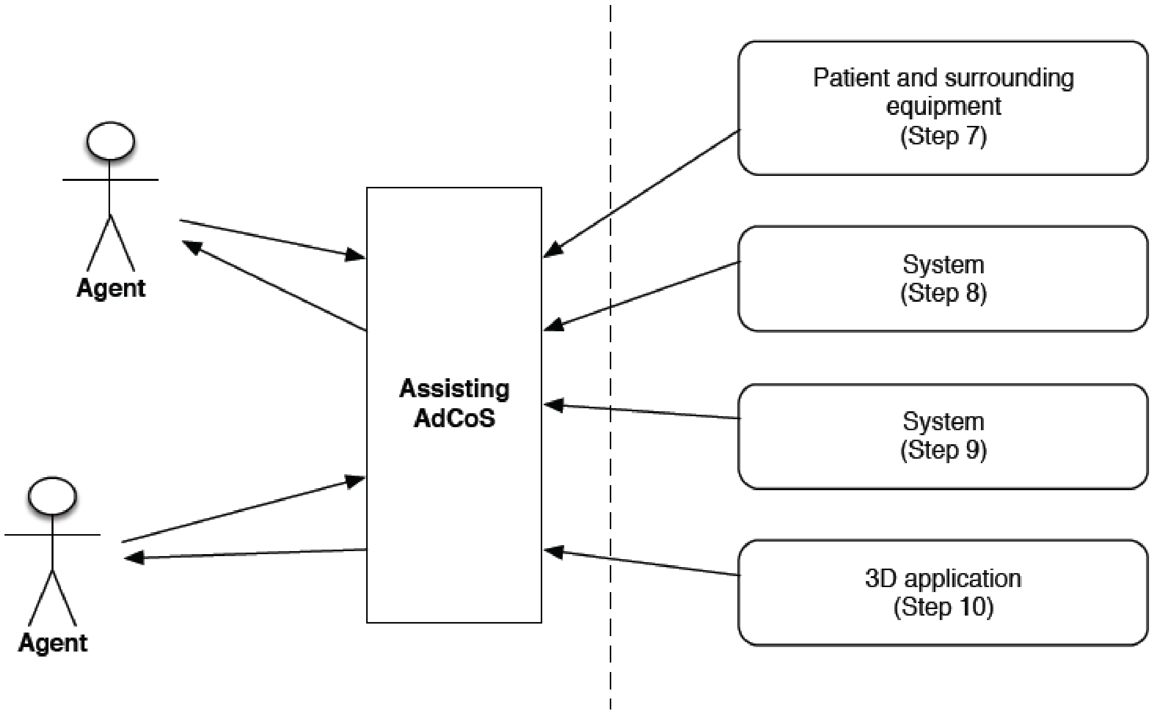

Figure 25 Other view on the AdCos as an 'assisting' system

4.9.2 Unmet needs

The design process of ***adaptive*** user interfaces, including validation of intermediate and final solutions, is hardly supported by tooling. It is therefore very likely that some tooling in the HF-RTP can be applied and leads to a workable design process.

4.9.3 Tool selection

Step of the tool-chain	Tools and techniques used
Requirements definition and tracking	• No tools found
Modelling of tasks, agents, UI and interaction	• PED: Helps to model 3D acquisition tasks and present only relevant information for the current task. Simulation helps testing the design. • EAD-FR: HGRAPH / Analysis of operator, patient and nominal interaction (based on patient characteristics and type of examination). Assess current operation and provide dynamic guidance according to the context. • Human Efficiency Evaluator: Integrates Task Editor, SCXML and CASCaS. Can be used as inexpensive way to do user testing of different solutions without need for access to hard to find target users. Allows to compare efficiency of different designs.
HMI	• CASCaS: Simulate user behaviour in a 3D acquisition procedure to get first feedback about possible interaction problems. • Tobii glasses
Implementation and integration	• LEA
Simulation and evaluation of user related aspects	• FaceLab 5 + Eyeworks software • HFC: Task analysis; Human Factors and Safety regulations and guidelines for

	metrics; • HFC: Tests for Cognitive Task Models. • ERG: Dikablis (Head-mounted eye tracking system) • RE:LAB: Empirical validation methods in simulators • SNV: Empirical analysis and validation methods of cognitive and communicative processes in automotive and control room domain

5 Conclusions

In this document an overview of the tools in the HF-RTP is given and the Healthcare AdCos's are described. A first step of the tailoring process consists of mapping the available tools on the AdCos's. As such, for each AdCos an inventory is made of which tools and services from the HF-RTP can be used in the steps of the tool chain and how they will help improve the current way of working.