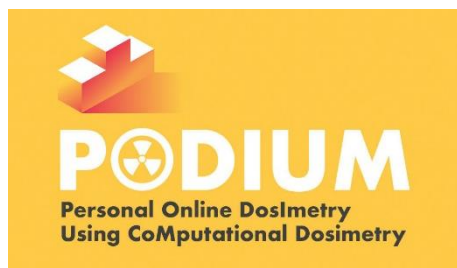




This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.



EJP-CONCERT

European Joint Programme for the Integration of Radiation Protection Research

H2020 – 662287

D 9.101 - Report listing all requirements of the software

Lead Author: Olivier Van Hoey

With contributions from: Merce Ginjaume, Nina Petoussi-Henß, Jan Jansen, Jonathan Eakins

Reviewer(s): Filip Vanhavere, Pasquale Lombardo, Mahmoud Abdelrahman and CONCERT coordination team

Work package / Task	WP 9	T 9.6, SST9.6.3.1
Deliverable nature:	Report	
Dissemination level: (Confidentiality)	Public	
Contractual delivery date:	2018-02-01 (M32)	
Actual delivery date:	2018-03-09 (M34)	
Version:	Month 1	
Total number of pages:	14	
Keywords:	Software requirements	
Approved by the coordinator:	2018-03-09 (M34)	
Submitted to EC by the coordinator:	2018-03-09 (M34)	

Disclaimer:

The information and views set out in this report are those of the author(s). The European Commission may not be held responsible for the use that may be made of the information contained therein.

Abstract

The goal of the PODIUM project is to develop a software application that allows calculating the radiation worker doses of interest by combining positioning information from a staff and object monitoring system based on the Kinect 3D camera and information on the radiation field and the room. The technical modules of the software will be developed by the project partners. The databases, the front end web application through which the users can interact with the software application and the back end management module calling the different modules, transferring data between the different modules and reading and writing data in the different databases will be developed by an external IT subcontractor. Therefore, a document has to be made that explains the context, provides a clear list of software requirements and gives already a first proposal for the software structure. With this document we can then go to possible subcontractors.

I. Background

- Radiation workers are normally equipped with small personal radiation detectors or dosimeters that allow to measure the radiation doses they receive during their work. Such measurements are limited because no personal dosimeter works perfectly for all radiation types. Especially, measuring neutron radiation is very challenging. Furthermore, the measurement gives only one value for the whole body while the radiation field might be very inhomogeneous. Therefore, in some specific cases the radiation workers are requested to wear additional dosimeters at the hands or close to the eye lens. This is the case in interventional radiology.
- The goal of this project is to develop software that allows calculating the radiation worker doses of interest by combining positioning information from a staff and object monitoring system based on the Kinect and information on the radiation field and the room.
- The software will be developed for two particular applications, a neutron workplace field and an interventional radiology room. Both applications will require a slightly different approach. The neutron workplace field has a radiation field that is rather homogeneous and that does not change in time except for a scaling factor changing the intensity of the field. The interventional radiology room has a radiation field that is very inhomogeneous and that does change in time significantly due to changes in the X-ray tube parameters and positioning of movable objects shielding and scattering the radiation. Therefore, the radiation field of the neutron workplace field can be precalculated, while that of the interventional radiology room will have to be calculated every time a significant change occurs. This calculation will be done with an already existing Monte Carlo radiation transport code MC-GPU.
- The software will also use two possible approaches to calculate the radiation doses. In the first and most simple approach the fluence energy and angular distribution of the radiation field at the position of the radiation worker is retrieved and convoluted with the appropriate fluence to dose conversion coefficients that are precalculated and stored in a database. In this way the radiation doses of interest are calculated by just multiplying and summing the appropriate numbers. In a second approach, also a direct calculation of the radiation doses of interest can be requested. This direct calculation will be based on the already existing Monte Carlo radiation transport code MC-GPU. This code simulates how the radiation source interacts with the room, objects in the room and an anthropomorphic phantom representing the radiation worker.

II. Users and roles



Figure 1: The PODIUM application roles

Manager: a person responsible of the system that manages the users and databases through the web interface.

- Views and modifies his/her user profile
- Views and modifies all user profiles and permissions
- Validates changes of the user profiles
- Views, adds, removes and modifies rooms
- Views, adds, removes and modifies operators

Radiologic protection responsible: a person who has the right of accessing to the radiation doses of all staff members and the responsibility of communicating personally with each of them.

- Views and modifies his/her user profile
- Views all procedures
- Views all computed radiation of all staff members
- Queries and views the radiation of:
 - a particular procedure
 - a particular room per procedure, day, week and month
 - a particular staff member per procedure, day, week and month

Staff member: a person that is in the radiologic room participating in a procedure and who is tracked by the system

- Views his/her profile
- Modifies his/her e-mail in his/her profile
- Applies for other changes in his/her profile
- Views his/her computed radiation
 - In a particular procedure
 - Per day, week and month

Procedure operator: a person that is in charge of the system during a particular procedure

- Views the procedures that he/she has created
- Views the rooms
- Views the operators

- Views all his/her procedures:
 - General data: id, room, staff, date, hour
 - Associated radiation field info , if any
 - Camera tracking file (position versus time file computed by the tracking system), if any
 - Simulation doses computed, if any
 - Status: blocked or not

- Creates a procedure:
 - Gives an identifier
 - Selects a room
 - Selects the staff member that is going to be tracked
 - Inputs the personal protection accessories worn by the staff member
 - Turns on the camera tracking process
 - Checks that the staff member is clearly identified by the Kinect
 - Starts the camera tracking
 - Pauses the camera tracking
 - Resumes the camera tracking
 - Stops the camera tracking and turns off the camera tracking process

- Edits the radiation field information

- Launches the radiation doses simulation with the default parameters

Doses calculation responsible: a scientist involved in the Monte Carlo simulation

- Views all sessions
 - General data: id, room, staff, date, hour
 - Camera tracking file (position versus time file computed by the tracking system), if any
 - Associated radiation field info , if any
 - Simulation doses computed, if any
 - Status: blocked or not

- Searches the radiation field information if they have not been entered by the operator

- Modifies the simulation parameters
 - Dose quantities
 - Dose calculation approach
 - Phantom

- Launches one of the available radiation doses simulation for allowed procedures, i.e. having:
 - The results of the camera tracking
 - The radiation field information

- Creates the voxel model for a particular room

Image processing responsible: an engineer involved in the design of the tracking algorithms

- Modifies the parameters of the tracking algorithm (only at the beginning of the implantation of the system)

III. Standard workflow for a procedure

The *manager* has previously created the first user profiles, including the anthropometric parameters of the staff members and the rooms.

The *procedure operator* logs-in and sees all his/her procedures in a table as below. He/she can click on any filed and get more information about them.

Session id	Date	Start	End	Room	Operator	Recording	Simulation #1	Simulation #2
A45gt	22/7/18	10:00	11:45	A45	OP897	R56.txt	Monte897.txt	blocked
A45gt	13/9/18	13:00	13:45	A45	OP897	R56.txt	Monte897.txt	Jkhksh.txt
A45gt	2/12/19	12:00	12:45	A48	OP897			

He/she creates a new procedure:

- Provides an identifier
- Selects a room
- Selects a staff member
- Turns on the camera tracking process
- Views an image captured by the Kinect system (or the video in real time??)
- Checks that the staff member is clearly identified by the Kinect
- Starts the camera tracking
- Synchronize the time between the camera tracking system and the machine
- Whenever the staff member exits and re-enters in the room:
 - Pauses the camera tracking
 - Check the staff member is clearly identified by the Kinect
 - Resumes the camera tracking
- Stops the camera tracking and turns off the camera tracking process
- Enters the radiation field data (in real time)

In principle, the operator is not the responsible of launching the dose calculations. It will be the task of the *Doses calculation responsible* or of the *Radiologic protection responsible*. However, he /she may be allowed to calculate them, with the default parameters.

Anytime, the *Doses calculation responsible* views all procedures. He/she chooses a procedure and selects the simulation parameters (type of simulation, phantom, etc). He/she launches the process of simulation. The status of the session is immediately modified in the database as being in-process so that nobody else can launch another simulation. The simulation process accesses to the data of the session through the API of the database, performs the computations and when done records the data of the simulation and changes the status of the session.

Anytime, the *Radiologic protection responsible* can launch the simulation of any procedure with the default parameters.

Anytime the *procedure operator* can launch the simulation of any of the procedures that he/she has created, with the default parameters.

IV. Software components

The website is two-fold:

- The front-end with the web-pages available to users and has these main views :
 - Login (all)
 - User profile and modification (all)
 - User's management (for *manager*)
 - For each database: (for *manager*)
 - Management view
 - Personal doses radiation view (for *staff members*)
 - All staff doses radiation view (for *radiologic protection responsible*)
 - Procedure list view (for *procedure operator, manager, Doses calculation responsible and radiologic protection responsible*)
 - Procedure creation view (for *operator*)
 - Simulation parameters view (for *Doses calculation responsible*)
 - Image processing parameters view (for Image Processing specialist) **future**
- The back-end with (e.g. in python with Django or flask or in Java) :
 - the users management system
 - the databases
 - the databases management functions
 - the queries functions
 - the management of the external processes (e.g. with celery, rabbitMQ and similar)
 - synchronization (written in C or C# or whatever)
 - simulation (written in C or C# or whatever)
 - voxelization (written in C or C# or whatever)
 - the camera tracking (written in C or C# or whatever)

Figure 2 illustrates PODIUM application's main workflow, the external components, the databases to which they access to read and write information and the views that provide users access to the different modules.

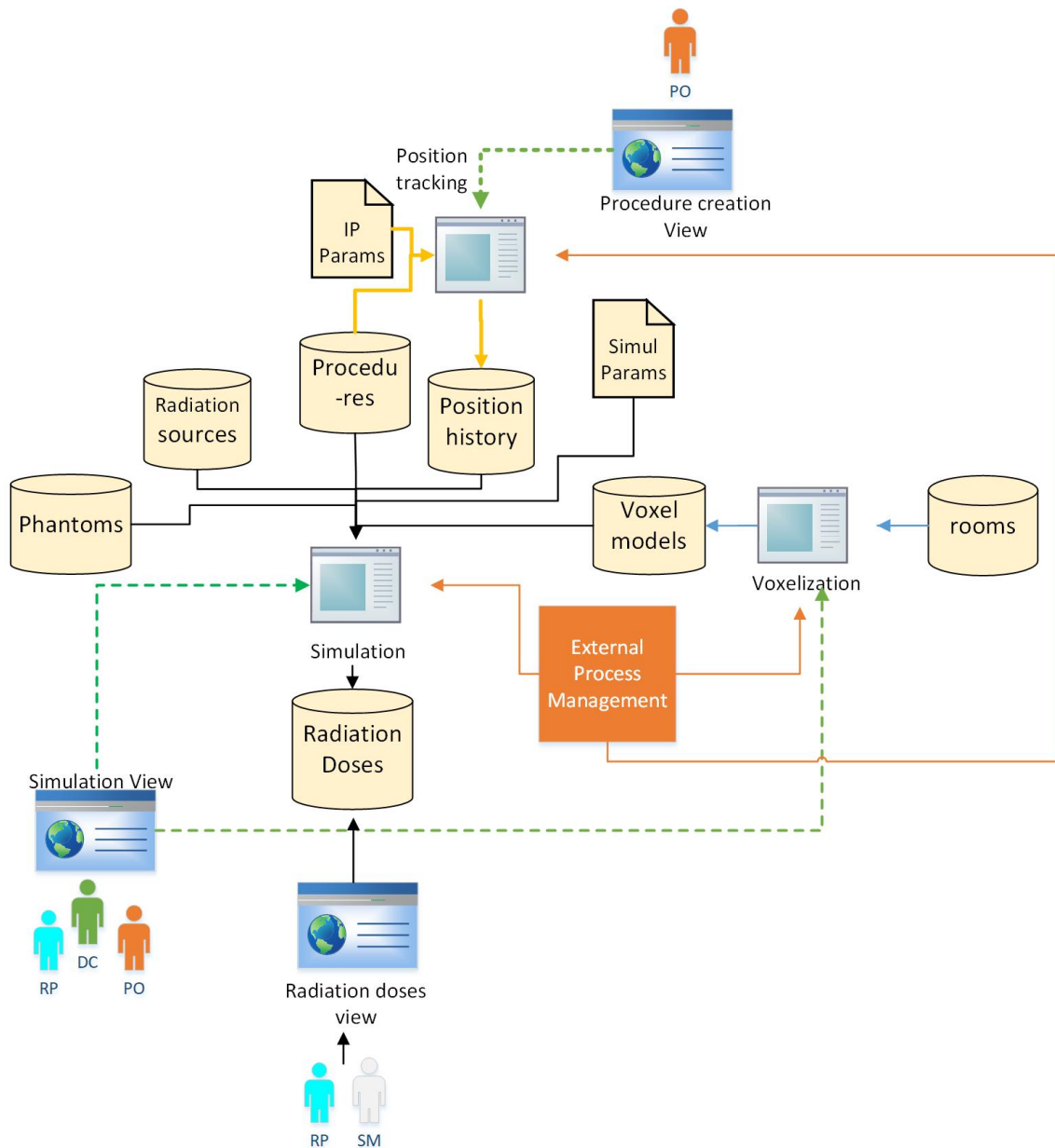


Figure 2 PODIUM application's main workflow. The Procedure Operator (in orange, at the top of the Figure) creates a Procedure through the website Procedure creation view. During the creation process, he/she launches the Position Tracking external process that takes a set of parameters (IP params), the procedure description and records, computes and stores in the database the positions along time. This process is external, and reads/writes in the databases through an API. The process is controlled by the External Process Management of the system. Anytime aside, the Doses Calculation Responsible (in green, at the bottom left) and eventually the Procedure operator and the Radiologic Protection Responsible launch the simulation process through the website Simulation View. The simulation is an external process that uses the procedure, the positions, the simulation parameters and other elements of the databases to compute the radiation doses. Through the same interface (but sporadically) the Doses Calculation Responsible only, can launch the external process of voxelization of the room. Finally, the Radiologic Protection Responsible and the Staff Member can view the computed doses, the former one of all users and the second one only his/hers. For that, they use the website Radiation doses view.

The parameters needed for the simulation (see Figure 3) are entered by the Doses Computation Responsible and the parameters needed for the tracking are entered by the Image Processing

Responsible, in both cases through the corresponding views. The latter function could be obviated, once the tracking algorithm is stable.

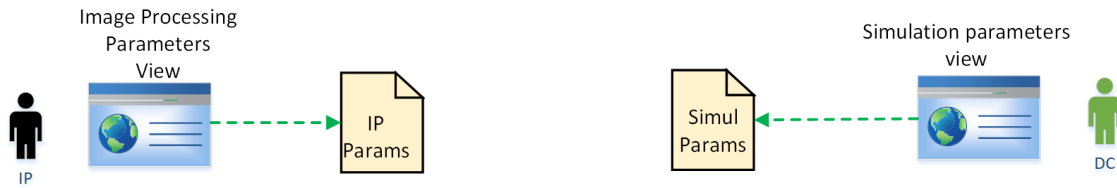


Figure 3: The parameters for the image processing algorithm and the simulation are entered by the corresponding users through the Image Processing Parameters View and the Simulation parameters view

Finally, Figure 4 shows the management services and views.

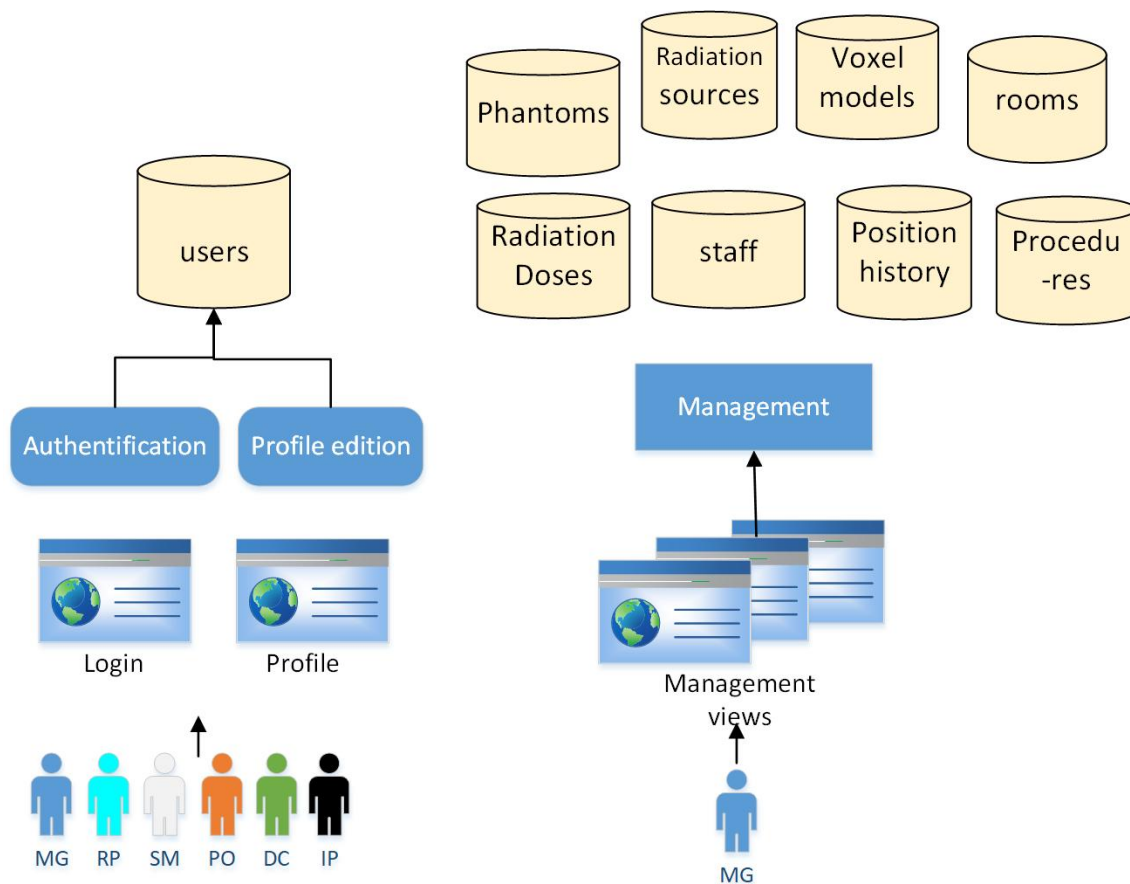


Figure 4. All users go through the login view to authenticate their identity. They can view and modify (with more or less permissions) their profile. The *Manager* manages the different databases, including the users' database through different management views.

Figure 5 shows a complete view on the components of the system.

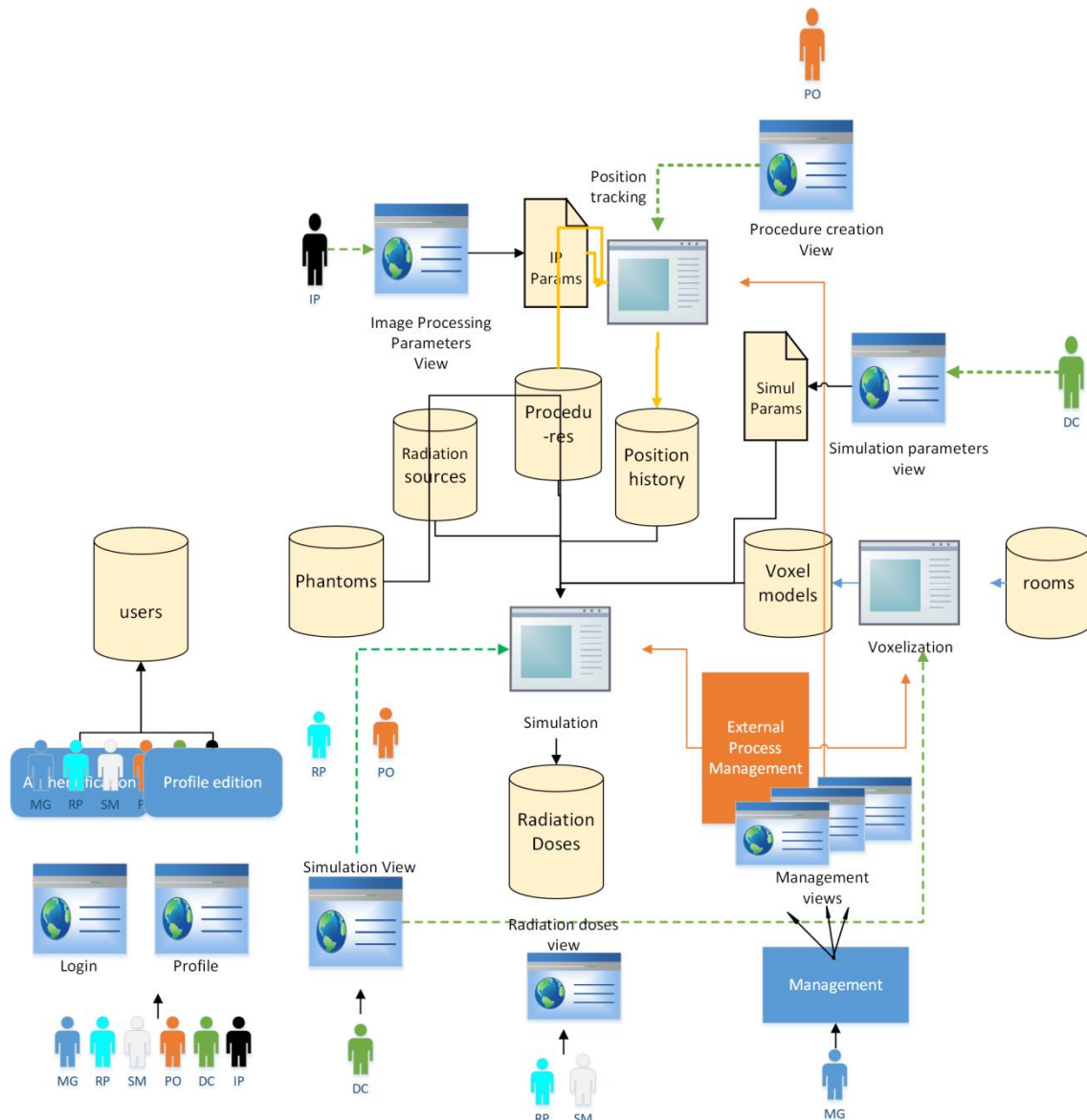


Figure 5: The whole picture of PODIUM application

IV.1. Modules to be developed by PODIUM partners

The technical modules will be developed by the PODIUM partners. Below is described what each of the modules will do. Important for the subcontractor is to know what will be the input and output of the different modules. This is still a first proposal. After discussion with the subcontractor some modifications might be required.

Geometry module

Input: room identification, procedure identification, time

Output: xml file with voxel geometry

This module should be able to generate the full geometry (including room, movable and fixed objects, phantoms, ...) in the format that is needed for the Monte Carlo calculation in the dose calculation

module. This format could be for instance an xml file with the voxel geometry and material specifications. To generate this, the geometry module will need information on the room selected by the user, the position of the staff and objects inside the room, the selected phantoms, ... This information can be looked up in the appropriate databases if room identification, procedure identification and time are provided. We already have some scripts to transform voxelized geometries that can be used to rotate or translate voxelized objects or phantoms. This module will be called by the radiation field module and the dose calculation module to get the appropriate geometry specifications for the Monte Carlo simulations.

Radiation field module

Input: room identification, procedure identification, time

Output: radiation field map

This module will be called if the dose calculation module uses the dose conversion coefficient approach. In that case the radiation field at the position of the staff members will need to be provided, both the fluence angular distribution and the energy distribution.

For the neutron workplace fields the radiation field will be constant, except for a scaling factor that will be determined based on the input from the neutron monitor. So, the neutron field can be precalculated for the whole room. The module should be able to look up the radiation field (neutron energy and angular distribution) at any location from the radiation source database.

For the interventional radiology the radiation field depends on the X-ray tube parameters, the presence of fixed objects, the position of possible movable objects and the position of phantoms. So, the radiation field will have to be calculated with Monte Carlo simulations whenever a one of this parameters has changed significantly. For this MC GPU will be called.

All required information for calculating the radiation field can be found in the database if the room identification, procedure identification and time are provided.

Staff and object monitoring module

Input: procedure identification

Output: time and position of joints of staff members and movable objects

This module should be able to command the Kinect in order to track and identify the staff and possible moving objects and write their joint positions as function of time in the staff and object databases.

The staff members and objects to be tracked can be retrieved from the procedure database given the procedure identification. The time and positions of the joints of staff members and movable objects are written to the position history database.

Kinect uses the USB3 port for fast connection. The current interface of the Kinect is written in C# and is linked to the game engine Unity. So, it will be best to write this module in C#.

This module will be started when the user starts the measurement.

Dose calculation module

Input: procedure identification

Output: calculated doses

The dose calculation module will be called after a procedure to calculate the requested doses. Two approaches will be possible.

In the first approach the doses are calculated with precalculated fluence to dose conversion coefficients. If only organ doses and effective dose are requested the average radiation field in front of the torso will be obtained from the radiation field module. The fluence energy distribution and angular distribution with respect to the torso direction will be convoluted with the respective large field fluence to dose conversion coefficients. If also skin dose to the hands or eye lens doses are requested the average radiation field at the hands or eye lens will be obtained from the radiation field module. The fluence energy distribution and angular distribution with respect to the surface normal at the phantom at these location will then be convoluted with the respective small field fluence to dose conversion coefficients for these particular locations. The calculated doses are then stored in the dose database.

For the Monte Carlo calculations for the interventional radiology, we will go for MC GPU because there is a lot of expertise on this code within the project consortium and it is able to run fast. This module will be called from the radiation field module to calculate the radiation field in the room and from the dose calculation algorithm to calculate organs doses when the MC approach is used instead of the dose conversion coefficient approach. The geometry and materials specification should be created by the geometry module. The tally specification should be created based on the kind of calculation that is requested (radiation field map for interventional radiology room to apply dose conversion coefficient approach or calculation of radiation doses of interest). MC GPU is written in CUDA and uses the GPU. In both approaches the calculation has to be done for all points in time for which an important change occurred (staff position, movable object position, radiation source, ...). These calculations should be integrated over time to get the total dose.

IV.2. Databases

Room database

This database should contain all possible rooms. Each entry should contain: room identification, radiation source identification, link to room geometry file in a format appropriate for the Monte Carlo calculations (xml file with voxel geometry), link to list with identifications of possible fixed objects in the room (table, table shield, patient, ...), list with identification of possible movable objects in the room (ceiling shield, movable shield, ...)

Radiation source database

This database should contain all possible radiation sources. Each entry should contain: source identification, link to radiation field file in appropriate format (precalculated 3D map of radiation field for neutrons, phase space file at exit of X-ray tube for different tube parameters for interventional radiology, ...)

Staff database

This database should contain all possible staff members. Each entry should contain: staff identification, first name, last name, height, weight, gender, ...

Object database

This database should contain all possible objects. Each entry should contain: object identification, link to object geometry file in a format appropriate for the Monte Carlo calculations (xml file with voxel geometry), for movable objects also identification information needed to recognize the object in the Kinect images

Position history database

This database should contain all position monitoring data from the staff and object monitoring database. Each entry should contain: procedure identification, time, staff or object identification and positions of the staff or movable object joints.

Dose conversion coefficient database

This database should contain all the dose conversion coefficients that are needed by the dose calculation algorithm. They give the organ dose per unit of fluence. These coefficients depend on the organ of interest, type of phantom, personal protection (lead apron, lead glasses), radiation type (photons, neutrons), radiation energy, radiation impact angle (polar angles with respect to torso direction). Further also small field coefficients could be defined for extremity dosimetry. These depend then additionally on the location of the small field (left hand, right hand, left eye, right eye or maybe even more detailed) and the radiation impact angle is then defined with respect to the surface normal of the phantom at that location.

Phantom database

This database should contain all the phantoms that can be used in the Monte Carlo calculations of the dose calculation algorithm. Each entry should contain: phantom identification, sex, height, weight, posture, personal protection, level of detail, link to the phantom file (xml file containing voxelized phantom).

Dose database

This database should include all doses calculated by the dose calculation algorithm. Each record should contain: procedure identification, staff identification and calculated doses.

Procedure database

This database should record all procedures. Each entry should contain: procedure identification, room, objects, staff, staff identification in Kinect (who is who in Kinect images), staff personal protection, phantom, calculated quantities, time evolution files of the radiation field (X-ray tube parameters or neutron dose rates from neutron monitor) and dose calculation approach (conversion coefficients or Monte Carlo calculation).