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PODIUM
Personal Online Dosimetry Using computational Methods

# EJP-CONCERT

## European Joint Programme for the Integration of Radiation Protection Research

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# D9.103 – An IPS based on an infrared reflection time-of-flight sensor camera together with the corresponding software

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# Content

# D9.103 (PODIUM D1.1) An IPS based on an infrared reflection time-of-flight sensor camera together with the corresponding software

## 1. Introduction

The objective of PODIUM is to develop an online dosimetry system based on computer simulations, which can potentially replace physical dosimeters. With this innovative approach, we also aim to improve personal dosimetry and radiation protection by reducing uncertainties, by accelerating the assessment of occupational doses and by increasing awareness among radiation workers.

The online dosimetry system of PODIUM is based on two principles:

- With the use of a body tracking device, we locate position and posture of workers in proximity of a radiation source;
- By means of fast Monte Carlo simulations or with a look-up table of pre-calculated dose conversion coefficients, we compute doses in real-time.

With this first deliverable of ST9.6.1, the PODIUM partners provide an indoor position system (IPS) for tracking the position and the posture of occupationally exposed workers. The IPS is constituted by a single KINECT v.2 Time-Of-Flight camera and by a software package consisting of two main programs. One program is used for the calibration of the camera, and the second is used for the acquisition of tracking data. The tracking system was developed by SCK•CEN, and it was tested with the collaboration of UPC.

The tracking device has the central role of the online dosimetry system of PODIUM. Its output, i.e. the worker(s) position and posture, constitutes the input to all the dose calculation modules.

As a first step, the tracking device will be used to monitor indoor workplaces with simple geometries, reason for which it is called Indoor Position System. In future developments, we plan to extend the use of the IPS to workplaces with increasingly complex geometries, and, if possible, even to outdoor applications.

### 1.1 Requirements for the IPS

For designing the IPS of this deliverable, we set a list of mandatory requirements. First, the IPS must be able to recognize the presence of a human body (or more than one) in a workplace, identify its posture and measure with accuracy the position of relevant human joints in the 3-Dimensions, in real-time. The definition of relevant joints depends on the application where the online dosimetry system is used. They may include chest, legs, head, arms, and even hands for those applications where the radiation field is very inhomogeneous. Regarding the requirements of accuracy, the maximum geometrical error in the tracking depends on the distance from the source. In most cases, a geometrical error of about 10 cm should be sufficient; with such accuracy, we expect that the uncertainty in the dose assessment will be substantially lower than that of current physical dosimeters. Further away from the source, even lower accuracies would be sufficient.

Secondly, as anticipated in the previous paragraph, the IPS will be used in applications where the workplace has relatively simple geometry. In practical terms, the IPS must be able to monitor workers moving within an area of about 10-15 $m^2$. This dimension is more than sufficient for the applications of WP4 of PODIUM (CONCERT ST9.6.4), i.e. Interventional Radiology (IR). However, the IPS can be used also for many applications of ST9.6.5 where the workers are in close proximity of a neutron source, like, for example, nuclear workers handling a canister with spent nuclear fuel.
The third requirement for the IPS is that it must be able to feed in real-time useful data to the dose calculation modules of the online dosimetry system. The definition of useful data is particularly delicate, since the type and the amount of tracking data depends on the specific approach that is used for determining doses. As it will be explained in greater detail in paragraph 2, for fulfilling this requirement the IPS must provide data in a structured table format, so that it will be easy to extract the information required as input by each of the dose calculation approaches.

Lastly, but not less important, the IPS must be simple, reliable and non-invasive, i.e. marker-less. In fact, we expect to implement the IPS to monitor real working scenarios, where it must not constitute an impediment for the workers or a potential source of danger. Ideally, once set-up, the hardware and the software of the IPS must be able to run for several hours per day without necessity of any intervention from the PODIUM developers. The simplicity aspect has also implications on the cost of the online dosimetry system of PODIUM. Supposing that the online dosimetry tool will be allowed as an official dosimetry method, the IPS should be cost-effective to compete with conventional physical dosimeters. In quantitative terms, the hardware of the IPS should not cost more than a few hundred euros.

# 2. Description of the IPS

## 2.1 The choice of Kinect v.2

Tracking methods based on Computer Vision (CV) are the ideal approach for achieving PODIUM requirements. Currently, various CV technologies are available for tracking human bodies. Some of them make use of traditional type of camera sensors, like optical photo-cameras. The most complex and advanced methods, instead, make use of depth sensors that can create 3-Dimensional images of a scene.

On the one hand, the conventional type of camera can be used to provide only 2-Dimensions body tracking, where the human joints are identified within *flat* images, i.e. 2D projection of the camera view onto the camera sensor. In theory this 2D data can be transformed into 3D position by means of geometric calibrations, but the geometrical error would not be lower than 10 cm. Also, the processing of 2D images demands high computational resources, which makes it nearly impossible to have real-time tracking with current hardware capabilities. For these reasons, the sole use of conventional optical cameras for tracking would not allow us to achieve the requirements of accuracy and performance of PODIUM IPS. However, this type of technology is growing fast, thanks to the advancements brought by Deep Neural Networks (DNN) in computer vision. So, this technology can still become useful in the future developments of ST9.6.1. For example, the OpenPose library for posture estimation from 2D images is a good candidate to be considered in the more complex IPS that we will implement in the next stage of PODIUM.

On the other hand, tracking technologies based on depth camera can directly provide the positions of the body joints, in 3D. Depth cameras are completely different from optical cameras. Instead of registering color intensity like in a conventional sensor, each pixel of a depth sensor measures the distance to the objects in front of the camera. With this principle, the depth camera can build real-time 3D maps of the scene in its field-of-view (FOV), with frame rates up to tens of Hertz. Structured light, Time-Of-Flight (TOF) and stereo camera are some of the most prominent methodology used for depth cameras. Among them, we evaluated that the TOF technology is the one offering the optimal compromise between geometrical accuracy, speed, maximum range in depth and cost of the depth camera. The other technologies would be either very expensive (like stereo camera), either less accurate and with smaller tracking range (like structured light).

The most famous and widespread TOF camera is the KINECT v.2. The KINECT was designed by Microsoft as an economical consumer-grade device for human-machine interaction. Thanks to an innovative algorithm for person and posture recognition, the device was programmed to interpret gestures and translate them into instructions for a wide range of applications, like videogames or assistive computer interfaces. The KINECT v.2 algorithm can track up to six human bodies within a distance of 4.5 meters from the camera; with an opportune placement, the KINECT v.2 can easily monitor 10-15 $m^2$ around a radiation source. Together with the device, Microsoft released a Software Development Kit (SDK), i.e. a rich collection of libraries which can be used to create software. The existence of the KINECT SDK is a key point, since it allows to create personalized programs making use of all the KINECT v.2 features (including the depth sensor and the recognition algorithm) and, at the same time, to generate personalized output files including the tracking information of all *the relevant human joints*, in a *structured table format*. The KINECT SDK has been continuously evolving since the release of its first version, in 2011. After several years of improvements, the SDK has reached a high level of reliability, which means, for our IPS program, high stability and high performances. The geometric error of this device is estimated to be about 1-3 cm, which is more than sufficient for achieving the minimum requirements of the IPS. Finally, the TOF sensor of the KINECT and the recognition algorithm are very fast, even on a standard computer, and they can provide real-time tracking with frame-rates up to 30 Hz. Based on these characteristics and on the objectives of PODIUM, the KINECT v.2 TOF camera was chosen for developing the first PODIUM IPS.

## 2.2 Specification of the KINECT v.2

The KINECT v.2 makes use of two sensors: an RGB camera for acquiring conventional RGB images (for pictures or videos, with a maximum resolution of 1920 × 1080 pixels) and a depth sensing module. Figure 1 shows a visual exemplification of the FOV of the 2 types of cameras in the KINECT. It should be noted that the FOV of the RGB camera is wider and shorter compared to that of the depth sensor. The FOV of the depth sensor has an aperture of 60° and 70° in vertical and horizontal directions, respectively, while the FOV of the RGB sensor has an aperture of 54° and 84° in vertical and horizontal directions, respectively.

The depth sensing module is constituted by an IR laser and by an IR camera with a resolution of 512 × 424 pixels. The laser illuminates the scene by emitting pulsed Infra-Red (IR) light, while the IR camera scores IR photons bouncing back after a reflection. Differently from the most common depth sensing technology based on structured light, KINECT v.2 calculates depth distances by measuring the phase shift associated to the reflected IR light on a pixel by pixel basis. The use of an IR illuminator means that the KINECT tracking algorithm can work even when the lighting conditions in the workplace are poor. The phase shift method, also known as TOF, allows the camera to reach a good compromise between range of the depth sensor, spatial accuracy, and high framerate. The camera generates color and depth images with rates up to 30 frames per second, which is much higher than what is needed for tracking radiation workers.

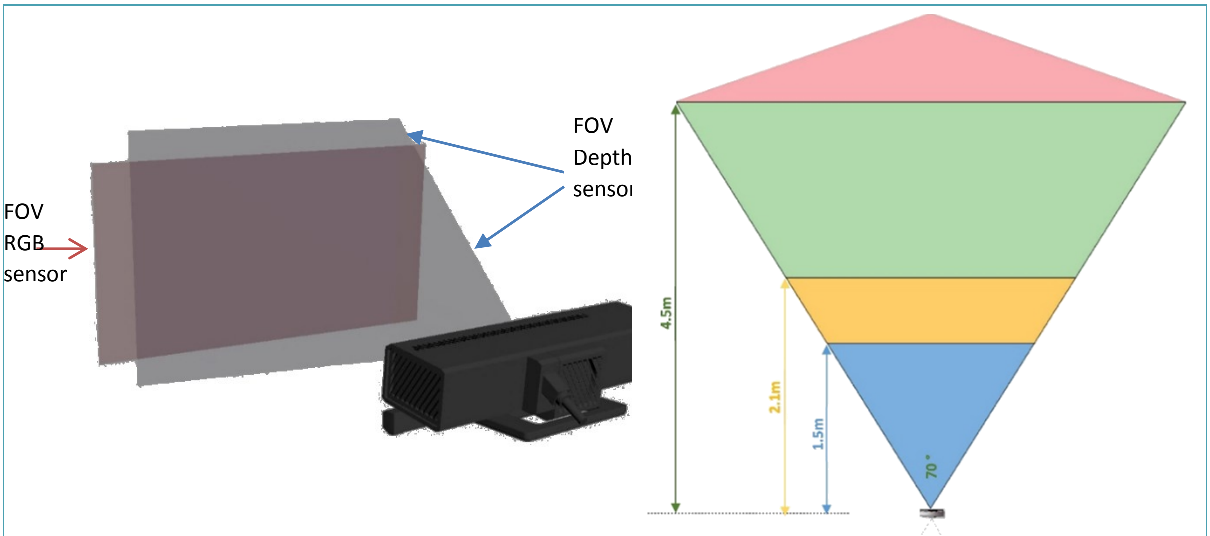



**Figure 1:** Field-Of-Views (FOVs) of the RGB and depth sensors of the KINECT v.2, and dimensions of the tracking areas. The ideal position of the tracked persons is between 1.5 m and 4.5 m.

## 2.3 Specifications of the IPS acquisition software KDA

As anticipated, the IPS is operated through a software package consisting of two main programs, developed by SCK•CEN. The first program is used for the calibration of the system and it is meant to be used only once, after the IPS has been set-up in the workplace. The second program, named KINECT Data Acquisition (KDA), controls the acquisition and the storing of the tracking data. Since the programs make use of special API(s) (libraries) and drivers for connecting to the KINECT, it is necessary to install a series of software to execute them correctly. Both of the IPS programs make use of the software development kit of the device, i.e. the “KINECT for Windows SDK 2.0”. Due to the SDK requirements, only computers running Windows 8 (or more recent) and equipped with USB 3 port will be able to connect the device and make use of the IPS software. Additionally, the IPS software makes use of some well-known Open Source libraries, like OpenTK, Emgu CV, Office Open XML and EPPlus. These libraries are used for processing the tracking data and for exporting it in table format.
KDA controls the acquisition of RGB and depth images, and it performs the KINECT recognition algorithm for identifying bodies and body parts on the depth images. Figure 2 shows the start screen with the acquisition settings, and the interface of the program while acquiring tracking data. The source code of KDA is made of a series of functions for acquiring and synchronizing the RGB and the depth images, and the recognition of body parts. Some of the functions are based on the KINECT SDK, while some others were programmed from scratch. While most of the source code was written in C# language, the graphic interface was written in XAML, to makes use of the Windows Presentation Foundation (WPF) graphical subsystem.

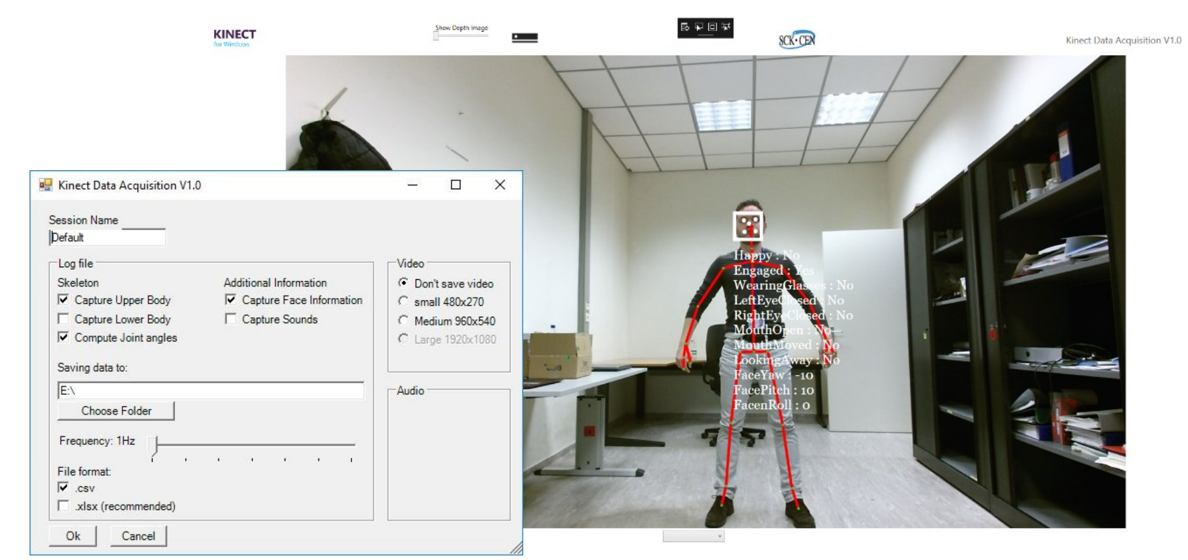



**Figure 2:** Interfaces of the KINECT Data Acquisition program

Figure 2 shows in red a *skeleton object* obtained by the KDA. This object is a sort of simplified virtual skeleton which stores the 3-Dimensional postural data and its variation in time. The skeleton object consists of an array of 25 joints arranged according to a kinematic chain which is consistent with the kinematic of the real human body. Figure 3 shows the joints and *virtual bones* connecting the joints. Each joint is tracked separately but according to the kinematic chain, and its corresponding C# object can be accessed independently to retrieve the corresponding spatial information. The KINECT v.2 algorithm includes, as well, a joint prediction model, which can be used to provide estimated joint positions when the view is partially occluded. KDA makes use of the prediction algorithm, but at the same time it keeps track of when it is applied. This is done by associating a tally parameter to each joint (Joint_inferred), which scores the level of confidence of the prediction algorithm. Thanks to the tally, it is easy for us to filter a tracked joint when its position is not inferred correctly by the prediction algorithm.

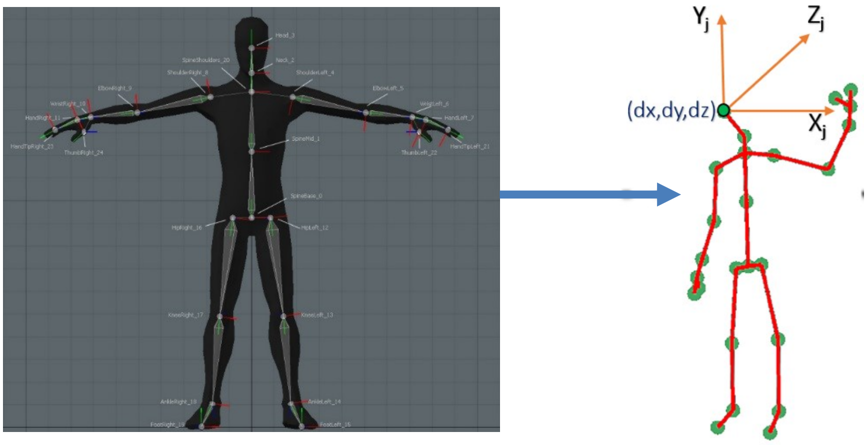
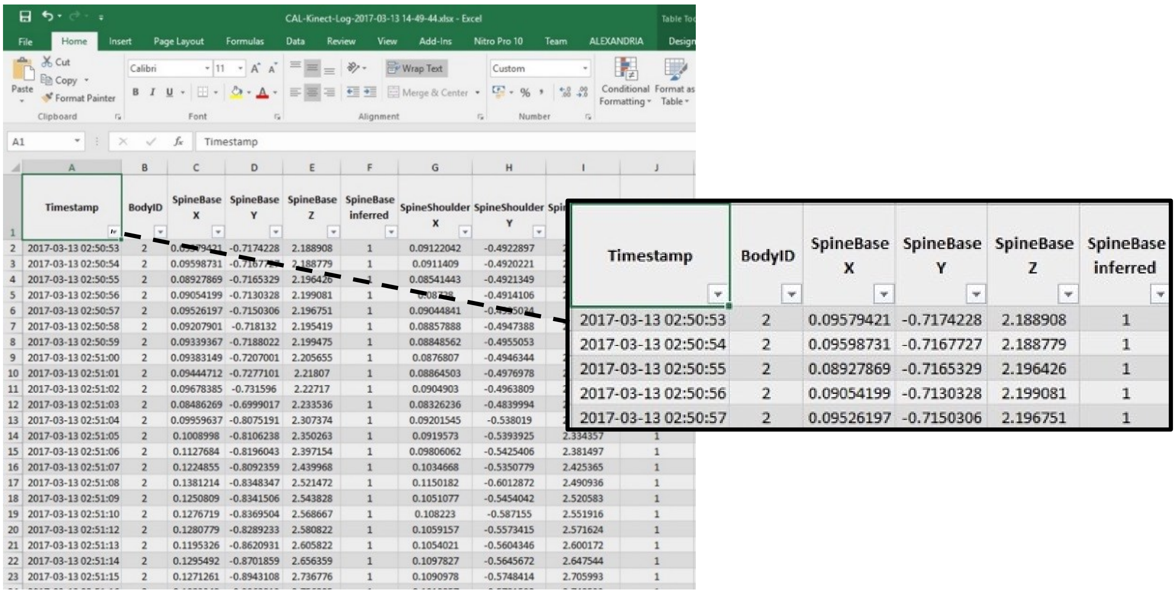



**Figure 3:** Overview of the 25 joints tracked by the KINECT v2 and corresponding index used for the skeletal tracking

The main objective of the IPS is the creation a real-time tracking data, which will feed the dose calculation programs of the PODIUM online dosimetry system. The real-time tracking data is provided by KDA in form of table with an output file. For each frame, a time stamp, the body ID, and the corresponding X,Y and Z coordinates of all body joints are appended at the end of the output file, which is constantly refreshing during an acquisition. In KDA, two formats of the output file can be chosen: Microsoft Excel standard file format (*.xlsx) or Comma-Separated Values (*.csv). Figure 4 shows a sample of the extracted information in CSV format. The use of a table format allows to easily filter the tracking data to extract coordinates in a way that is convenient to the dose calculation modules. This output file is the only data that is actually recorded by KDA; while the interface shows the live video stream from the KINECT, the program does not store any image (nor depth nor RGB).



| Timestamp | BodyID | SpineBase X | SpineBase Y | SpineBase Z | SpineBase inferred |
|---|---|---|---|---|---|
| 2017-03-13 02:50:53 | 2 | 0.09579421 | -0.7174228 | 2.188908 | 1 |
| 2017-03-13 02:50:54 | 2 | 0.09598731 | -0.7167727 | 2.188779 | 1 |
| 2017-03-13 02:50:55 | 2 | 0.08927869 | -0.7165329 | 2.196426 | 1 |
| 2017-03-13 02:50:56 | 2 | 0.09054199 | -0.7130328 | 2.199081 | 1 |
| 2017-03-13 02:50:57 | 2 | 0.09526197 | -0.7150306 | 2.196751 | 1 |

**Figure 4:** Example of KDA output file in CSV format. The file includes the collection of 3-Dimensional positions for each the 25 joints constituting the skeletal object, with a sampling rate of 1 Hz.

Finally, it is important to underline that for the moment KDA is run as a standalone application, with its own interface. However, PODIUM is going to develop a web-app which will control a series of technical modules for tracking and dose calculation. When the web-app will be developed, KDA will run as background batch process. Then, the web-app will execute directly the KDA process, without need for any interaction to start the acquisition of the tracking. The process will be carried out in the background, with the settings inputted through the web-app interface.

## 2.4 Calibration of the IPS

In theory, the IPS should provide the coordinates of the workers' joints with respect to the workplace where he/she is performing an activity. With this data, it is possible to calculate the distance from the radiation source, and thus estimate doses. However, the raw data from the IPS consists of the coordinates of the joints expressed only relatively to the *camera* coordinate system. When changing the position and the orientation angle of the camera, the joints coordinates will change accordingly. Therefore, the tracking data cannot be used directly to extract the actual positions and postures of the workers with respect to the workplace, which is the *real-world* coordinate system. So, for using the tracking data in our online dosimetry system, we need to transform the camera coordinates to real-world coordinates. This is done by means of a calibration process, which estimates many IR camera parameters for defining the camera coordinate system. For calibrating the IPS, SCK•CEN developed a calibration program, whose interface is shown in Figure 5. The calibration process is performed only once, after fixing the camera location and orientation in a given workplace.

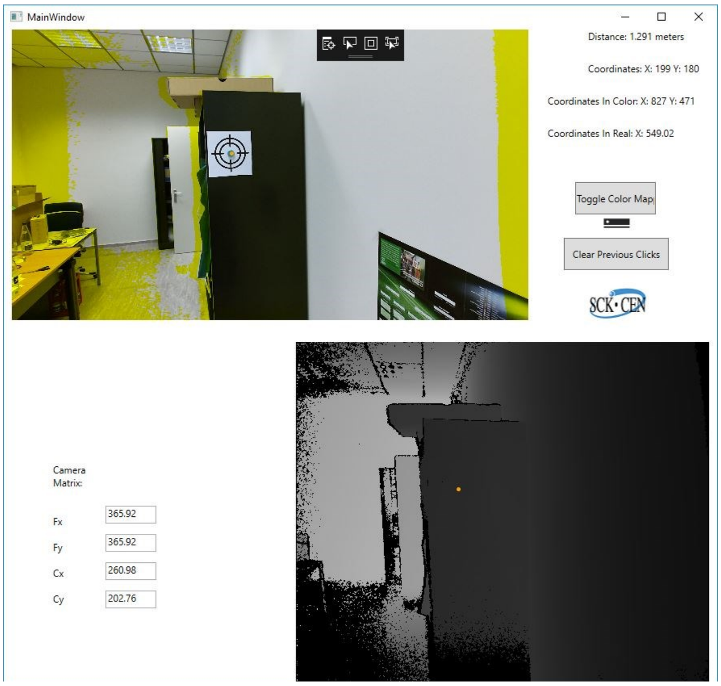



**Figure 5:** Calibration program for the PODIUM IPS

The camera parameters include intrinsics, extrinsics, and distortion coefficients. To estimate the camera parameters, we must detect 3D world points from the depth camera and then identify their corresponding 2D image points with the optical sensor. We can get these correspondences using multiple images of a calibration pattern, such as a checkerboard. Using these correspondences between pixels from the depth and RGB images, we can solve a system of equations for the camera parameters.

To achieve this objective, we developed a calibration protocol. The protocol calculates the camera matrix using the extrinsic and intrinsic parameters. The extrinsic parameters represent the rigid transformation from the 3D world-coordinate system to the 3D camera-coordinate system. The intrinsic parameters represent a projective transformation from the 3D camera-coordinates into the 2D image-coordinates.

Mathematically, the extrinsic parameters are described by a rotation matrix, **R**, and a translation vector, **t**. The origin of the camera-coordinate system is located at its optical center, and its **x** and **y** axis define the image plane. A graphic representation of the extrinsic parameters is shown in Figure 6.

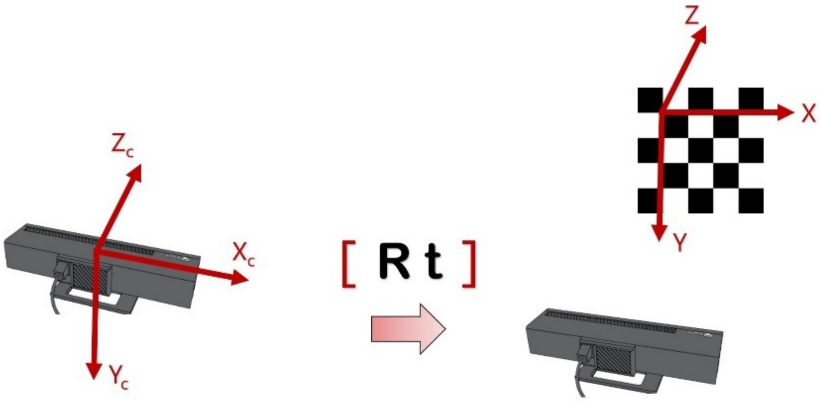



**Figure 6:** Schematic representation of the extrinsic parameters, which represent a rigid transformation from world-coordinate system (X, Y, Z) to the camera-coordinate system (Xc , Yc , Zc).

The intrinsic parameters include the focal length, the optical center, also known as the *principal point*, and the skew coefficient. However, due to the inner difficulty in assessing the skew coefficient, we assumed it to be equal to 0, which simplifies the intrinsic calibration. Thus, the camera intrinsic matrix, $K$, is defined as:

$$K = \begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix}$$

In theory, the intrinsic transformation matrix of the KINECT v.2 is given by Microsoft in a form of mapping function. The mapping, provided by the official SDK, is the result of the factory intrinsic calibration. However, because of the mechanical inaccuracies in the manufacturing and assembly processes, the predefined intrinsic calibration could be slightly inaccurate, and change with each individual KINECT camera. For this reason, we perform a procedure which can calibrate accurately the IPS, once it is installed in its location. The procedure consists of 3 steps:

1. Place a known pattern or a marker (Figure 7) in the view of the camera in a defined real-world coordinate of the scene. The marker is placed within the FOV of the KINECT. The marker will serve as reference point for the new world-coordinate system, so its location must be measured with respect to the workplace and to the radioactive source.

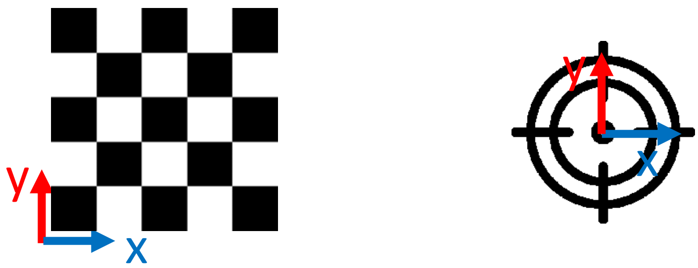



**Figure 7:** Examples of patterns used for intrinsic calibration (checkered-board and crosshair)

2. Perform standard camera calibration to determine the intrinsic parameters (focal length, position of the principal point and the coefficients that describes the lens distortion) of both RGB and IR camera by detecting the pattern. In this way, a personalized **K** can be determined with greater accuracy for the individual KINECT v.2 camera.

3. Convert the reference point 2D image coordinates (u, v) in pixels to normalized camera-coordinates by solving the following system of equations:

$$\begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X_c/Z_c \\ Y_c/Z_c \\ 1 \end{pmatrix}$$

The overall image formation process, including both extrinsics and instrincs, is given by:

$$\underbrace{s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix}}_{\text{2D Image Coordinates}} = \underbrace{\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}}_{\text{Intrinsic properties (Optical Centre, scaling)}} \underbrace{\begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix}}_{\text{Extrinsic properties (Camera Rotation and translation)}} \underbrace{\begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}}_{\text{3D World Coordinates}}$$

In this way, we constructed a transformation matrix to re-map the coordinates of the tracked joints with respect to the position of the reference marker. Figure 8 shows a schematic representation which wraps up the calibration when applied to a tracked skeleton object. The whole procedure was implemented in the calibration program, to ease the calibration when setting the IPS in new workplaces or when then testing different IPS setups which require the camera to be moved.

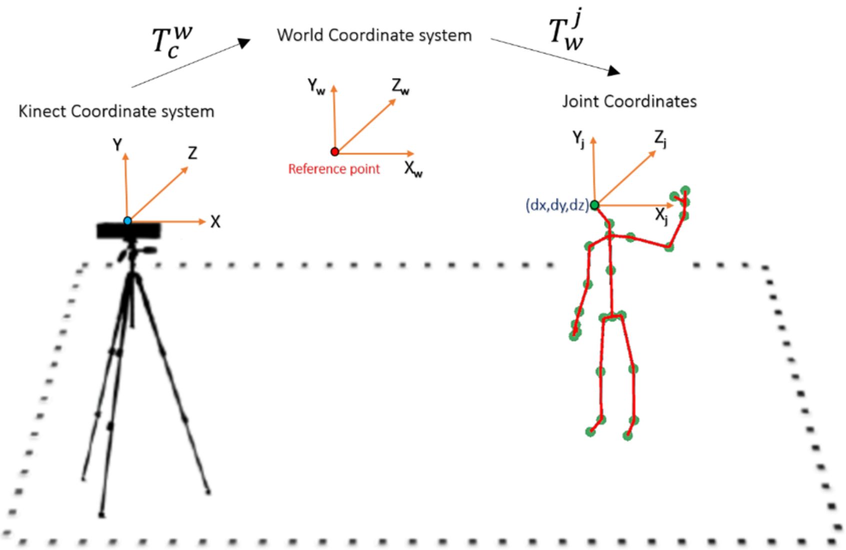



**Figure 8:** Scheme showing how the calibration procedure allows to transform the coordinate system from the KINECT (i.e. camera-coordinate system) to any reference point (i.e. word-coordinate system)

## 2.5 Workflow for setting and starting acquisition with PODIUM IPS

1) **Positioning of the KINECT**

   When setting up the IPS, the camera is positioned in a location with a clear view of the area around the radiation source. The ideal position of the KINECT is at about 2 meters of height (or higher) and facing the monitored subjects. It is important to reduce the chances of unforeseen occlusion of the view of the tracked individual, in particular of the exposed parts of the body.

2) **Calibration**

   Once the KINECT camera is positioned, the calibration procedure is performed to relate the recorded joints positions to real-world coordinates, which identify the position of the person in the workplace.

3) **Image acquisition**

   Once the camera is calibrated, the image acquisition can be started. The sampling rate of the postural data can be adjusted from 1 Hz to 30 Hz, where the highest threshold is imposed by the maximum frame-rate of the KINECT skeleton tracking. Normally, a sampling rate of 1Hz would be more than adequate for the purposes of PODIUM. However, other conditions can be selected depending on the requirements of the data processing. The acquisition is stopped when monitoring is finished. This is now done manually, but it is planned to be performed automatically through the new PODIUM application.

4) **Data output**

   KDA processes the camera signal to obtain a depth image on the first place and then it writes the postural data to an output file with table format (Figure 9).

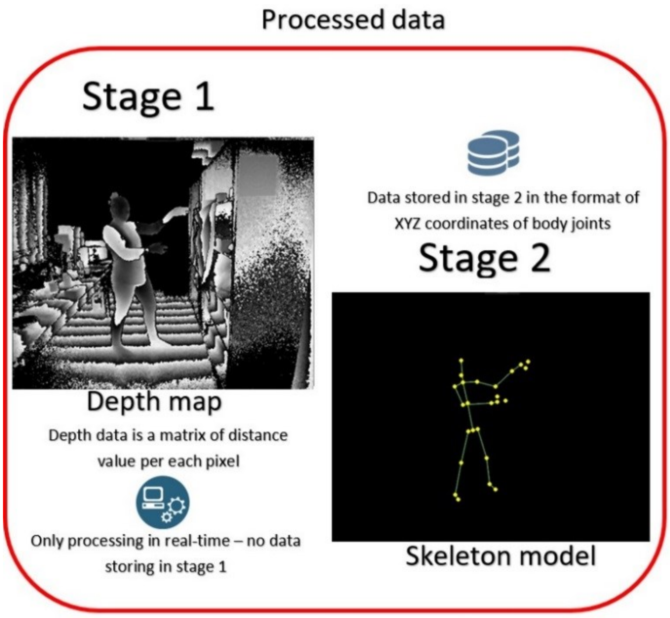



**Figure 9:** Scheme of the data processing

## 2.6 Integration of the IPS into the process-flow of dose calculation

The developed IPS will be integrated in the online dosimetry system of PODIUM. The IPS is fundamental for calculating workers' doses, as they depend on the position and posture of the workers compared to the position of the radiation source. For brevity, the details about the designing of the web-app software are not included in this deliverable. However, in the development of the IPS we accounted already for the web-app process-flow, so that the system which can be integrated easily in the online dosimetry system. Figure 10 shows an example of the process-flow of the online dosimetry tool.

In a few words, the PODIUM dosimetry system makes use of a series of technical modules. The modules are executed in a synchronized manner (in the background) through a web-app interface (the front-end). Each of these technical modules has a specific function, but, in principle, we can think that each module has to process some input data (according to its function), and then it has to create an output file compatible with the next module being executed. The technical modules are: the tracking module, the phantom module for selecting a phantom type and posture, the Monte Carlo module for running simulations, the geometry module, the source module and the dose conversion coefficient calculation module. The execution of the various modules will happen in parallel and/or in sequence (in case the output of a module is used to feed the input of another), depending on the approach used for calculating doses.
The KINECT v.2 camera and the KDA software correspond to the tracking module. The output file of the IPS are then used by the dose calculation modules. Two approaches are foreseen for the dose calculation: accelerated real-time Monte Carlo (MC) simulations with MC-GPU, and standard MC together with a look-up table of pre-calculated dose conversion coefficients. The online dosimetry system will automatically switch from one module to another, depending on the type of workplace and on the radiation field.

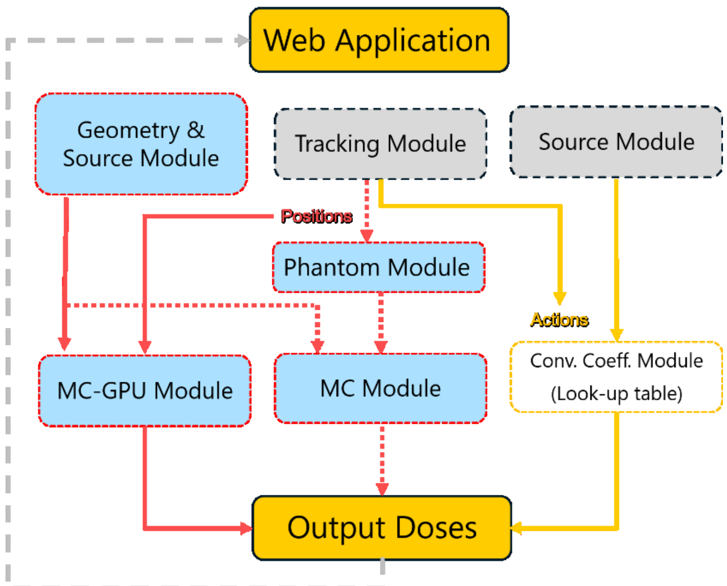



**Figure 10:** Example of Web-App scheme for calling back-end modules.

## 3. Current limitations and future work

The IPS presented in this deliverable was successfully tested in simple workplaces within SCK•CEN and UPC, and in a catheterization laboratory (Cath-lab) of UZ Brussels (Vrije Universiteit Brussel). However, the IPS still has some limitations. Some of the limitations will be addressed with the development of a more advanced IPS, which will be released with the next deliverable of ST9.6.1.

The main limitations are:

a. The range of the person tracking algorithm is restricted to about 4.5 meters;
b. The Field-Of-View of the KINECT v.2 depth camera is limited to 84 degrees horizontally and 54 degrees vertically;
c. There might be occlusions affecting the view of the tracked workers;
d. There might be a misidentification of the tracked workers;
e. The position of the joint coordinates can show some little fluctuations and sporadic outliers.

The first three limitations are somehow due to the intrinsic hardware features of the KINECT v.2, and they cannot be resolved without changing the tracking setup. However, a correct placement of the KINECT can easily prevent the risk of occlusions, allowing a clear view of body parts of interest. Another possibility is the use of multiple KINECT cameras pointing the scene from different and complementary viewpoints. We already started studying how to use 2 KINECT cameras in a single IPS, and the tests showed that this approach could further improve the accuracy of the tracking. For this purpose, we will create a program for synchronizing real-time tracking data between the two cameras. Thanks to this approach, we can be able to increase the monitored surface from 10-15 $m^2$ to about 20-30 $m^2$. Finally, as already mentioned in paragraph 2.1, with the use of optical cameras and with OpenPose we will develop an IPS capable of monitoring even the largest areas, including outdoor workplaces.

Another limitation is that the current tracking software does not provide an algorithm for identifying individuals. In the future, we will try to implement an algorithm based on the recognition of clothes, body features and faces. Thanks to this algorithm, we will be able to further individualize the monitoring and to improve the automatization of the tracking software.

Finally, some little fluctuations of ± 1.5 cm, known as jittering, have been identified in the joints' coordinates. The joint jittering is a well-known problem for the KINECT v.2, and it is due to the noise of the depth images and to the tracking algorithm. To reduce the jittering, we propose to sample the depth images with a higher frequency, i.e. 30 Hz. This high sampling rate will allow us to filter the tracking data, thanks to which we can smooth jittering and spikes. UPC is currently developing a filtration algorithm, which will be applied to the output file from KDA by means of a simple program. The algorithm is based on two steps: firstly, detecting and rejecting the outliers in the joint position data and secondly, smoothing the trajectories. The advantage of the algorithm is that it will not introduce a compromised delay, which could cause a desynchronization in the acquisition time. In this way, we will be able to still provide real-time tracking data, without requiring high computational resources.

We are also developing an improved and completely automatic version of the calibration program, which will allow us to ease the set-up of the IPS, and that will improve the reproducibly of the tracking.

## 4. Conclusions

The development of the Indoor Positioning System constitutes an important step for the PODIUM project. The IPS consists of a single KINECT v.2 camera and of two programs. The first program is used for the calibration of the system, while the second governs the acquisition of the tracking data. The system was designed to be simple and reliable, and to comply with the requirements of accuracy and performance that we demand for the PODIUM online dosimetry system. The software for acquiring and recording tracking data was conceived to be easy to use, by means of a simple graphical interface. We tested the IPS with measurements both in controlled environments (i.e. the laboratories of SCK•CEN and UPC) and in actual workplaces (CHU Liege, VUB), acquiring tens of hours of tracking data. The extensive tests in controlled environments allowed us to characterize the performance and the limitations of our first IPS. In virtue of these results, we now have the confidence for continuing with the next stages of PODIUM, in which we will implement the IPS in selected workplaces.

In the next months we will distribute the system to the PODIUM partners. ST9.6.1 participants will take care of setting up the system and of performing the calibration for each workplace. However, after a short training, ST9.6.4 and ST9.6.5 partners will be able to operate autonomously the IPS through its acquisition program. During our measurement campaigns, we will collect huge amounts of tracking data, which will be used as input to ST9.6.2 for the creation of a database of dose conversion coefficients. This data will also allow ST9.6.1 to better characterize the typical positions and postures that the nuclear workers adopt when performing their practice. This information will be fundamental for designing the second and more advanced IPS, which will address some of the limitations of the first IPS.

To conclude, with this IPS we achieved a first important step towards our online dosimetry system, allowing us to start extensive measurement campaigns to monitor medical staff in Interventional Radiology and workers in neutron fields.