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

D6.6 Tailored HF-RTP and Methodology Vs1.5 for the Healthcare Domain

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Executive Summary

The following document describes the process of adaptation of the HF-RTP, which is being developed in the HoliDes project (WP1), to the Healthcare domain, with a special focus on the description of the AdCoS and tool chains developed by the partners. It is the follow up deliverable of D6.4. It is explained how the tailoring methodology provided by WP1 is applied in the Healthcare Domain.

This document is the result of many collaboration activities between the AdCoS developers in WP6 and the method tools and technology (MTT) providers in WP 2 to 5. There are many MTTs in HoliDes but not all of them are relevant for every AdCoS. Those which can assist in the Healthcare domain design processes are listed here.

1 Introduction

This deliverable describes how the Human Factors Reference Technology Platform (HF-RTP) methodology Vs1.5 and the HF-RTP, which are being developed in WP1, are applied and tailored in the Healthcare domain. In particular, it focuses on the application of the tailoring rules provided by WP1 and defined in D1.4.

1.1 Objective of the document

Deliverable D6.6 describes the results of the HF-RTP tailoring methodology applied to the Healthcare domain for the third project cycle, see Figure 1

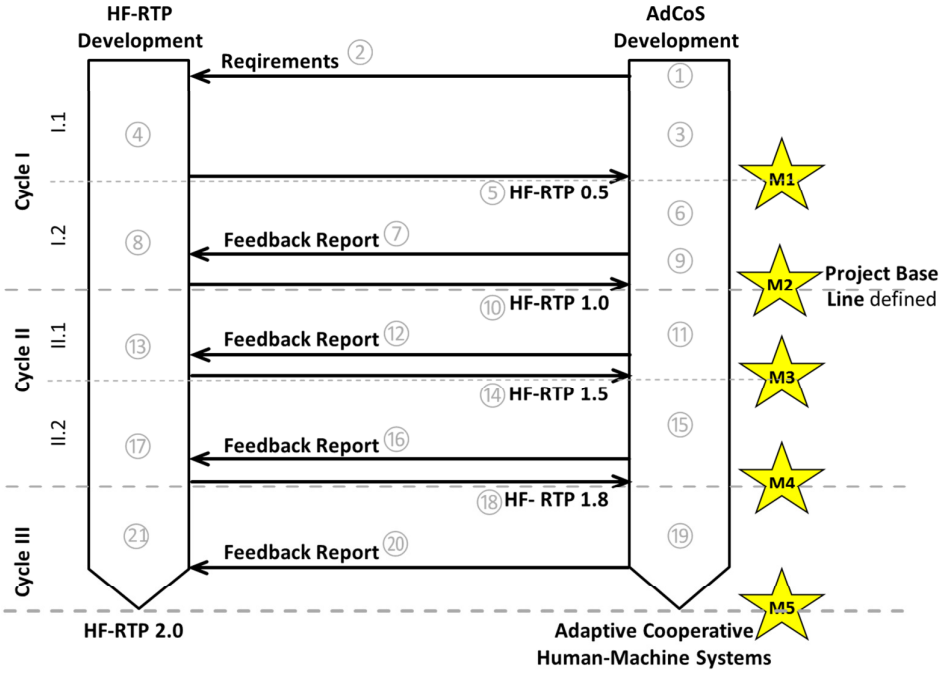


Figure 1: Overall workflow taken from the HoliDes proposal.

The HF-RTP and the tailoring methodology (version 1.5) developed in WP1 and delivered in D1.4 are applied to the AdCoS of the Healthcare domain. The previous version for tailoring of the HF-RTP in WP6 has already been provided in D6.4, which was based on the HF-RTP version 0.5 (M1).

1.2 Structure of the document

The document starts with short introductions about meta modelling, tailoring steps and the platform builder tool. In chapter 5 a brief overview and update is given of the Healthcare AdCoS's. Chapter 6 describes in detail the relevant tools in the HF-RTP which have been used in the Healthcare AdCoS. The document concludes with a short summary, conclusions and an outlook of planned activities.

2 Meta Modelling

The Common Meta Model (CMM) is intended to be a logical data model used for the exchange of components in a Human Factors reference technology platform. It covers all of the 4 domains (Control room, Aerospace, Automotive, and Healthcare) albeit in different levels of granularity. Figure 2 shows the Common Meta Model as proposed by Work Package 2.

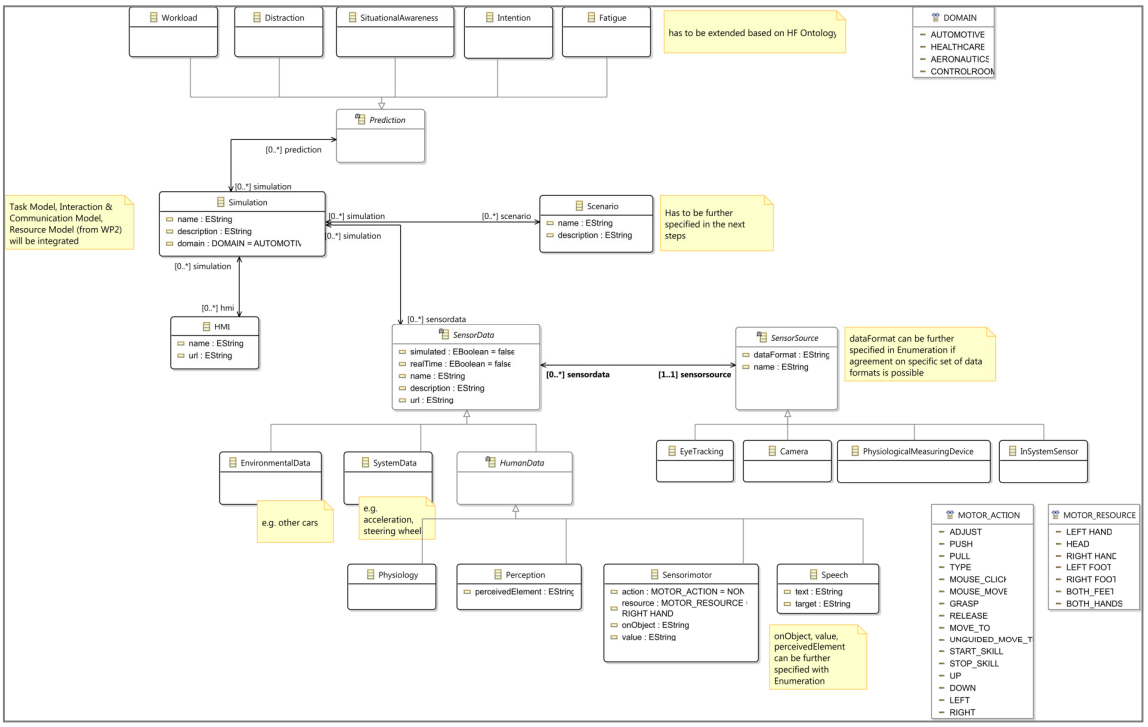


Figure 2 The Common Meta Model from WP2

The current Common Meta Model is largely focussed on Automotive, addressing human machine interaction related to motor actions. In WP6 no references have been made to the meta model.

3 Tailoring Steps

The tailoring steps have been described in D1.4. In brief they are:

1. Identification of the purpose of the project and the used tool chain
2. Selection of methods and tools
3. Definition of semantics and information mapping between methods and tools
4. Implementation of information models and connectors.

In deliverable D6.4 an intermediate description has been given about how the tailoring rules are applied in the Healthcare AdCoS. The WP6 partners are still following the proposed tailoring steps. Steps 1 and 2 have been finalized, all partners have selected the methods and tools they will use in their AdCoS or AdCoS development process. Partners are working on the connection between methods & tools and integrating it in their AdCoS process (step 3) now and are preparing for step 4.

3.1 Revisions to the tailoring steps

No revisions have been made to the tailoring steps as described in D1.4.

3.2 Feedback on the tailoring steps so far

The tailoring steps are in use as proposed. No additional feedback has been received.

4 Platform Builder

The platform builder in HoliDes from WP 1 has been made available through the HoliDes website. www.holides.eu/PlatformBuilder
Figure 3 shows the login to the platform builder.

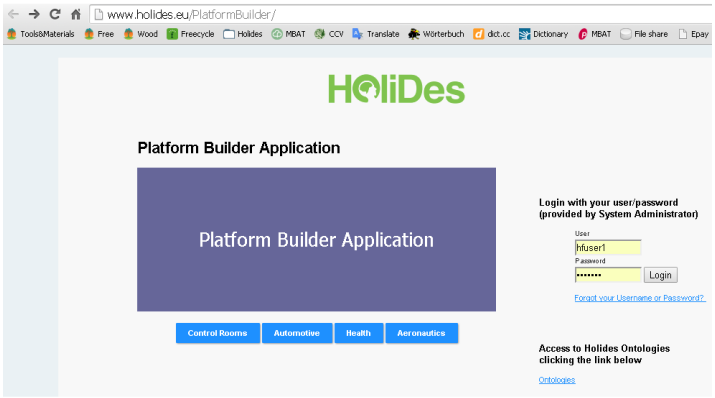


Figure 3 - The Login Screen for the Platform Builder

The idea behind the platform builder is to allow someone developing a tool chain to see what is available in the human factors domain and let the developer make an informed decision as to what is available for them to use.

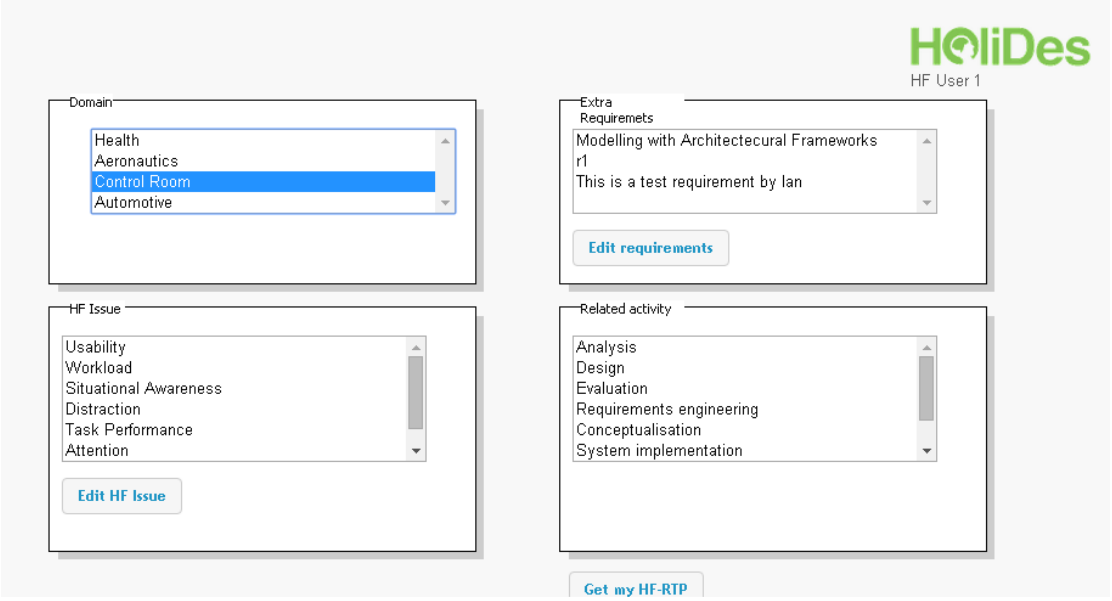


Figure 4 Screen for the querying of Methods Techniques and Tools (MTTS)

Figure 4 shows the screen for querying the MTTS. The idea is that one selects the domain in which they are interested in.

4.1.1 Testing the platform builder

The platform builder (PB) tool has been tested by checking the PB result given various input combinations of HF-issue and Related Activity. Test results are shown in Table 1

Table 1: Platform builder test results

	HF Issue	Related activity	Platform Builder result	Comment
1	Task performance	Design	HEE	It is ok.
2	Workload	Analysis	No result	At least GreatSPN should appear.
3			CASCaS HF-Guideline generic Theatre technique for acceptance test	It is not easy to understand the comparison

4	Usability	Analysis	No result	

The general functioning of Platform Builder is intuitive and full evaluation would be performed when the matureness of implementation is completed (currently a prototype implementation is provided). However, we provide the following feedback that would be useful for the next step of the implementation:

- On the search form (PB input menu), it would be good to show only the available options for the domain or HF issue selected. For instance, if there are no MTT for "safety" issue in Health domain, it is better that safety option is not listed or draw it in another color.
- The access to Documentation is important to understand the managing of the tool. Currently the documentation is not ready.
- The comparison of tools is not easy to read. It would be better to use a table with one column per MTT

The name "Platform Builder" suggests that it can or will create a platform to build a tool set on. This may be the target for a final version, but the current version only shows one or more tools if you select the right combination of *HF issue* and *Related Activity.* As such, in the current form, the Platform Builder does not offer more functionality than the excel sheet with a list of all available tools + descriptions.

5 AdCoS Development

This chapter provides a brief update on the Healthcare AdCoS's. In Deliverable D6.4 these have been described already in more detail, therefore in this deliverable only a brief description and status update is provided.

5.1 Guided patient positioning (Philips MRI)

Overview of the AdCoS
The Guided patient positioning system provides guidance to operators of MRI scanner during preparing and positioning patients for MRI examinations. 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, operators are trained for this. The on-line guidance system intends to improve usability and to reduce risks, also in case of novice, less experienced users.

Status of the AdCoS development
Various models with different views have been made to describe the system and its functionality. AWI provided a means-end model, which presents a hierarchy starting from the concrete components of the systems. PHI made a task map and workflow graphs. EAD-F is working on a model to capture the adaptive aspects of the system. Discussion with HFC is ongoing regarding user tests, which may be used as input for the user tests facilitated by U-DAT of PHI (User Test – Data Acquisition Tool).

5.2 Safe parallel transmit scanning (UMCU)

Overview of the AdCoS
The MRI parallel RF transmit system is a rather sophisticated platform, therefore there is a need for a clear user interface. In addition, the power deposition in the patient's body has to be monitored, to avoid heating of the patient. SNV will apply Empirical Analysis tool to this problem and the UMC Utrecht team will develop a fast procedure to estimate the SAR in a patient specific way. The first step in this direction will be the construction of a database of numerical patient models.

Status of the AdCoS development

SNV has designed a test to help developing the parallel transmit interface. This approach is based on a "focus-group", that is, no more than five to eight people who are MRI operators without experience of transmit systems. The idea of Empirical Analysis is to collect ideas and fruitful discussion from all participants in the test. A moderator and an assistant moderator lead the focus group through each session. Information about each participant's background and behaviour during the test is recorded. Tape recordings will be taken. In addition, a list of questions for the participants has been assembled to lead them through the testing process.

5.3 Robust VCG triggering system (Philips MRI)

Overview of the AdCoS

ECG triggering is often required during MRI scans to avoid image artefacts due to motion of the heart or blood flow. However, it is not very easy to obtain reliable trigger signals, since both the magnetic field and the scanning techniques distort these signals. Additional guidance for the operator is required during patient preparation and scanning to improve the reliability.

Status of the AdCoS development

PHI created an extensive task map, showing the hierarchy of tasks. This is used as input for an Axure model (PHI) that simulates the user interface and is used for early usability evaluation. U-DAT (PHI) is applied to facilitate the user tests. Discussions with HFC are ongoing to determine if this can be connected to their validation and test methods. The HF-filer (AWI) is intended to be applied to store the results.

5.4 iXR 3D Acquisition (Philips iXR)

Overview of the AdCoS

The iXR 3D Acquisition AdCoS is about the use of an X-ray angiography system during minimally interventional treatments. X-ray image guidance is used and to allow better visualization of the anatomy and planning of the treatment, a 3D rotational scan is made. Performing such a 3D scan is very complex and requires highly skilled personnel.

It is the aim of this use case to develop an AdCoS that eases the 3D scan procedure by developing an improved HMI that greatly simplifies the workflow.

Status of the AdCoS development

After a thorough task analysis of both the existing and new UI these task models have been shared with OFF and HFC. OFF has used the task models to derive from them a virtual work environment in which all relevant tasks for the 3D acquisition can be simulated and cognitive loads can be calculated to compare the efficiency of both UI versions. HFC has analysed the task models and is preparing the next steps for empirical task analysis.

PHI has worked on first prototypes of the new User Interface for 3D acquisition. The prototype has been shown to end users for first evaluation of the new workflow and to check how the new workflow is appreciated.

5.5 Querying openEHR data (ATOS)

Overview of the AdCoS

The main objective of this AdCoS is to **improve diagnostic process and treatment** of the patient, for that purpose, the system keeps patient EHR updated and complete, due to two different approaches:

1. From professional perspective: This AdCoS provides effective and fast access to patient clinical data, PHR (Patient Health Record), by any authorized physician at any location. This PHR contains data like demographic details, habit patterns, family history and several patient studies (DICOM images) provided by the hospital environment (HIS-Hospital Information Systems) like Radiological studies.

2. From patient perspective: This AdCoS provides effective remote access for the patient to his or her PHR. In addition, the patients are allowed to modify some data like demographic, habits or personal details in order to keep their information as updated as possible.

Status of the AdCoS development

The status of the AdCoS development is as follows,

1. Human Efficiency Evaluator (HEE) from OFF has been used to improve the model of this AdCoS as described in D6.5. At this moment, HMI functional modelling analysis is under investigation, further details will be provided.

2. Modelling the AdCoS from a means-end perspective has been used during the design phase. This approach facilitates the implementation stage of

the AdCoS by taken into account the human factors related to the end user.

3. AEON as the cloud message management platform to be used, in order to communicate the data between the modules (yourEHRM and the tablets/web applications, sensors, etc). The architecture followed is explained in section 6.6.

4. Data race detector & healer has been used to find inconsistencies in the java source code and to detect and heal data races and atomicity violations in the use of the GUI (same doctor accessing the same EHR or image). Further details in section 6.7.

5. The HF-filer will be used for the validation process, we will start evaluating the tool in the coming months.

5.6 Internal analysis and reporting (ATOS)

Overview of the AdCoS

Internal analysis and reporting AdCoS generates clinical reports based on data coming from heterogeneous and fragmented healthcare information systems.

In D6.5 the main objective of this AdCoS have been defined:

1. **Generate 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. This report is internal to the hospital and includes risk analysis, predictions, etc.

2. **Generate patient clinical report**: The system allows generating patient clinical reports in order to provide a general overview of his/her health status. This report includes clinical patient data. MRI, Lab Tests, prescriptions, etc., any EHR data that the professional considered desirable.

Status of the AdCoS development

From D6.4 it was planned to use some identified tools. The status of the AdCoS development and integration is as follows,

1. The Human Efficiency Evaluator (HEE) from OFFIS had been used to improve the model of this AdCoS as described in D6.5. At this moment, HMI functional modelling analysis is under investigation, further details will be provided in D6.7 - Implementation of the Health AdCoS and HF-RTP Requirements Definition Update (Feedback).

2. Modelling the AdCoS from a means-end perspective has been used during the design phase. This approach facilitates the implementation stage of the AdCoS by taken into account the human factors related to the end user.

3. Data race detector & healer has been used to find inconsistencies in the java source code and to detect and heal data races and atomicity violations in the use of the GUI (same doctor accessing the same EHR or image). Further details in section 6.7.

4. The HF-filer will be used for the validation process, we will start evaluating the tool in the coming months.

5. LEA: As we are using Machine Learning techniques to efficiently learn about behaviors. Currently we are gathering data sets to test the tool.

6. APA: To detect behavior patterns from the EHR data and the DICOM images. Currently we are gathering data sets to test the tool.

7. CBR: The Case Base Reasoning is widely used in eHealth environments, the application of this tool will allow to solve statistical problems based on the solution of similar cases in the past. Due to the fact that we don't have sufficient data to compare similar cases this tools has been rejected in the AdCoS.

5.7 Operator task schedule and guidance (Integrasys)

Overview of the AdCoS

The objective of this AdCoS is to ease the development of a workflow solution for medical environment (hospital) that focused in aspects related with the proper assignment of tasks in a clinical laboratory environment to operators and the ability of manage real time instructions (alarms, checkpoints, reminders). In this way, an optimisation of the workflow and the cooperation between operators is achieved.

To meet this objective a prototype implementation of a dynamic platform that helps hospital operators to carry out their daily tasks will be

developed. This platform has the functionalities of assign/re-assign tasks to operators and gives context-aware instructions to operators. For those functionalities, different user interfaces are foreseen: Tablet, smartphone, smart-watch.

In the other hand, a second objective is to implement a workflow simulation tool that helps us to pre-validate the implementation of the AdCoS, before the full implementation on real hospital is carried out.

Status of the AdCoS development

We advance in the modelling of the use case and provide a model of our AdCoS, with several diagrams: GreatSPN, UML sequence diagrams, graphical and functional mock-ups, flow diagrams and block diagrams. Simple GreatSPN models were created and the tool was assessed.

6 RTP Instance

This chapter describes for each relevant MTT why and how it is used in a particular AdCoS.

6.1 HEE

6.1.1 Usage in the 3D Acquisition AdCos

The Human Efficiency Evaluator (HEE) is a tool that is able to simulate human machine interaction and compare workflow aspects against each other. In the case of the 3D acquisition AdCoS the HEE is very useful because PHI already has an existing UI and also some ideas on how to improve a complex part of the workflow by introducing guiding elements and adaptivity.

The following steps have been taken in the 3D Acquisition use case and the use of the HEE:

1. Use case analysis (PHI)
2. Detailed task description of the existing UI (PHI)
3. Graphic representation of the existing working environment i.e. Human Machine Interface (PHI)
4. Mapping of tasks on the graphic representation of the HMI (OFF+PHI)
5. Creation of an Operator Model and an Environment Model (OFF)
6. Virtual operator simulation, calculation of workflow execution time and workload FoM (OFF) See Figure 5
7. Detailed task description of the AdCoS (PHI)
8. Graphic representation of the new UI (PHI)
9. Mapping of tasks on the new graphic representation of the HMI (OFF+PHI)
10. Creation of an Operator Model and an Environment Model (OFF)
11. Virtual operator simulation, calculation of workflow execution time and workload FoM (OFF)
12. Comparison of existing and new workflow (PHI+OFF)

Steps 2-6 and 7-11 basically are the same steps but applied to 2 different HMIs.

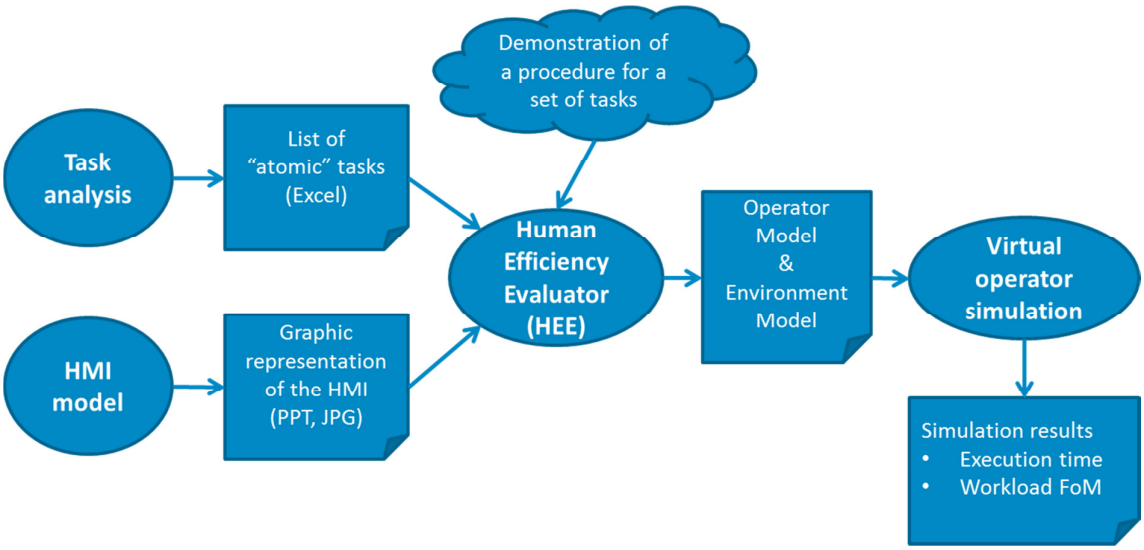


Figure 5 HEE related data flow in the 3D Acquisition AdCoS

Step 2 already has been described in earlier WP6 deliverables. Steps 3+4 have been a joint effort by PHI and OFF in which the application specific info from PHI has been captured and formalized in the HEE tool. The result is shown in Figure 6.

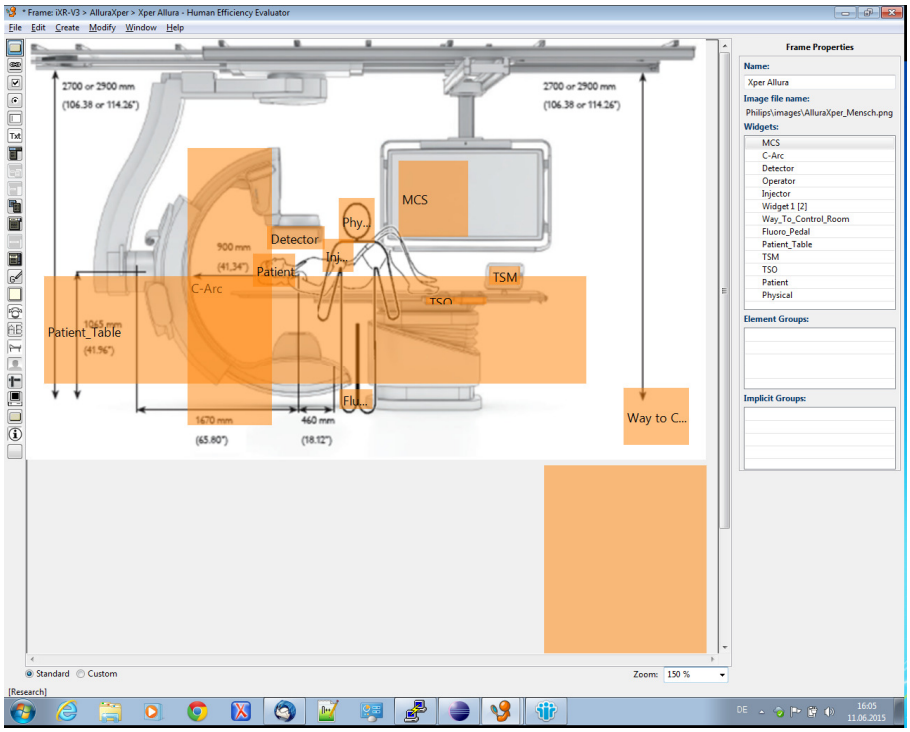


Figure 6 Graphical representation of the HMI (result of step 3)

In step 4 the individual tasks and their related UI items from the task analysis are mapped on the HMI. The results for the existing and the new UI are shown in Figure 7 and Figure 8.

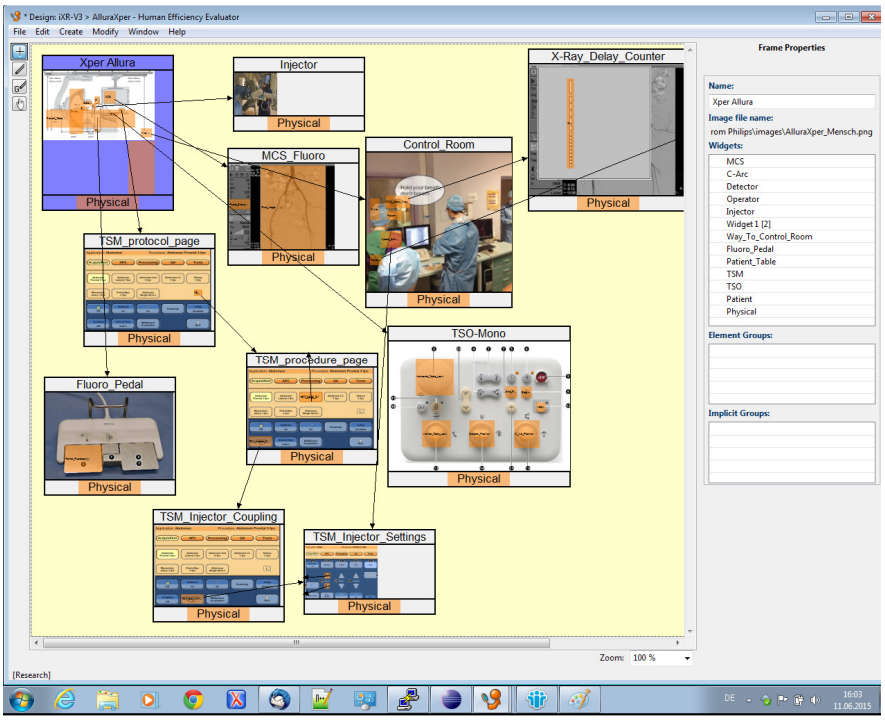


Figure 7 Mapping of UI items on HMI (old)

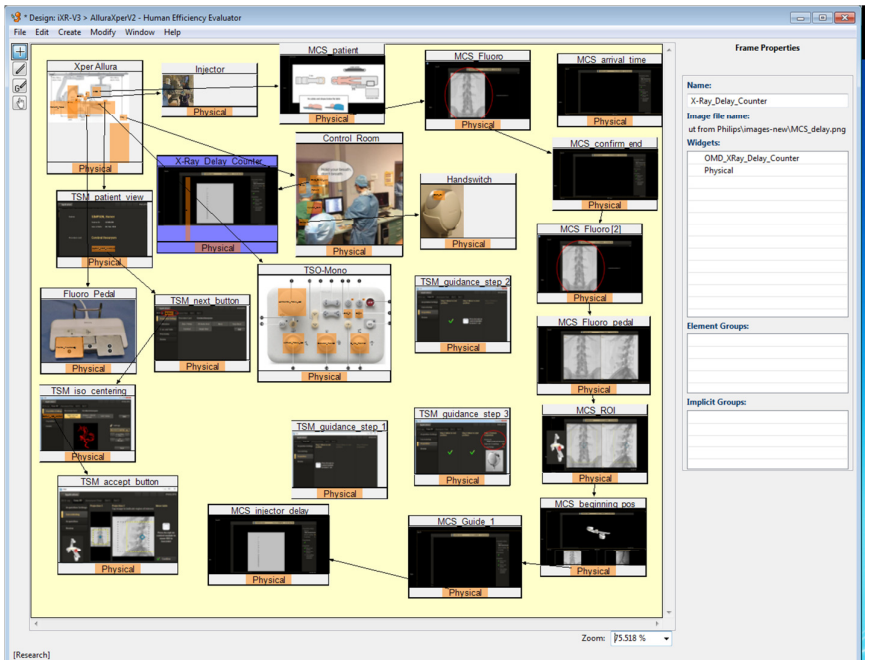


Figure 8 Mapping of UI items on HMI (new)

In step 5 an operator model and environment model are created in the HEE. This consists of a step-by-step description of a certain user scenario, i.e. preparing and making a 3D rotational scan. This results in a script that can be "played" and at the same time visualizes the user interactions with the system. See the right part of Figure 9.

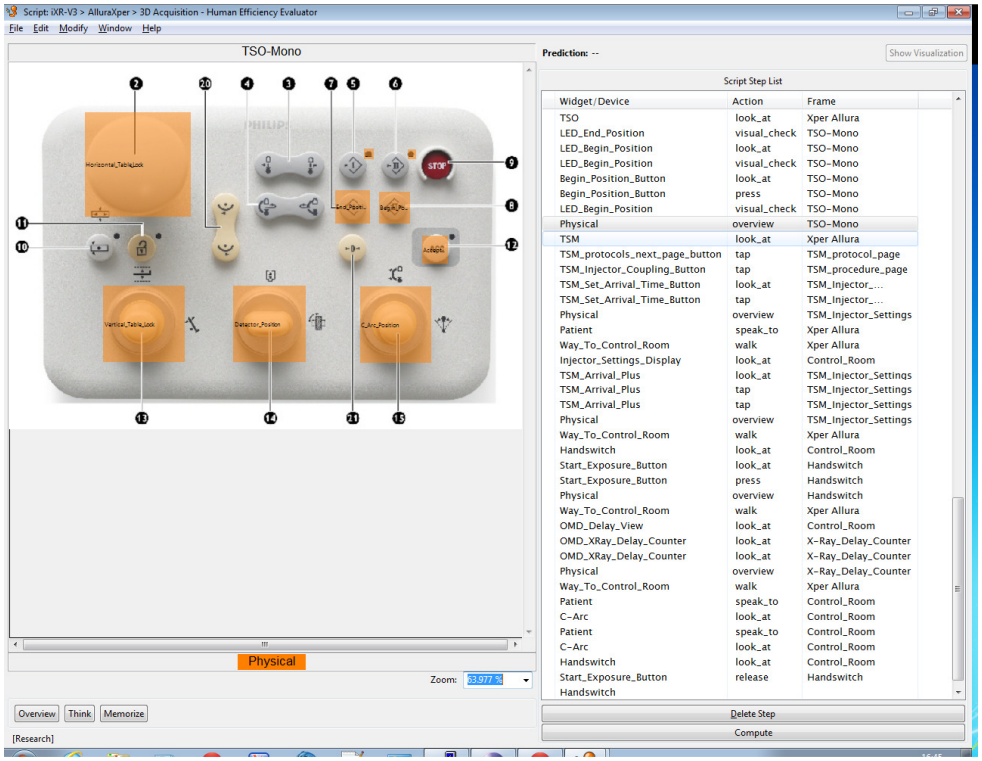


Figure 9 Example HEE script in the 3D Acquisition AdCos

<u>Expected results</u>

The HEE tool allows a quantified comparison of the proposed new UI against the existing UI and can identify bottlenecks in the workflow that require attention in the design of the new UI.

6.2 Empirical Analysis

6.2.1 Usage in the Safe Parallel transmit scanning AdCos

The safe parallel transmit scanning project follows two interacting paths. At one side, the interface for the human operator is being designed. To iteratively improve the interface, a test has been designed which makes use of a focus group. Empirical Analysis was used for the design of this test. In the following table we present the first draft of the Empirical Analysis process:

For this focus group we want no more than five to eight people (and we want to lead them through an open discussion by a skilled moderator. The idea is to have a group large enough to collect ideas and fruitful discussion but to avoid that some participants are left out.

- A focus group should last more or less one hour and half
- There should be present a moderator and a moderator assistant to tape or record the focus group.
- Take info on gender, age, their role
- Run a tape recorder during the session
- Take notes in case recorder fails or tape is inaudible
- Note/record body language
- Avoid that only one person or few persons speak

In the next table, we report the instruction of the focus group:

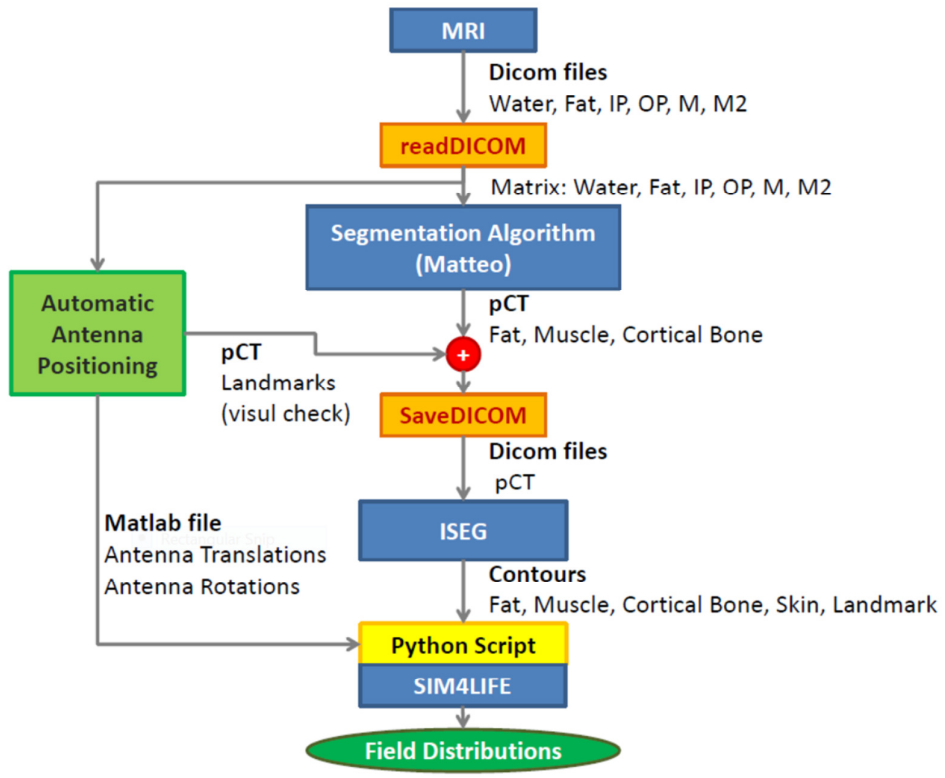
RECRUITMENT AND INSTRUCTION FOR THE PARTICIPANTS
Thank you for your willingness to participate in our focus group. We would like to hear your ideas and opinions about this new tool (you can show a picture or you can describe the tool to create a context). The information that will be collected will be used to test and improve the new tool. You can choose whether or not to participate in the focus group and stop at any time. Although the focus group will be tape recorded, your response will remain anonymous and no names will be mentioned in the report. There are no right or wrong answers to the focus group questions. We would like to hear the opinion from everyone.
Questions and "suggestions to keep the conversation" 1) We know you are familiar with interfaces like this or similar to this one. 2) How often do you use it? 3) As you can see this interface changed with respect to the previous ones… 4) Did you see the differences? Can you tell me if they improved the tool or not? 5) Which are the features that improved the tool? 6) Which are the features that worsen the tool? 7) What do you think of the graphic 8) What do you think of the position of the elements in the interface 9) What do you think of the steps to start the process

10) Which kind of suggestions you have

11) How much time did you need (do you think you need) to learn how to use the tool properly?

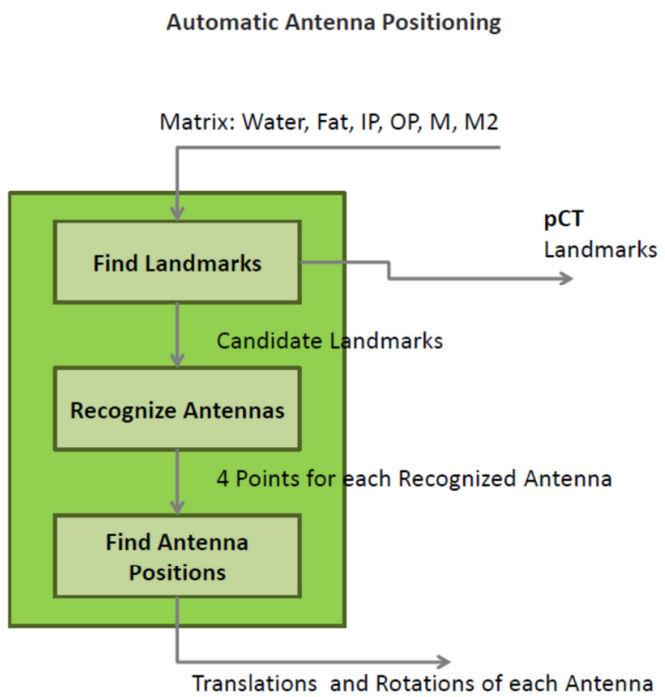
Thank you for your participation and for the useful information you provided to us. Do you want to add anything else?

In parallel to the test design, new steps have been taken to extend the patient specific SAR database. This part of the project is relevant for the desing of the user interface (see previously reported part). A number of patient scans have been processed into numerical models. Electromagnetic simulations have been run for all the new models and stored in the database. This work will continue during the next months, bringing the population size to about 50 elements.
The next two figures illustrate the progresses achieved in the past two months.
First, the workflow of the whole patient model construction is shown (Figure 10). Afterwards, the solution strategy for the coil positioning problem is presented (Figure 11).



A human subject undergoes MRI scanning with a parallel transmit array. The data is processed through segmentation to obtain a digital model. Meanwhile, the actual positioning of the parallel transmit antennas is automatically performed (steps are illustrated in the following figure). At the end, the patient model and the antenna array are fed into the SAR simulator (SIM4LIFE software). These steps are repeated for each patient. 50 patients are expected to be scanned and processed according to this scheme.

Figure 10 The Building of a numerical model and the corresponding SAR simulation



Each antenna contains four landmark, that is, tiny elements filled with water which react with the MRI scanner to emit a signal. The landmarks are automatically recognized and a set of candidate points is formed. Since each antenna contains exactly 4 points at fixed reciprocal distances, the spurious ones are discarded and the antennas are recognized on the basis of the true landmarks. Finally, the actual position of the antenna gives the translation and the rotation with respect to the reference.

Figure 11 Solution strategy for the automatic Antenna positioning problem

The data from the first few patients have already been processed. We are acquiring more experience with the procedure and we expect to complete the database within the next few months. Note that the processing of a patient takes about one day. In addition, patients have to be scheduled for MRI exam (the first step in the chain). This implies that time is needed to find the patients and to scan them. This step is clearly not automatable.

6.3 GreatSPN

6.3.1 Usage in the Operator Task schedule AdCos

In previous deliverable D6.4 we analysed the use of the GreatSPN tool for this AdCoS. Petri Net is a good candidate for task modelling. Basic Petri nets (usually referred to as place-transition nets) were used to create models for clinical guidelines. They are easy to learn and the diagrams are easy to understand. Petri nets are based on graph theory, and thus can be defined mathematically. The simplest Petri net modelling tools have some level of simulation capability, which really helps in verifying that the model captures what was expected. However Basic Petri nets cannot model every aspect of clinical processes. For example, they do not handle well time, rules, data, or complex control-flow sequences well. Fortunately GreatSPN is based on *Generalized Stochastic Petri Nets and their colored extension: Stochastic Well-formed Nets*. GreatSPN approach also allows for performance analysis and resource allocation optimization.

Some scenarios were analysed in deliverable 6.5 and also, models of these scenarios in GreatSPN were included. Further detail can be found in D6.5. The first model represents the preparation of reagents and quality controls of liquids in the Automated Laboratory of Biochemistry General (SAR) of the Hospital Macarena of Seville. It is represented in Figure 12.

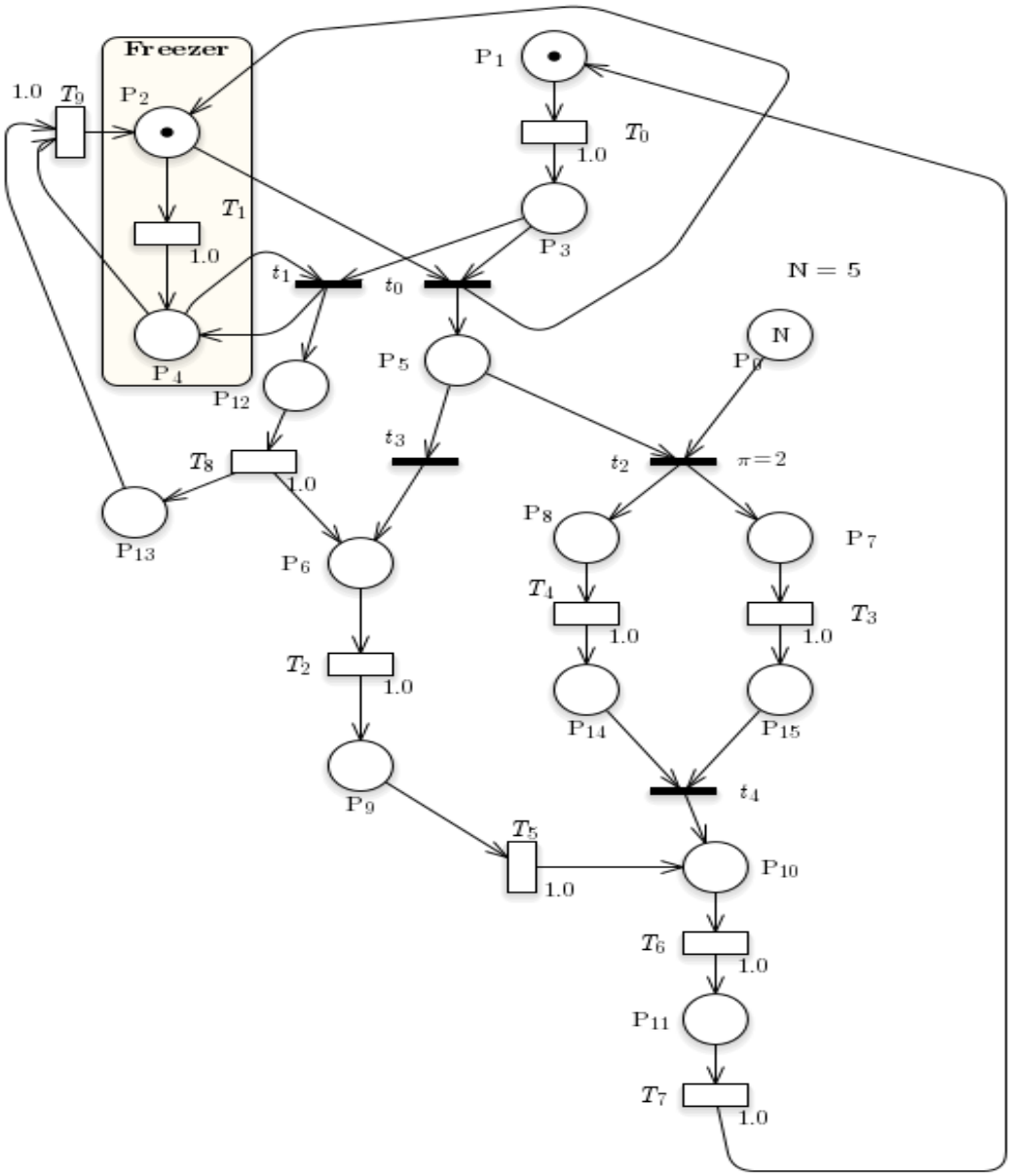


Figure 12: GreatSPN model of reagent and QC liquids preparation procedure

The second model represents the protocol for the quality controls review. It is illustrated in the following Figure 13.

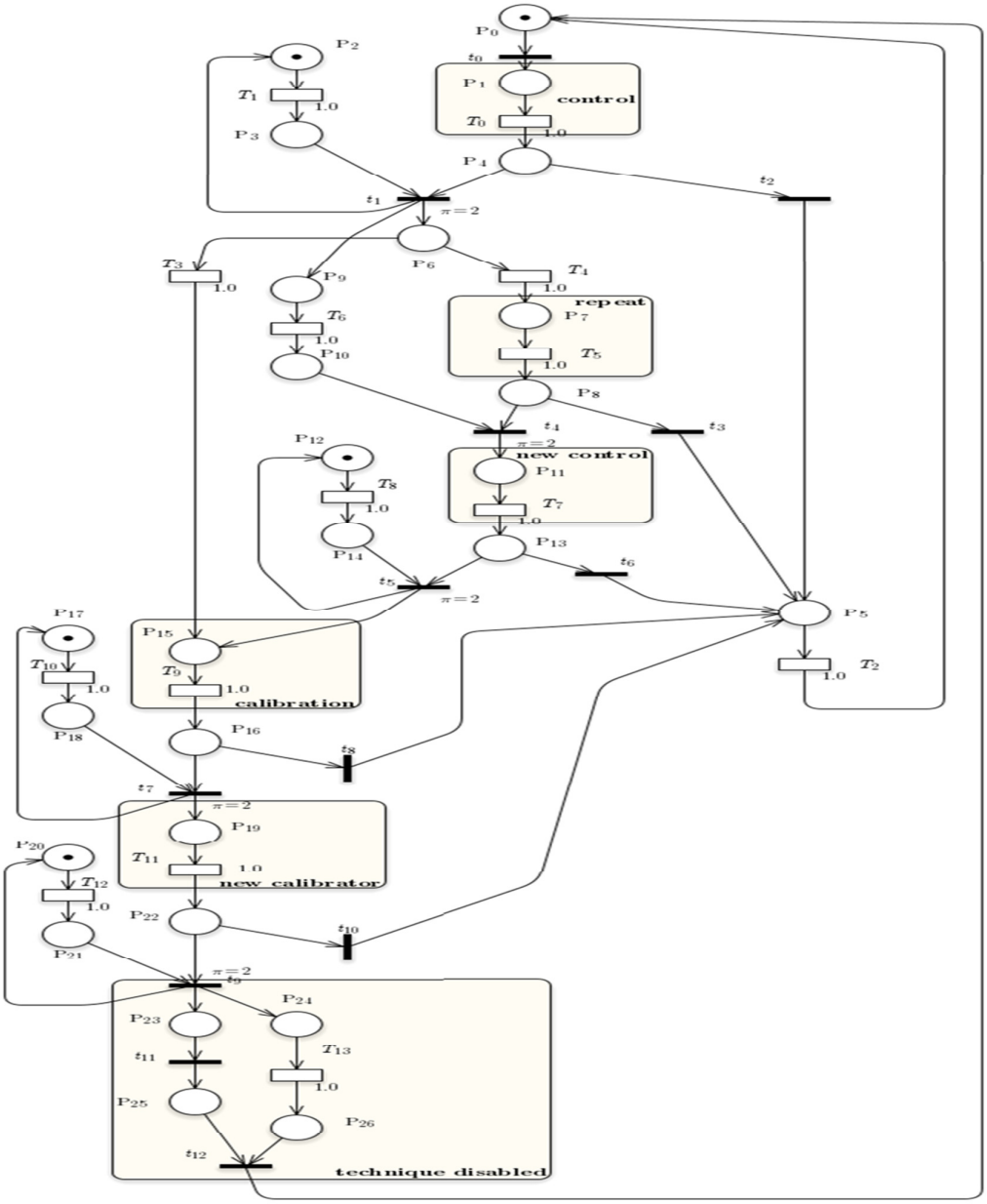


Figure 13: GreatSPN model of review of the quality controls procedure

In this stage of design, a new more complex scenario has been modelled with GreatSPN. The scenario modelled is the scenario #1 Preparing analyser, as represented in Figure 14.

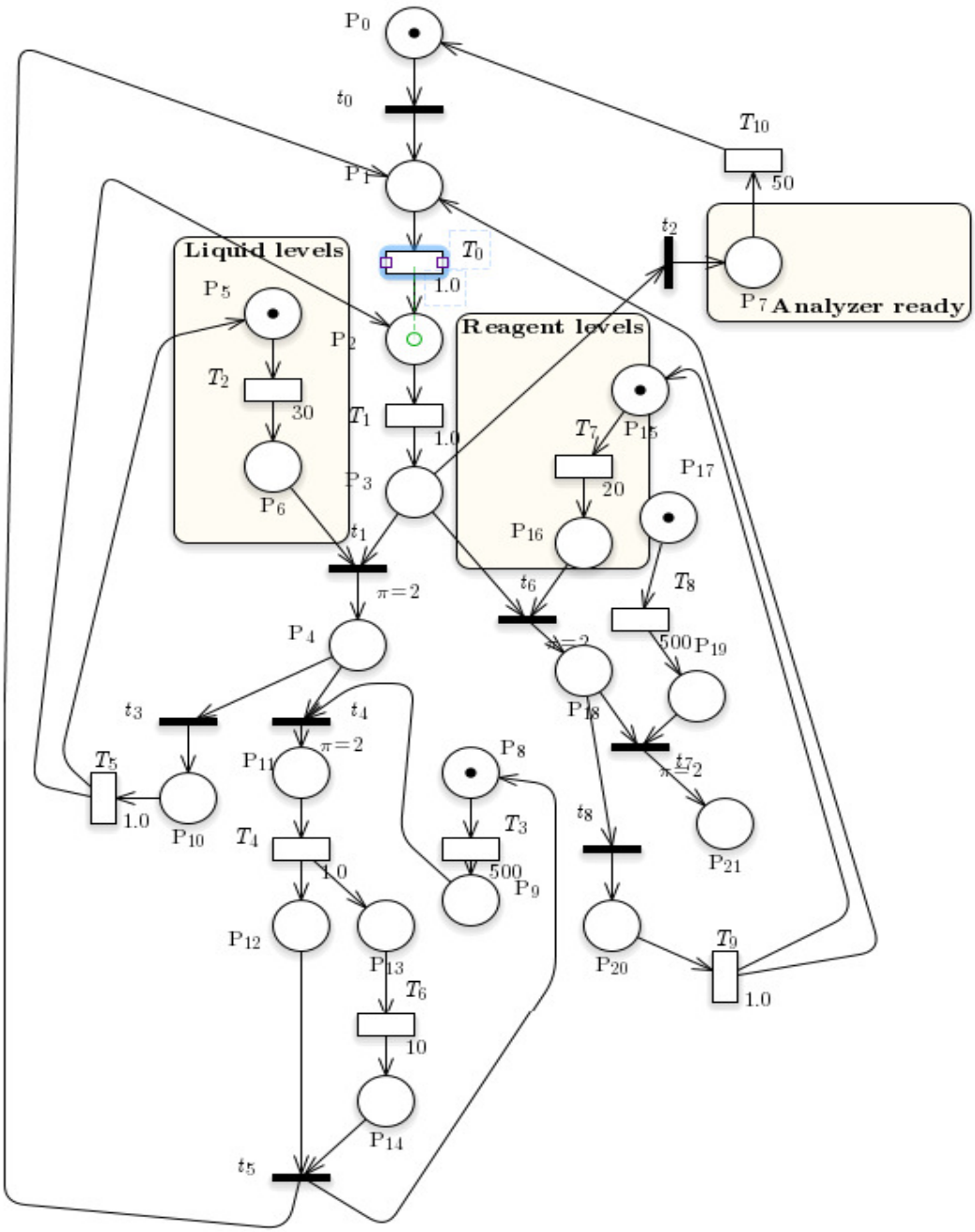


Figure 14 GreatSPN model of the analyser preparation procedure

The different entities that composed the GreatSPN diagram are described in Table 2:

Table 2 GreatSPN entities

Label	Phase	Description
P0	Initial phase	Technician is ready to prepare the analyser for the workday.
P1	Powering on	Technician powers on the analyser.
P2	Register in HoliApp	The technician is registering the analysis and the task in the HoliApp
P3	Programming analysis	Technician is programming the different analysis that the machine must do this day.
P4	Low level of liquids	The machine has low auxiliary liquids level. It is necessary to replenish.
P5, P6	Machine auxiliary liquids level	These phases model the parallel process of depletion of the different auxiliary liquids. P5 models that the machine has enough level and P6 models that the machine has low level.
P7	Analyser ready	The analyser is ready to work.
P8, P9	Auxiliary liquids availability	These phases model the availability of auxiliary liquids in the laboratory. P8 models that the enough quantity of liquids is available and P9 indicates that is no enough liquids available.
P10	Liquids filling process	The technician is filling the machine with the auxiliary liquids needed.
P11	No liquids available	The technician informs that there are no auxiliary liquids available through HoliApp.
P12	Machine disconnected	Machine keeps disconnected until the operator bring new auxiliary liquids.
P13, P14	Operator	This parallel event models the auxiliary liquids provisioning by the operator
P15, P16	Machine reagents level	These phases model the parallel process of depletion of the different reagents. P15 models that the machine has enough level and P16 models that the machine has low level.
P17, P19	Reagents availability	These phases model the availability of reagents in the laboratory. P17 models that the enough quantity of reagents needed is available and P19 indicates that is no enough reagents needed available.
P18	Machine without reagents	The machines do not have the reagents needed for the analysis of the workday. It is necessary to replenish them.
P21	Machine not operative	The reagents needed for the techniques programmed are not available so the machine is not operative. Although is possible to use the machine if the technique if disable. The technician must decide this action.
P22	Reagents filling process	The technician is filling the machine with the reagents needed.

Using these GreatSPN models it is possible to build a more complex model. Considering the scenario presented in the deliverable 6.5 (seeFigure 15), there are three technicians managing the different equipment connected to the robotic chain. The following GreatSPN schema models the actions of the technician A that manages the ADVIA analysers B and C.

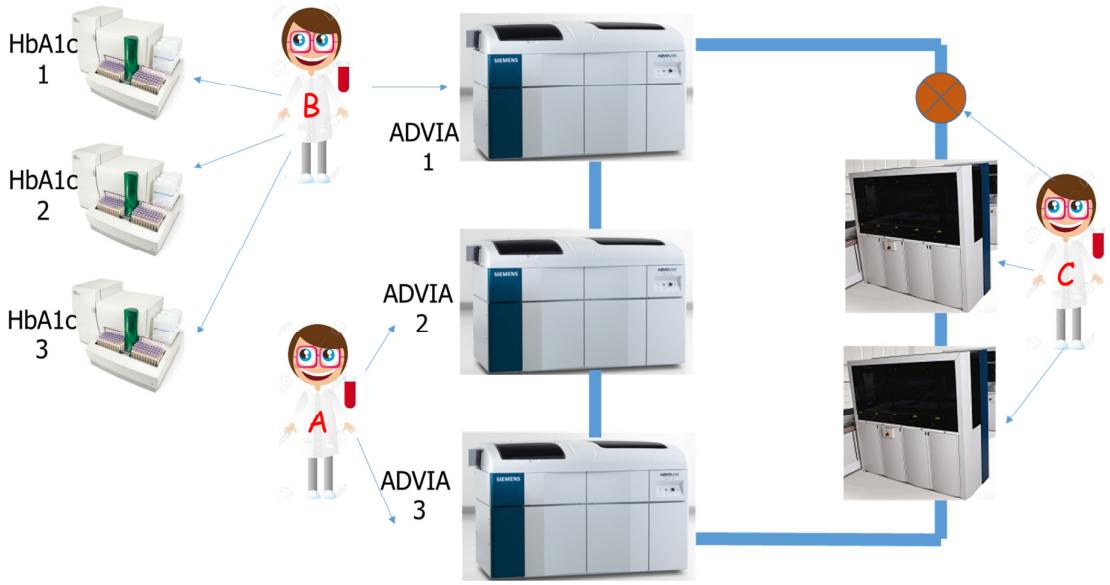


Figure 15 View of the AdCoS scenario considered

Figure 16 represents a GreatSPN model, of the full scenario, whose complete workflow is described in D6.5.

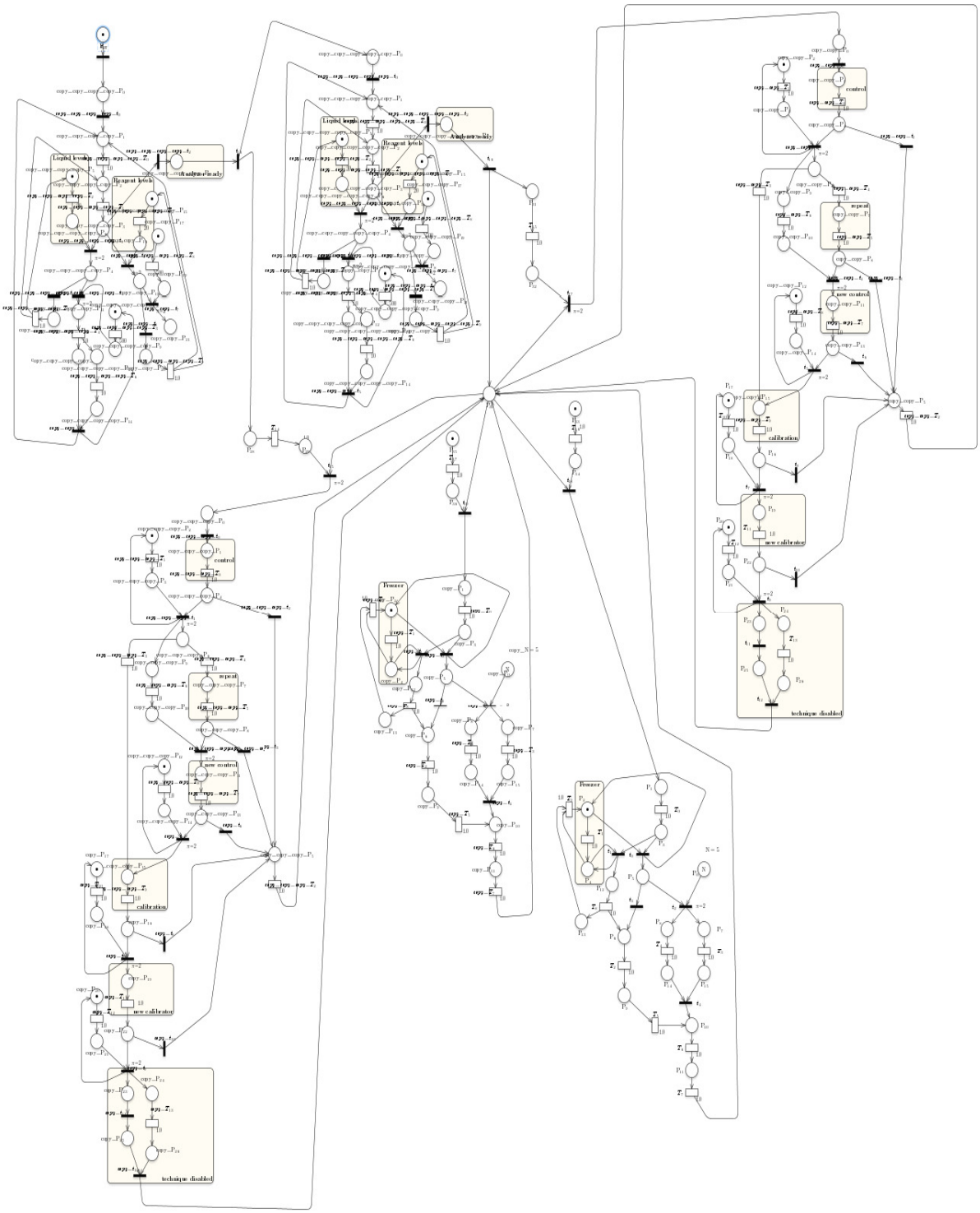


Figure 16 GreatSPN model of the technician A simple workday

The model in Figure 16 includes the simple actions that the technician A can perform throughout the day. These actions with the conditionals considered were explained in the workflow diagrams of the AdCoS in the deliverable 6.5 and modelled in the GreatSPN models exposed. Following the diagram, the technician prepares the analysers and enters in a waiting phase. The events that it is necessary to attend are the quality control review and the liquids preparation and refill. The model does not include maintenance task and secondary task in order to ease it. Still, the simple scenario proposed is difficult to model due to the limitation of general Petri Nets: Petri Nets are not suitable for studying systems exhibiting continuous dynamic behavior that: (1) cannot be described by a set of discrete states, (2) cannot be broken down to atomic processes, or (3) are dependent on spatial properties.

Some conclusions can be extracted after experiment with the tool.

The simulation results obtained are not precise enough due to the non-deterministic events cannot modelled with precision. These events involve model human behaviour or random events as failures.

Also, the complexity of the modelling based on Petri Nets is problematic because it requires complex models that hinder the visualization of the workflow due to the fact that it is necessary to use a high number of states to model simple algorithms of tasks.

The functionality that is missing is the capacity to manage or interact with other distributed processes in execution time. This tool only has simulation features that could be useful to probe a model but is useless to manage the task assignation. The lack of this feature and the limitations found during the experiments indicate that it could be better to find another tool.

Different existing alternative workflow technologies have been studied. These tools are being used mainly in business environment but it is possible to adapt it to health applications. For this application, it is necessary that the tool would have a graphical editor, a simulator and an execution engine. In the following table the tools have been analysed from these points of view.

Table 3 Overview and comparison of tools

Tool Name	Availability of an analysis tool	Tool modeling features	Graphical editor	Simulation	Execution engine	User manual
YAWL	X	X	X	X	X	X
jBPM Tool		X	X			
Yaoqiang-BPMN-Editor-2.1.21		X	X			
Bonita	X	X	X	X	X	X
bpmn2bpel		X	X			

Two tools have been selected as the most interesting options. These tools are Bonita and YAWL.

- Bonita

  Bonita Open Solution is a workflow tool consisting of two major parts. These are Bonita BPM Studio which is the graphical environment for creating a process and contains the designing tools, the whiteboard and the form builder, and Bonita BPM platform which is the deployment and testing platform for the processes, Bonita BPM platform contains the web portal, the engine, and the database.

  The graphical interface of Bonita studio, the whiteboard, allows the user to draw processes directly by using notation compatible with the Business Process Modeling Notation (BPMN) standards. The Bonita execution engine runs behind the graphical interface, which connects the processes to the existing system to deploy and run the process.

- YAWL

  YAWL (Yet Another Workflow Language) is a workflow language based on Petri Nets theory with a graphical representation and well-known workflow patterns. YAWL uses a control-flow perspective pattern and manages to extend Petri Net's lack of support for patterns such as cancellation, multiple instances, and the generalized OR-join with dedicated constructs to deal with the data perspective, resource perspective, and exception

handling patterns. The tool uses Hibernate (hibernate.org) as a database framework which provides a transparency layer between YAWL and the back-end database used to support it.

The analysis of the workflow tools revealed that YAWL editor workspace is designed in an efficient way. The graphical editor is designed to make the work easy for the users when working with a workflow design.

With YAWL, the users always get an instant update about the workflow design in the analysis result tab provided at the bottom of the tool. Analysis results show the task name, problem type, and suggestions to fix the problem. When there is no problem, the analysis results tab still shows a note of not finding any validation problem with the current design YAWL

Conclusions: GreatSPN presents complete features for modelling and simulate the workflow of the targeted scenarios. Two main drawbacks: (i) in its current version, it is not possible to perform simulation in real time, with external events that triggers certain actions and (ii) the large variability of human action in this environment is difficult to model. The non-deterministic nature of the scenario, make difficult to model such scenario. On the other hand we have analysed othr tools, and find out that YAWL and BONITA are two tools that cover the requirement of real time simulation, which is one of the main objective of this use case.

6.4 AEON

6.4.1 Usage in the Querying openEHR data AdCos

AEON is a cloud platform to create applications with real time communications channels. The architecture is based on the strong communication needs that we face nowadays, with billions of interconnected devices and short times of response. Thus, the technological solutions used for the implementation are based on strong requirements about: performance, response and scalability, making use of the most advanced cutting edge technologies.

AEON platform offers a shared cloud-based message queuing framework enabling messaging between various entities that wish to communicate with each other seamlessly and reliably using standard vendor neutral protocols

6.4.2 Benefits

- Communicate applications and services through a real time network

- Easy to use, easy to integrate in developments: AEON provides an SDK to connect your services and devices over a globally scaled real-time network
- Performance, Scalability and Reliability: High performance for message delivery and data exchange between business processes and devices and from device to device. AEON is able to handle multiple types and priorities of messages, whilst at the same time providing the necessary Quality of Service. AEON provides reliable messaging with durability and persistence and needs to scale well for extremely large volumes.
- Big Data: AEON can take care of the cloud messaging of the data capture from M2M environments and big data flows.

6.4.3 Technical description

Online technical documentation can be found here[2]. In a nutshell, AEON should (publish/subcribe) be as easy as:
Publish over a channel (snippet $2):

```
sdk = new AeonSDK(channel.PUB_URL);
msg = { "number": 1};
sdk.publish(msg);
```

Subscribe to a channel (snippet $3):

```
sdk = new AeonSDK(channel.SUB_URL, config.YOUR_ID , config.YOUR_DESC);
sdk.subscribe(function(msg){ console.log(msg)});
```

Then the subscriber can read all the messages posted by the publisher.

6.4.4 Integration with the "Querying openEHR data" AdCoS

We are supposing that almost every module will be provided using the service oriented approach (SOAP, REST …) then we need a way to communicate the building blocks. One way to connect the components is using a cloud messages management platform (or Enterprise Service Bus (ESB)). Then the modules send the messages to the ESB queries, topics and other modules can consume them filtering out depending in certain conditions.

ATOS has its own cloud message management tool called **AEON** that we used to connect the modules with the standardization storage infrastructure (yourEHRM). This approach cannot be applied to the DICOM

[2] http://lcb.herokuapp.com/public/doc/html/apidoc/apidoc.html

images due to large size of data. Next figure shows the interaction with some possible components in the AdCoS.

Figure 17 Integration of the "Querying openEHR data" and AEON platform

6.5 Data Race Detector & Healer

Data Race Detector & Healer was planned to be used to control thread activities as atomic tasks, therefore, the owner was contacted in order to get more details about how to integrate the analyser into our software.

Unfortunately, we have to say that RaceDetector and Healer depend on IBM Concurrency Testing Tool[3] which is unfortunately closed source, licensed and unmaintained for some time. Getting license from IBM takes a lot of effort and it is expensive, for all these reason it has been decided not to use it, but nevertheless there is an alternative: RoadRunner.

[3] ConTest, https://www.research.ibm.com/haifa/projects/verification/contest/

RoadRunner (RR) is a dynamic analysis framework designed to facilitate rapid prototyping and experimentation with dynamic analyses for current java programs. Currently a new version of RR is being developed which replaces ConTest. RR already provides basic detection functionality. It is able to detect data races, possible deadlocks and locking policy violations[4]. RR integration may require a little longer getting results.

6.6 U-DAT – User test Data Acquisition Tool

6.6.1 Usage in VCG Triggering

U-DAT is being further developed to support a formal abstraction level. The right abstraction level will enable the definition of a clear input and output interface by means of an agreed upon (UML) structure. Once that is in place, U-DAT can connect to other tools from the HF-RTP. For example other tools might support the creation of a structured task model that can be used as (UML) input to U-DAT. Vice versa, U-DAT can create a structured output format that can be used by other tools to create summary reports or further analysis.

In the context of AdCoS VCG triggering the original task analysis has been transformed into the U-DAT structure. The original task map shows the relations between User Roles, Tasks and Steps. See the VCG task map in Figure 18:

[4] https://github.com/stephenfreund/RoadRunner/blob/master/rr.pdf

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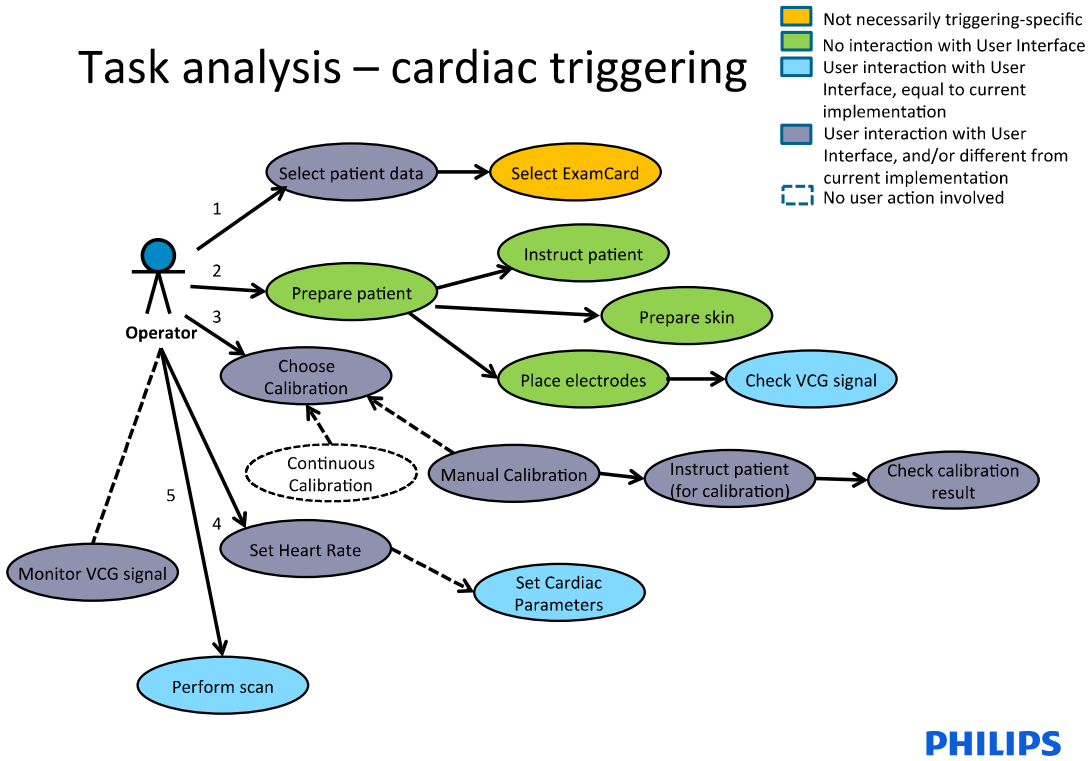

Figure 18 VCG Triggering Task Map in U-DAT structure

The task model shows a number of possible relationships that need to be captured in the U-DAT input interface:

- include
- optional
- specialization
- continuous

In addition, the MTT that might provide the input to U-DAT should also address the following entities:

- task/step identification
- context of use
- user role
- user goal
- criticality

From this information we might generate the U-DAT structure as depicted below in Figure 19 for VCG Triggering:

ID #	Context of Use	User Role	From	Relation	Task	Step	User Goal	Criticality		Task Score			Comments	Root cause analysis (close call / fail)
								Hazard	Essential	Succes	Close call	Fail		
Scenario 1: The operator is at the scanner console. **Select the patient data for patient X from the RIS**. Once done, **open the ExamCard database browser and select the ExamCard "Cardiac exam"**. **Call in patient X from the waiting room, check the patient for contra-indications and explain the procedure to the patient**. **Next, ask the patient to change clothes (hospital gown is provided) and clean the skin in order to apply the VCG electrodes. Once the electrodes are applied, check the VCG signal at the display on the operator's console.** You are satisfied with the quality of the VCG signal. **Provide head set and nurse call to the patient, and place the coil on the chest.** Back at the operator's console, you decide to use the manual VCG calibration. **Selecting this option and perform the necessary steps.** **When you are satisfied, start the scan.**														
Task_1	Zone 3 / Console	MR Operator	MR Operator	include	Register a patient		Enter New Exam details to start exam of (the next) patient							
Task_2	Zone 3 / Console	MR Operator	Task_1	include	Select Exam Card		Select the right procedure for the scheduled examination							
Task_3	Zone 3 / Console	MR Operator	MR Operator	include	Check VCG Signal		Verify that the VCG signal that is detected, is good enough to start the examination							
Task_4	Zone 3 / Console	MR Operator	MR Operator	include	Choose Calibration		Ensure that VCG data is calibrated in order to get reliable R-top detection throughout the exam.							
Step_1	Zone 3 / Console	MR Operator	Task_4	specialization		Manual Calibration	Ensure that VCG data is calibrated in order to get reliable R-top detection throughout the exam.							
Step_2	Zone 3 / Console	MR Operator	Step_1	include		Instruct patient	Optimize patient-related circumstances under which VCG calibration is performed							
Step_3	Zone 3 / Console	MR Operator	Step_2	include		Check calibration result	Verify that the VCG calibration is completed successful, operator wants to intervene and repeat the process							
Task_5	Zone 3 / Console	MR Operator	MR Operator	include	Set Heart Rate		At ExamCard level, operator specifies the patient's heart rate (as well as other properties such as laterality, anatomic region etc)							
Step_6	Zone 3 / Console	MR Operator	Task_5	optional		Set cardiac parameters	Fine-tune the scans as saved in the selected ExamCard for the specifics of the current patient							
Task_6	Zone 3 / Console	MR Operator	MR Operator	include	Perform scan		Acquire cardiac triggered scan with reliable R-top detection							
Task_7	Zone 3 / Console	MR Operator	MR Operator	continuous	Monitor VCG Signal		Verify the quality of the VCG signal, in order to intervene if needed							

Figure 19 U-DAT structure for VCG Triggering AdCos

The inputs to U-DAT are the columns from the left up until Task Score. This particular U-DAT for VCG Triggering can be directly used for a formative or summative user test. The output that U-DAT captures is the columns Task Score, Comments and Root-Cause analysis. This structured output can form input to report generating MTTs.

7 Summary and conclusions

This document provides an update on the tailoring steps of the HF-RTP. One of the tools to support the tailoring process is the PlatformBuilder, which is a web based tool that suggests possible tools that can be used given a certain HF issue. Feedback from the WP6 AdCos owners is collected in chapter 4 to improve this tool.
Furthermore, in chapter 5, an overview and brief status update is provided of the WP6 AdCoS's. Chapter 6 describes which MTTs are applied in the Health AdCoS's and how they cooperate, with a focus on why and how certain MTTs are used.

The Healthcare partners have made good progress in modelling and developing their AdCos. Some prototypes are available and ready for first evaluations. As has been described in chapter 6, MTT's from the HF-RTP have been integrated in the AdCoS development process or workflow.

8 Way forward and upcoming activities

8.1 Guided patient positioning (Philips MRI)

Q4-2015
- Apply U-DAT for Guided Patient Positioning user tests
- Explore application of HTC tooling for Guided Patient Positioning

Q1-3 2016
- Adapt task model to U-DAT and transfer output to HF-Filer using adapters

8.2 Safe parallel transmit scanning (UMCU)

Design/evaluation UI.

October 2015
- Discuss first mock-up of UI design

November 2015:
- Implement first version of UI.
- First focus group session with participation of SNV at UMC Utrecht.

December 2015 - December 2016
- Redesign of UI.
- Evaluation of UI with 1-2 more session of focus group.

Development RF safety monitor tool

October - November 2015
- Creation of automatic segmentation and EM modelling pipeline based on volunteer scans

December 2015 - February 2016
- Scanning of male volunteers
- Building of subject database of calculated SAR pattern

February 2016- December 2016
- Development of selection criteria to select a model from the database for a given patient.

8.3 Robust VCG triggering (Philips MRI)

Q4-2015
- Apply U-DAT for VCG Triggering user tests
- Explore application of HTC tooling for VCG Triggering

Q1-3 2016
- Adapt task model for MR AdCoS to U-DAT and transfer output to HF-Filer using adapters

8.4 3D Acquisition (Philips iXR)

Q4-2015:
- HMI performance comparisons using HEE

Q1-2016

- User evaluations and questionnaires
- Implementation of the new User Interface

Q2-3 2016
- Measuring performance indicators

8.5 Querying openEHR data (ATOS)

Q4-2015:
- RoadRunner evaluation and integration if this is deemed suitable.

Q1-2016:
- HF-filer evaluation tool.

Q2-4 2016:
- AEON tool evaluation, analysis and integration if this is deemed suitable.
- Initial prototype implementation.

8.6 Internal analysis and reporting (ATOS)

Q1-2016:
- HF-filer evaluation tool.
- Gathering data sets in order to test machine learning tools.

Q2-3 2016:
- LEA tool evaluation, analysis and integration (if proceed)
- APA tool evaluation, analysis and integration (if proceed)

Q4 2016:
- Initial prototype implementation.

8.7 Operator task schedule and guidance (Integrasys)

Q4-2015:

- Initial Information Model and detail definition of infrastructure
- Initial prototype implementation

Q1-2016

- Prototype implementation (2016) -> Simulator of adaptable workflow with distributed users

Q2-Q3-2016

- Evaluation and analysis: HEE, and functional and non-functional evaluation
- Refinements of implementation and feedback

Glossary

ACC = Adaptive Cruise Control

ADAS = Advanced Driving Assistance Systems

AdCoS = Adaptive Cooperative Human-Machine Systems

CMM = Common Meta Model

DODAF = Department of Defence Architecture Framework

DAS = Driving Assistance Systems

EV = Ego Vehicle

FCW(S) = Forward Collision Warning (System)

HF = Human Factors

HF-RTP = Human Factors Reference Technology Platform

HMI = Human Machine Interaction

HMS = Human Machine Systems

HoliDes = Holistic Human Factors Design of Adaptive Cooperative Human-Machine Systems

MOVIDA = Monitoring of Visual Distraction and risks Assessment

MTTs = Methods and Techniques

PADAS = Partially Autonomous Driving Assistance Systems

RR = Road Runner

RTP = Reference Technology Platform

UC = Use Cases

V-HCD (platform) = Virtual Human Centred Design (platform)

WP = Work Package

9 List of figures