D2.3

SPARK MODULES PROTOTYPE

Approval Status

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H2020_ICT_2015_SPARK_688417

TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.

H2020_ICT_2015_SPARK_688417

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
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1 EXECUTIVE SUMMARY

This deliverable describes the outcomes of task 2.4 "Development of the modules prototypes composing the SPARK platform". This task falls under the WP2 activities, which aim at defining the modules of the SPARK platform. The prototypes of the modules have been developed by using the most promising technologies and technical solutions identified in task 2.3. These modules prototypes will be used by the SPARK consortium to validate, during the activities of task 2.5, different technical solutions according to the metrics elaborated in task 2.2 and described in the deliverable D2.2.

This deliverable describes the hardware and software structure of the prototypes of the modules and their functionalities. In addition, it demonstrates the technological feasibility of the ICT solutions claimed in the project proposal and it could be used to increase the awareness in to what extent the SPARK platform will be able to support the creative actors and enhance their creativity.

The document starts with an introduction that reports the rationale behind the activities of task 2.4. Then, after a brief overview, each module is described in detail by highlighting the choices made with respect to the technologies analysed and presented in D2.1. In actuality, it has been decided to discard some of these technologies for different reasons (e.g. limited suitability for the SPARK application domain, limited maturity of technology, excessive cost etc.). Finally, the last part of the deliverable provides a critical analysis on the usage and the integration of these modules within the SPARK platform.

2 INTRODUCTION

The main objective of SPARK project is the development of an ICT platform supporting the creative co-design sessions. From the beginning of the project, the SPARK Platform has been schematised as a set of modules that perform specific functions. The two main modules

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constituting the SPARK platform are the Spatial Augmented Reality (SAR) module and the Information System (IS) module. The SAR module will enable the participants of a collaborative creative session to build a mixed prototype of the proposed creative concepts, by allowing the combination of 3D shapes, textures, images and sketches on a physical object. The main purpose of the Information System (IS) module is, instead, to manage the resources used by the SAR module to generate the mixed prototype. In addition, the IS module should give the possibility to review and report the results of the co-design sessions. In previous tasks of WP2, for both modules different technical and technological solutions have been identified, as presented in D2.1. In task 2.4, it has been decided to analyse the parts constituting these two modules and to develop them in a prototypal form in order to check the hardware and the software, which could be used in WP3 for the final implementation of the platform.

2.1 Modules overview

The SAR module integrates technologies for visualisation, tracking and interaction. Visualisation requires the use of one or more video projectors. While the projection quality depends on the performance of the projector, other aspects, which relate to the visualization parameters, are independent from the hardware specifications. Since the superposition of several projections is already supported by some commercial technologies, the development in this task, focused on calibration procedures for projectors. In SAR applications, tracking technology has to assure the perfect alignment of projected images onto the physical prototype. During the task, some of the identified technologies have been implemented to compare their functionalities. Finally, the interaction technology provides the user with metaphors that allow interacting in real time and in a natural way with the mixed prototype, without interfering with the SAR projection. The interaction methods proposed are hands free with the use of static or dynamic gestures recognition devices. Once enabled, the gestures performed by the user, trigger actions as rotating, scaling, moving and deleting elements projected on the surface of the mixed prototype.

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Within the SAR module, all these technologies are integrated and managed by a dedicated software application. In the integrated platform, this software application will provide the users with functions for the manipulation of the mixed prototype. To start demonstrating and checking the functionalities of future SAR software, a demo version has been developed. Although this demo version has been developed by using simple Augmented Reality (AR) technology, it allows the SPARK consortium to evaluate and discuss about several issues that should be solved in the final release of the software.

Eventually, in the integrated platform the IS module will interact directly with the SAR module and receive all the modifications applied to the mixed prototype. In particular, the SPARK consortium identified some important features that are summarized in the following:

- manage users;
- organize the resources for co-design sessions of a specific product of a specific client;
- track all changes applied to the mixed prototype during the execution of the co-design session;
- visualize the results and generate reports.

In this document, a first version of the IS module is presented. It already includes most of the features listed above and proposes some solutions related the future integration with the SAR module. In addition, complementary visualizers for the IS module have been developed with the purpose to offer an alternative and independent visualisation modality, with respect to the SAR visualization. The need for these complementary visualizers emerged in WP1, when in some design sessions the end-user partners required to display, for instance, the digital representation of the mixed prototype onto a calibrated monitor in order to assess with the highest precision colours and textures of surface materials. Since the complementary visualizers are WebGL-based, they could be also shared with remote participants to the co-creative session.

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3 VISUALISATION

The visualisation of the SAR module enables a correct projection of images onto the physical prototype used during the co-design session. The theory is quite simple and it is well managed by most visualisation tools based on the OpenGL standard. Most viewers use this standard and they can produce the same image quality. However, it is important to ensure the synchronisation of multiple projectors, since the SPARK platform could include more than one projection system. Consequently, the visualisation modules should include calibration methods to control the projected images according to the physical scene.

3.1 PARAMETERS OF THE VISUALISATION SIMULATION

A visualisation simulation is controlled through a theoretical model, which matches eye perception with high accuracy. The basic parameters involved in this theoretical model are presented in the following. Figure 1 describes the overall process. A virtual object is defined in a given frame. The eye is located at a point *E* and observes the scene in the gaze direction $\vec{n}$. The $\overrightarrow{up}$ vectore designates the orientation of the head around $\vec{n}$. A projection plane π is normal to $\vec{n}$ and at the distance *D* from *E*. Then, any point *A*, *B* or whatever is projected in the plane π by intersecting the plane with the line (*EA*) or (*EB*).

A video projector is working in the same model and it will properly send information in the scene if the centre of vision *E* is properly located as well as the projection direction $\vec{n}$ and its orientation $\overrightarrow{up}$. The *D* parameter plays as a zoom effect and should be normalized for SAR applications.

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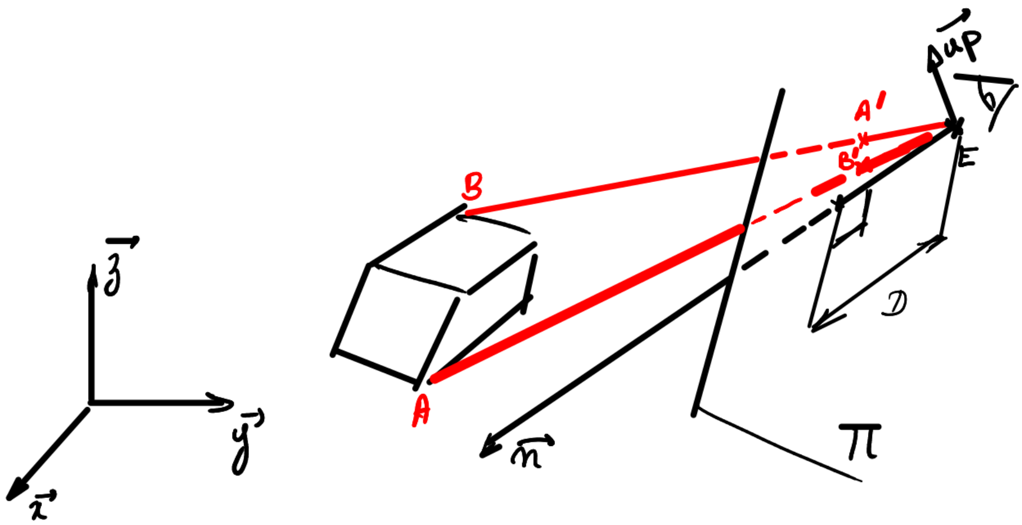

Figure 1: Projection perspective model.

The parameters to take into account for projection are:

- clipping planes: far and near plane at a given distance of the Eye. Everything in front of the near plane or after the far plane is hidden.
- angle of view: human vision as video projectors have a restricted vision or angle of projection. This angle of view is about *15*°.
- image ratio: defining the proportion of the screen in x, and y. A full-screen projection on a *16/9* video projector will have an image height H such that: $H = 9/16\,W$ where W is the image wide span.
- translation in $\vec{x}$ and $\vec{y}$. A standard visualisation system send an image centred on the point intersecting the line (E,$\vec{n}$) and the projection plane π. The centre may be translated in the plane π.

All these parameters define the projection volume and they have to be sharply identified through a calibration procedure. Next section proposes a possible calibration procedure that should be integrated into the SPARK platform.

In addition, some optical effects can be added through lens or with virtual deformation of the image. Shearing angles can be introduced and must be tuned to the zero value of the video projector (keystone parameter). Other effects, such as the barrel/fish-eye, should be avoided by controlling the related control parameters of the video projector.

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Finally, the focal point of the video projector has to be tuned. It is usually done with a manual setting, which should be set to get sharp images at the centre of the physical scene of the projection. The quality with a single projector will be better at a given distance of the video projector and will be lower for nearer or longer distances. Therefore, with this model, the projection volume and the position of the video projector within the scene must be sharply calibrated for a good SAR visualisation.

3.2 PROJECTION VOLUME CALIBRATION

Every OpenGL-based application provides all the basic parameters to control projected images. Anyhow, it is mandatory to calibrate position and orientation of the video projector with respect to the physical scene unless images will be at least slightly translated and at worst fully disconnected from the expected projection target: a short mistake on the video-projector orientation provides huge gaps in the real scene at a long distance. Section 3.3 will demonstrate the proposed processes to fix the position, but the candidate processes expects to have a good model of the "projection volume" and potential deformations due to optical effects including shearing angles, barrel or fish-eye effect, and focal convergence.

The projection volume is determined, once for all, for every video projector. In principle, manufacturers might provide these data for each projector, but in actuality this is seldom the case. Consequently, an experimental process to measure the projection volume has been set up.

The issue is to determine:

- the real centre of projection of the video projector (the theoretical point *E*);
- the view angle;
- the ratio (it is usually pre-determined);
- the up vector (it is usually obvious).

Let put the video projector on a horizontal surface, as shown in Figure 2. The two clipping planes (far and near planes) normal to the horizontal plane and normal to the orientation of

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the video projector have to be identified. The far plane is at the distance *Df* of a reference frame selected on the video projector. The near plane is at the Distance *Dn* of the same reference frame selected on the video projector.

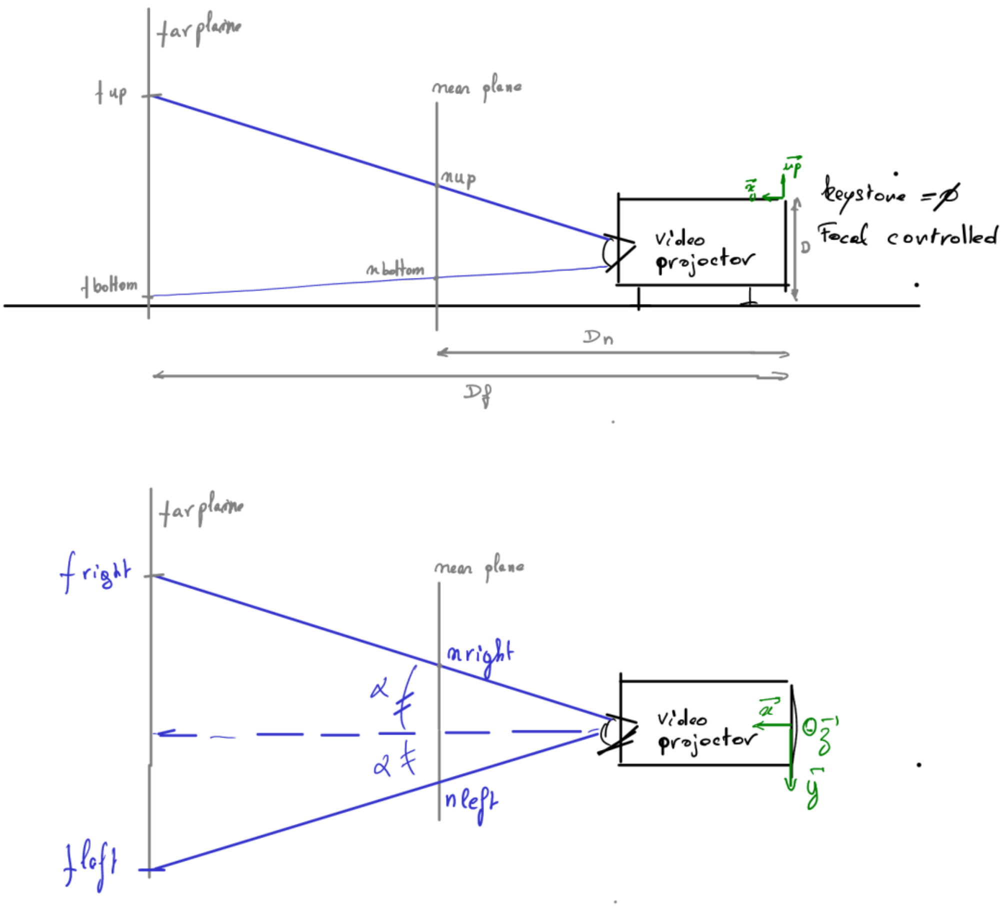

Figure 2: Calibration of the projection volume (frustum) of a video projector.

The projection has to be symmetric on left and right. Then f_{rigth}, f_{left} b_{rigth} and b_{left} measures will allow to measure the angle of view:

$$tg(\alpha) = \frac{f_r}{D_f - D_E} = \frac{n_r}{D_n - D_E} = \frac{f_l}{D_f - D_E} = \frac{n_l}{D_n - D_E}$$

Where: α and D_E are unknown,

f_r, n_r, f_l and n_l are measured

D_f and D_n are given by default

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We can conclude about α and D_E:

$$D_E = \frac{f_l D_n - n_l D_f}{f_l - n_l}$$

The measures f_u, f_b, n_u, n_b are providing the heighth of point E on $\vec{z} = \overrightarrow{up}$ axis and the translation of the center of projection along $\vec{z}$

A technical template will be designed and manufactured to properly locate the video projectors and the two projection planes at determined positions. A plate cantilevered on a rail with a mobile and indexed projection plane would be necessary. A pre-print grid on the projection plane will ease the measure of distances on the projection area.

3.3 Calibration of the projector location

Once the projection volume is calculated, it is important that position and orientation of the projector are well known. To get this calibration two methods are presented in the following. The first is based on the projection of a set of points; the second is based on the alignment of a physical artefact with respect to its simulated image.

3.3.1. Calibration by points

This approach for the calibration of projectors is based on measuring the position of points, which are projected by the video projector, and, from these data, deducing the video projector location/orientation.

The first way to do this is to project three points onto a surface. From these three points and the video projector projection volume that we have determined before, we can get the video projector location/orientation, as shown in Figure 3.

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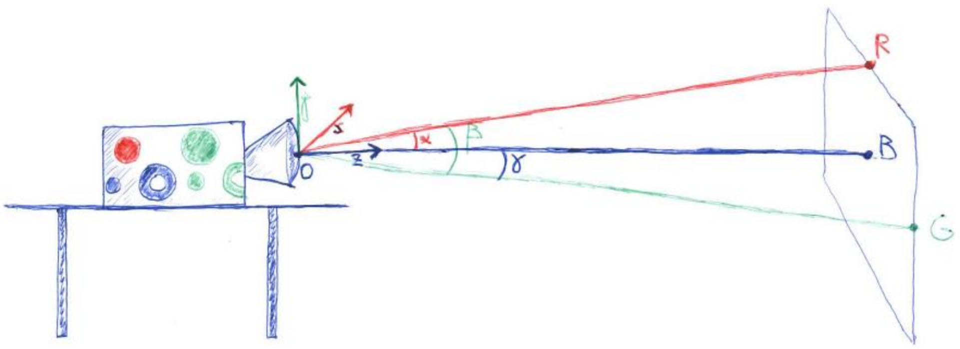

Figure 3: Three-point Calibration.

However, this method implies knowing the parameters related to the projector field of view.

Another way to get this calibration is to project three points on two different planes. From these six points, the video projector field of view and its location in the physical world are easily calculated.

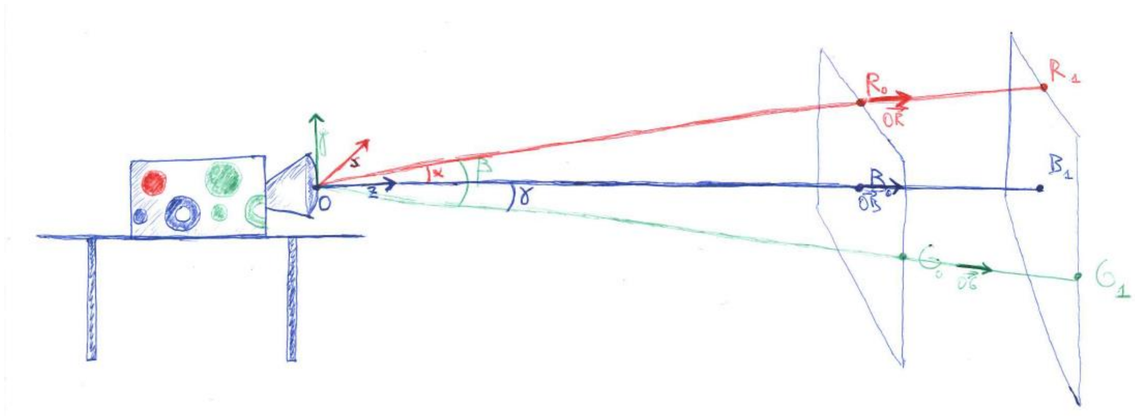

Figure 4: Six-point Calibration.

3.3.2. Calibration by artefact

The calibration method is based on the alignment of a tracked physical artefact onto its image provided by the projector. Position and orientation of tracked object provide the information to derive position and orientation of video projector.

The first step of the calibration method is to calibrate the physical artefact according to the tracked marker, which is fixed on it. The reference frame of the projected artefact, in fact, is not

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the same of the one in the physical world. It is necessary to calculate the transformation matrix that provides the location of the artefact in the virtual scene starting from the physical location of the marker in the real world. This is done by putting the physical artefact at a well-known location and by comparing it with the data of the tracking device, as shown in Figure 5.

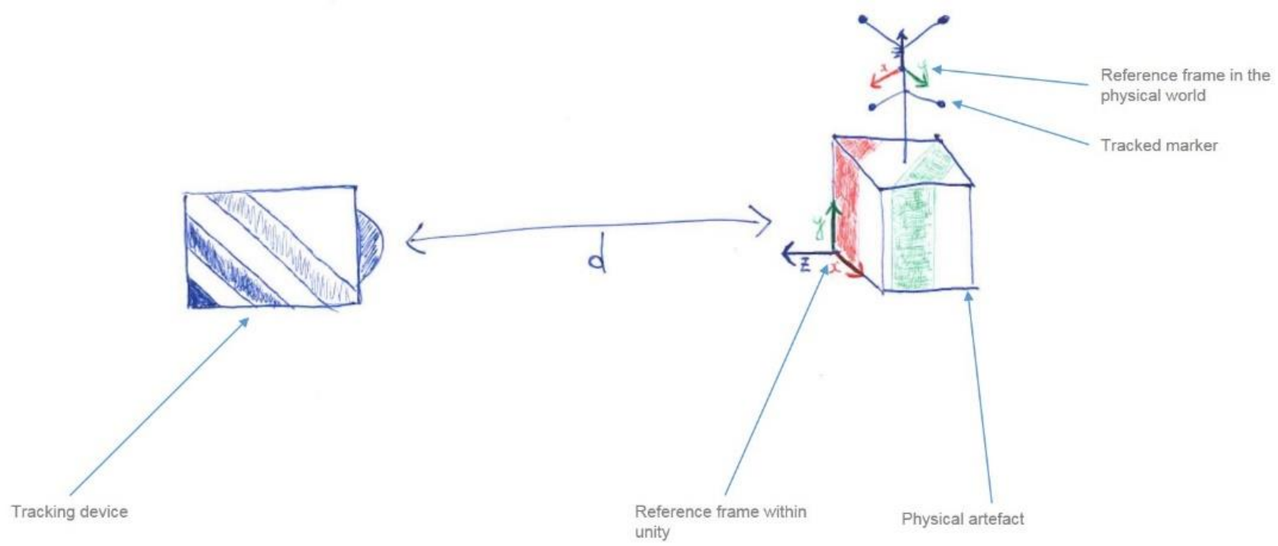

Figure 5: Calibration of the tracked artefact.

Once the artefact is calibrated, the rest of the calibration process can be performed by putting the physical artefact, which is still tracked, onto its projection, and from these data, by calculating position and orientation of the video projector in the virtual scene, as shown in Figure 6.

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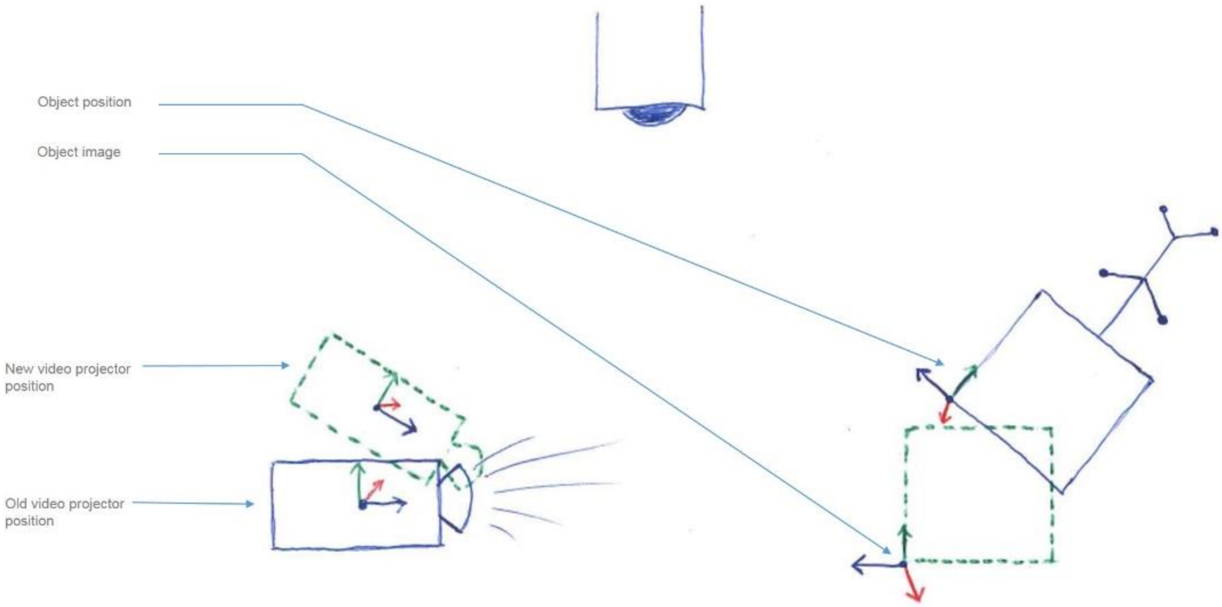

Figure 6: Project calibration with tracked artefact.

3.4 CALIBRATION OF A MULTI-PROJECTION SYSTEM

The calibration of multi-projection system requires the calibration of every single projector. Consequently, for each projector it is necessary to properly define the projection volume and the location of the projector, as described in sections 3.2 and 3.3.

The issues of multiple projections mainly relates to the managing of overlapping area and gaps, as shown in Figure 7.

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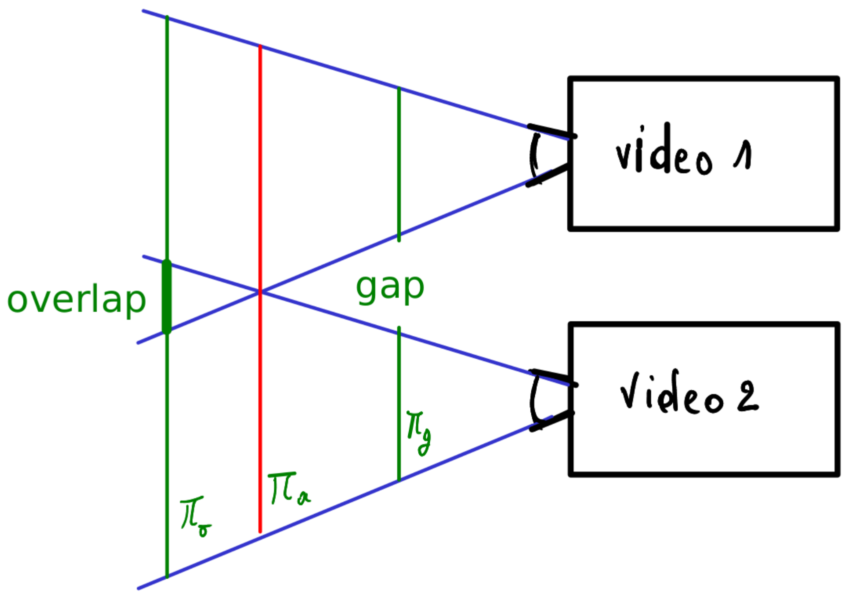

Figure 7: Overlapping images and gaps between images.

To control these issues two methods have been investigated. The first method is to physically locate video projectors in order to align the borders of two projected images. Unfortunately, even in a favourable case, where two projectors are parallel, non-overlapping images are only possible on the single plane π_a. On plane π_o an overlap may occur while on plane π_g a gap is created. For projection on a wall, well-calibrated positions would fix $\pi_o$matching the wall. Then two independent images will be projected. However, in a SAR environment images are produced within the whole projection volume (between near and far plane) and, consequently, overlapping and gaps cannot be avoided. The area for the physical scene must be almost on the left of $\pi_o$and a second strategy must be applied to avoid overlapping images.

A second method considers the projected scene as a set of objects. At each frame, every object should be placed with respect to the frustum of each video-projector. Then, the following cases occur:

- The object is owned (almost partially) by a single frustum: it is displayed by the corresponding projector.

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* The object is out of every frustum: the object will be hidden by default by the projection system: nothing to do.
* The object is shared by several frustums: then a rule should select the best frustum and associate the objet to a single video-projector. While in this situation, the object should be hidden for the other projectors.

The second method should be more effective in a SAR environment since the projection is done on dedicated objects while the overall background of the scene could be rendered as a full black colour.

4 TRACKING

The SAR platform needs that the projection is directly driven by the position of physical objects within the real scene. The next section provides a generic tracking model suitable to undertake tracking issues independently from the specific tracking technology which will be selected. Then, the other sections report sequentially the technological solutions, which have been identified in the previous tasks of WP2:

* electromagnetic sensors based tracking
* infrared recognition based tracking
* video analysis based tracking
* inertial sensors based tracking

The last subsection summarises and compare the solutions according to the generic tracking model defined in section 4.1.

4.1 GENERIC TRACKING MODEL

A tracking system suitable for the SPARK platform should provide the following functions:

* Recognition of the objects present in the physical scenes. This may include a characterization of the quality of recognition. This function may be translated in a meta language as follows:

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- *tracking_artefacts_ids() → int [ ]*: at a given frame time, this functions returns the set of ids recognized in the physical scene among a list of registered artefacts ids;
- *tracking_artefact_quality_level(id) → float*: given an artefact *id* returns a level of recognition quality within *[0,1]*. If the object is not in the scene, this value is equal to *0*. If a specific technology cannot identify a quality level, value *1* should be returned when the artefact is detected (turning *id* into a binary variable).

- Identification of the position and orientation of objects in the scene. This also may include a quality indicator about this position.
  - *tracking_position(id) → Th:float[4*4], Q: float*: for an artefact *id* recognized in the scene, this function returns:
    - Th: a homogeneous function of the position of the artefact within the main frame of the physical scene.
    - Q: a float value identifying the quality of the tracking. For some technologies, this value cannot be estimated, then a binary value should be applied.
- A calibration procedure of the main frame. The global frame of the physical scene may be identified. The tracking system may have an internal basic frame, but the point is to define the frame in which the artefact positions will be returned by the *tracking_position()* function. The calibration is usually dependent on the tracking technology, but once the tracking system delivers positions of artefacts a basic function could register the current position of a given artefact as the new reference frame:
  - *tracking_set_reference_frame(id) → Boolean*: this function takes as a reference frame the current position of a physical artefact at a given frame. Then, if the artefact is moved, this reference frame does not follow the artefact. The returned Boolean value validates that the *id* was visible at a specific frame.
- A calibration procedure of a physical artefact to identify a reference position of the tracked physical artefacts.
  - *tracking_calibrate_artefact(id, x, y, z, roll, pitch, yaw) → Boolean*: when this function is activated, the current position of the artefact is get through the *tracking_position()* function. A correction of the transformation matrix is applied to deliver a position at the *x, y, z* position with an orientation defined via the roll pitch and yaw angles.

Consequently, tracking technologies have to be investigated according to the functions previously defined and listed hereafter:

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H2020_ICT_2015_SPARK_688417

- *tracking_artefacts_ids() → []*
- *tracking_artefact_quality_level(id) → float*
- *tracking_position(id) → Th:float[4*4], Q:float*
- *tracking_set_reference_frame(id) → Boolean*
- *tracking_calibrate_artefact(id, x ,y ,z ,roll, pitch, yaw) → Boolean*

4.2 Electromagnetic sensor based tracking

Electromagnetic sensor based tracking system uses the electromagnetic field, which is generated by its emitter, to calculate position and orientation of its own sensors. The system used to implement the test setup for this project is the Polhemus Patriot. This device can share information with client applications, as the SAR module, through the Polhemus VRPN plugin that is a middleware server receiving Polhemus data and sending them to client applications. The Polhemus Patriot used for the test has two sensors, which can be easily distinguished by their ids (*tracking_artefacts_ids*). Figure 8 shows the components constituting the device.

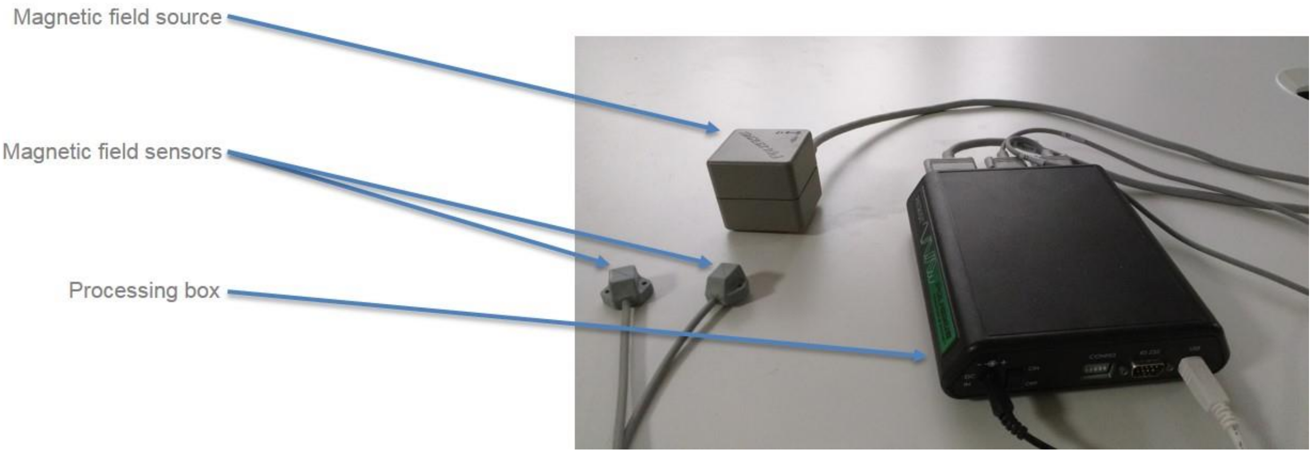

Figure 8: Electromagnetic device used for the test.

The world reference frame is located, by default, in the centre of the magnetic source field (*tracking_set_reference_frame*). There is no function to get the tracking precision, so *tracking_artefact_quality_level(id)* was not implemented. The *tracking_position(id)* function is recovered by using the Polhemus VRPN plugin, while the *tracking_calibrate_artefact(id, x , y, z, roll, pitch, yaw)* was not implemented since the quality of tracking values were very low. When

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trying to test the device, in fact, some strange behaviours have been observed when retrieving the sensors locations. Figure 9 shows the setup implemented to test the device. The test consists in putting one of the two sensors of the device in a predefined location and in evaluating the collected data.

Figure 9: Test setup (left) user during the sensors positioning (right).

The test did not produce successful results most probably because the performance of the Polhemus device was negatively affected by metallic objects. After this first attempt, the Polhemus has been tested more deeply in a bigger room, which should be further isolated from potential electromagnetic disturbance, such as metallic objects. There, the Polhemus device has presented similar tracking issues. It seems that the sensors are affected by the rebar of the floor slab: by moving the source from 37cm high to 84cm high, in fact, the quality of the tracking significantly increased. After a discussion with the Polhemus Company, they suggested to increase the distance between the sensors and the floor, so as to make it bigger than 1/3 of the distance between the magnetic source and the sensors. Due to this significant and uncontrolled variability of the device, the magnetic sensors have been assessed as not suitable for being integrated in the SPARK platform.

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4.3 INFRARED RECOGNITION BASED TRACKING

Infrared tracking technology uses high-reflective markers and multiple cameras to calculate position and orientation of an object. The idea in the SPARK project is to paint invisible markers onto the artefact with invisible infrared ink. Therefore, the marker would be invisible to the users of the platform and we could project the image onto the artefact without having the projected image disturbed by any kind of markers. In order to test the suitability of this technology, the Optitrack V120:Trio system has been used for the test.

Figure 10: Optitrack V120:Trio system used for the test.

Since the three IR cameras are firmly fixed, no camera calibration is needed. To use more than one system the required calibration procedure is normally easy and well validated. The marker IDs are set within the Tracking Tool software (*tracking_artefacts_ids*). Tracking Tool is the Optitrack software used for communication and configuration of Optitrack cameras. This software can directly be used to calibrate the artefact (*tracking_calibrate_artefact(id, x , y, z, roll, pitch, yaw)*). The connection of Optitrack with the SAR module should be done by using Tracking Tool and UIVA. UIVA is a middleware server that enable to share tracking data with multiple client applications. It receives information from Tracking Tool and sends this information to the client application. The main reference frame is located in the middle of the IR cameras but it is possible to define other reference frames within the working volume of the

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system (*tracking_set_reference_frame(id)*). This technology provides very accurate tracking data but requires a specific preparation of the object to be tracked.

4.4 VIDEO ANALYSIS BASED TRACKING

In a video-analysis-based tracking system, a single camera is capturing the scene. Then an image-processing algorithm recognizes sub-images. The deformation of the sub-image provides a position, an orientation and a distance with respect to the camera. The camera is working with the same perspective model of a video projector (Figure 11).

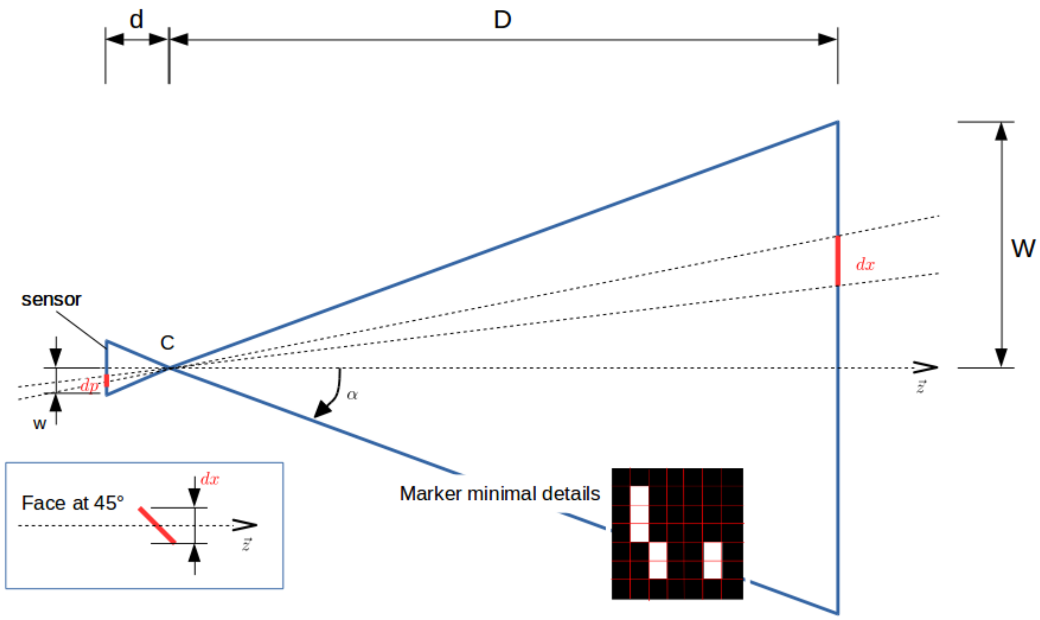

Figure 11: Influence of distance on image recognition quality [Al-Meslemi & Noel 2016]

The conditions of usage of this method have been studied in the master thesis of Yahya Al-Meslemi and accepted for publication in the proccedings of the EURO-VR2015conference [Al-Meslemi Y., Noel F., Spatial Augmented Reality environments design rules, EURO-VR conference, Athens, November 2016 – publication in progress].

The following functions have been defined:

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tracking_artefacts_ids() → []: An artefact may be recognized by a sub image, which plays the role of a tag. Then, a dictionary of tags associates a physical image to an identifier. As soon as it is recognized, a tag leads to a physical artefact id. This function is thus directly provided by the system. The detection algorithm duration is a quadratic function of the camera resolution. On a core i7 Vpro processor with 16 GB of RAM, the algorithm computes 20 to 30 frames per seconds with a resolution of 1280 x 800 pixel.

tracking_artefact_quality_level(id) → float: A quality indicator about the image recognition is provided through image processing. This is a strength of this tracking system, which is not produced by other tracking tools. Quality depends on image recognition but also on the distance between the tracked object and the camera. Figure 11 highlights the issue: w is half the horizontal or vertical resolution of the camera.

*tracking_position(id) → Th:float[4*4], Q:float*: Position and orientations are provided with a good tolerance. As a complementary information, it must be taken into account the average ambient light and the contrast of the image used as a tag. Minimal ambient light is necessary to capture clear images and the tag will be better if it has high contrast.

tracking_set_reference_frame(id) → Boolean: the reference frame is by default associated with the centre of the camera. All positions and orientations provided by the previous function are given in this frame. It is easy to use an extra tag, which locates a reference frame. The position of this tag is given by a transformation matrix $[MR]_c$ as every other tag$[MT]_c$. Then the position of a tag within the reference frame is directly obtained through a simple matrix product:

$$[MT]_r = [MR]_c^{-1}[MT]_c$$

tracking_calibrate_artefact(id, x, y, z, roll, pitch, yaw) → Boolean: as every tracking solution, an extra method may change the artefact frame to align the returned position at a given position on the artefact.

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In conclusion, video-analysis based tracking system is a suitable technological option, but requires big tags at medium and long distances. It has a medium frame rate but has the strength to provide a good detection quality.

4.5 INERTIAL SENSORS BASED TRACKING

Inertial sensors are able to capture the 360-degree orientation in the three global axes and allow for calculating the orientation between the fixed sensor coordinate system and a global reference coordinate system. The inertial sensor used for this initial implementation is the model LPMS-B2 by LP-RESEARCH. This small and wireless sensor communicates with the computer through Bluetooth technology. The measurements are taken digitally and are transmitted to the data analysis system in the form of orientation quaternion or Euler angles. The data transmission rate is up to 400 Hz. The quaternion orientation allows measurements without encountering Gimbal-lock issues. This is achieved by using a four-element vector to express the orientation around the axis. The device uses three different sensing units: 3-axis gyroscope (for angular velocity), 3-axis accelerometer (it detects the earth's gravity field) and 3-axis magnetometer that measures the direction of the earth magnetic field. Thanks to the integration of data from the accelerometer and magnetometer, the orientation information is very accurate, stable and it is characterized by a fast sample rate. The available output data are Raw Data, Euler Angle, Quaternion, and Linear Acceleration. The Raw Data of the three sensors (gyroscope, accelerometer and magnetometer) are accessible by the host system based on the LPBUS protocol. The integration of the device in the SPARK platform consists in placing the sensor attached to the physical prototype and it wirelessly transmits, via Bluetooth, its orientation in the environment (max distance 20 m). To test the sensor it has been placed, as shown in Figure 12, on the bottom part of the physical prototype. In future implementations, the sensor could be hided inside the physical prototype thanks to its small dimension.

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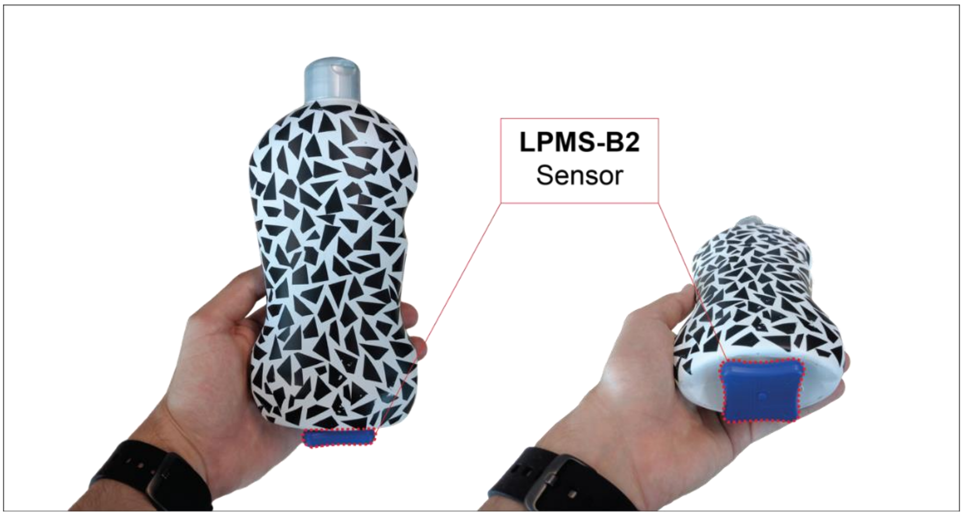

Figure 12: Position of the sensor used for the preliminary tests.

The orientation tracking feedback has been tested by using the LPMS Control software (version 1.3.5) in order to assess its real-time performances and its orientation tracking accuracy. The suitability of the technology was observed with dedicated tests, as shown in Figure 13. The results of these tests have shown that the software is considerably reactive and accurate with respect to the motions of the physical object with the attached sensor. The LPMS Control software shows a 3D preview that associates the 3D coordinates to a 3D model .OBJ file.

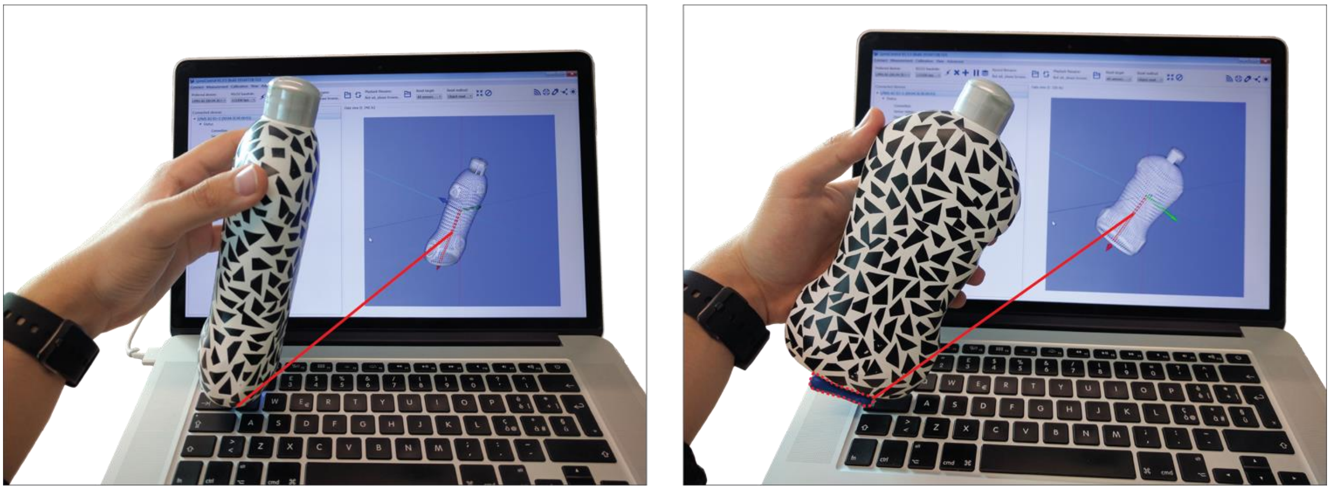

Figure 13: Orientation tracking tests: the control software shows the live 3D orientation view of the respective physical prototype that has the LPMS sensor attached.

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Inertial technology does not allow tracking the absolute position of the prototype and the relative position is naturally affected by errors, since its value is obtained via a double integral of the linear accelerations. However, within the SPARK platform, this sensor could be used as a complementary tracking technology to fix the possible orientation errors that occur during the manipulation of the prototype.

4.6 Summary about tracking technologies

The following table provides a summary of pros and cons of the investigated tracking technologies according to the functions defined in section 4.1:

- *tracking_artefacts_ids() → []*
- *tracking_artefact_quality_level(id) → float*
- *tracking_position(id) → Th:float[4*4], Q:float*
- *tracking_set_reference_frame(id) → Boolean*
- *tracking_calibrate_artefact(id, x ,y ,z ,roll, pitch, yaw) → Boolean*

	ARTEFACTS_IDS	ARTEFACT_QUALITY_LEVEL	TRACKING	SET_REFERENCE_FRAME	CALIBRATE_ARTEFACT
ELECTROMAGNETIC	IDs of the sensors	Not provided	Low precision because of electromagnetic disturbance	Position of the electromagnetic emitter	Not done
INFRARED	Set by user	Not provided	Good precision, but it could be disturbed by white light containing IR frequency	Use of default Optitrack mainframe	Done within Tracking Tools
VIDEO ANALYSIS	Set by user	A quality level is provided	Expects big tags, which may disturb the SAR scene	With just an extra tag to locate the reference frame	Common with all methods
INERTIAL SENSORS	IDs of the sensors	Not provided	Good precision thanks to integration data between gyroscope, accelerometer and magnetometer	Default global reference frame	Need of a complementary tracking solution

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5 INTERACTION

This section provides a description of two interaction systems (Leap Motion and Intel RealSense F200 Camera) that have been investigated to allow interacting with the mixed prototype in a natural way by directly using user's hand. In line with the expected functionalities of the SPARK platform, tracking user's hands enables the movement of a digital cursor along the 3D model surface. To this extent, the user is able to perform diverse operations as for instance, moving a graphic element all along the model surface, place it in the desired position, select it and modify its position and/or its scale and/or rotation. In the SAR environment these two interaction systems could allow the user to interact with the mixed prototype without interfere with the visualization that is projected on the prototype surface. In order to activate the hands free functions, the user make independently a selection on a GUI that can be projected directly on a surface or displayed on an external GUI.

Figure 14: Leap Motion (left), Intel RealSense (right)

5.1 LEAP MOTION

The Leap Motion system consists of two cameras with wide-angle lenses that allow for a stereoscopic view of the real scene and of three infrared LED that track the not-visible light. The Leap Motion system is able to track the position of the hand, the single fingers and the

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forearm. In order to recognize the hand, the operating field of the device has to be max. 60 cm and wide 120° and 150° in the two directions. The position of the Leap Motion controller has to be necessarily above or below (max. distance 60 cm) the user hands to show the palm or the back, achieve a reliable tracking of the hand and to be comfortable for the user while he/she is performing some of the above-mentioned actions.

For what concerns the hand movements, the Leap Motion SDK is able to recognize four dynamic hand gestures:

- Circle: a movement of a finger drawing a circle in the air;
- Swipe: the long and linear movement of a finger;
- Key tap: the movement of a finger that press a keyboard button in the air;
- Screen tap: the movement of a finger that press a button positioned on a wall in front of the user.

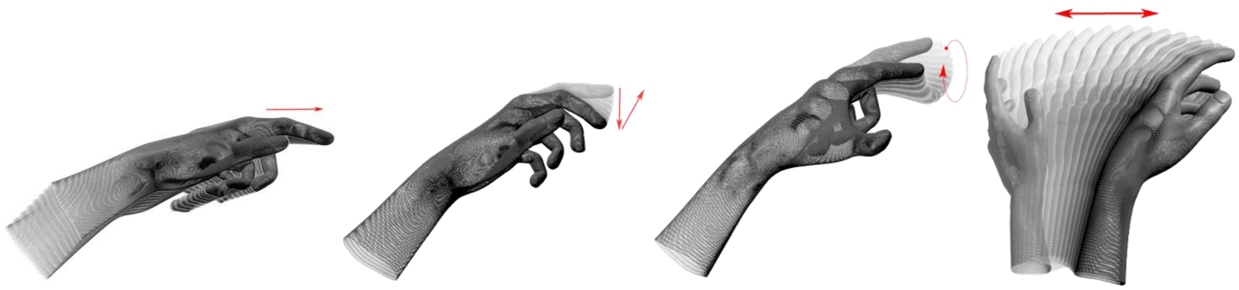

Figure 15: Leap Motion gestures

The Leap Motion hand gestures have been embedded in a custom application and tested in order to assess their applicability for the SPARK platform. In particular, a cursor that moves freely across the 3D model surface is attached to the hand tracked by the device and a graphic element can be attached to the cursor in order to let the user move them with the natural motion of the hand. The movement of a cursor/graphic element across the surface of the model, through the tracked hand resulted efficient, smooth and convenient. Critical issues appear when the user needs to use one of the dynamic gestures available in the SDK, in order to trigger the selection function of the graphic elements. Indeed, the gestures need a specific hand movement in order to be triggered and the system does not always recognize this

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movement at the first attempt. Moreover, the motion of the hand to perform the gesture (e.g. screen tap gesture) causes also the displacement of the cursor displayed on the 3D model. In case of elements with a bigger size, the selection results efficient, while if the user is interacting with many small elements positioned close to each other on the 3D model surface, the selection operation results to be not always consistent and precise.

5.2 Intel RealSense Camera (model F200)

The camera system is made up of two cameras and one IR projector. The first camera is a colour (1080 HD - RGB) camera while the second one is a depth camera with a Band Pass filter and it is used in conjunction with the IR laser projector in order to identify the object depth and position. The camera is able to track human hands, faces and objects. F200 camera enables to track two hands simultaneously (e.g., two right/left hands of different people). The number of joints in the tracked hand is 22 and it makes the hand tracking very accurate. The camera allows for background segmented from the hand; it means that it is able to exclude the hand and change the background. In order to make the hand tracking effective, the operating field of the camera has to have a minimum length of 20 cm and max length 60 cm. In addition, the camera needs to entirely visualize the hand and to move slowly in order to be able to recognize the hand and its movements. From an interaction point of view, the SDK allows for the recognition of many dynamic and static hand gestures: thumbs up/down, fist, 2-finger pinch (close, open), full hand pinch, big 5 (open, hi five), wave (motion), V-sign, Tap (motion). The static functions are very interesting for operations that require high precision (e.g. selecting a graphic element on the model surface, where there are many of them). Actually, when the gestures is recognized, the action is triggered and the user does not have to move his hand (which otherwise would lead to the missing of the right selection).

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Figure 16: Intel RealSense gestures

6 AR SOFTWARE APPLICATION

The AR software application is a demo application that will constitute the core of the SAR module. This application provides the users with functions for the manipulation of the mixed prototype and other functionalities that should be integrated into the SPARK platform. This section describes the structure of the AR software application, the operations needed to prepare the mixed prototype and all functions provided by the application.

6.1 STRUCTURE OF THE APPLICATION

The core of the AR software application has been developed by using Unity 3D (https://unity3d.com/) and VUFORIA AR library (https://www.vuforia.com/). However, as shown in Figure 17, the application consists of other elements needed for the execution of the application. In particular, these elements are the two parts that generate a mixed prototype: physical part and virtual part. The physical part is the object that the user holds in his/her hands and where the virtual part is rendered. Both parts have to be prepared in advance before using the application. Following subsections describe how these two parts have to be managed and

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prepared in order to make them suitable for the AR software application.

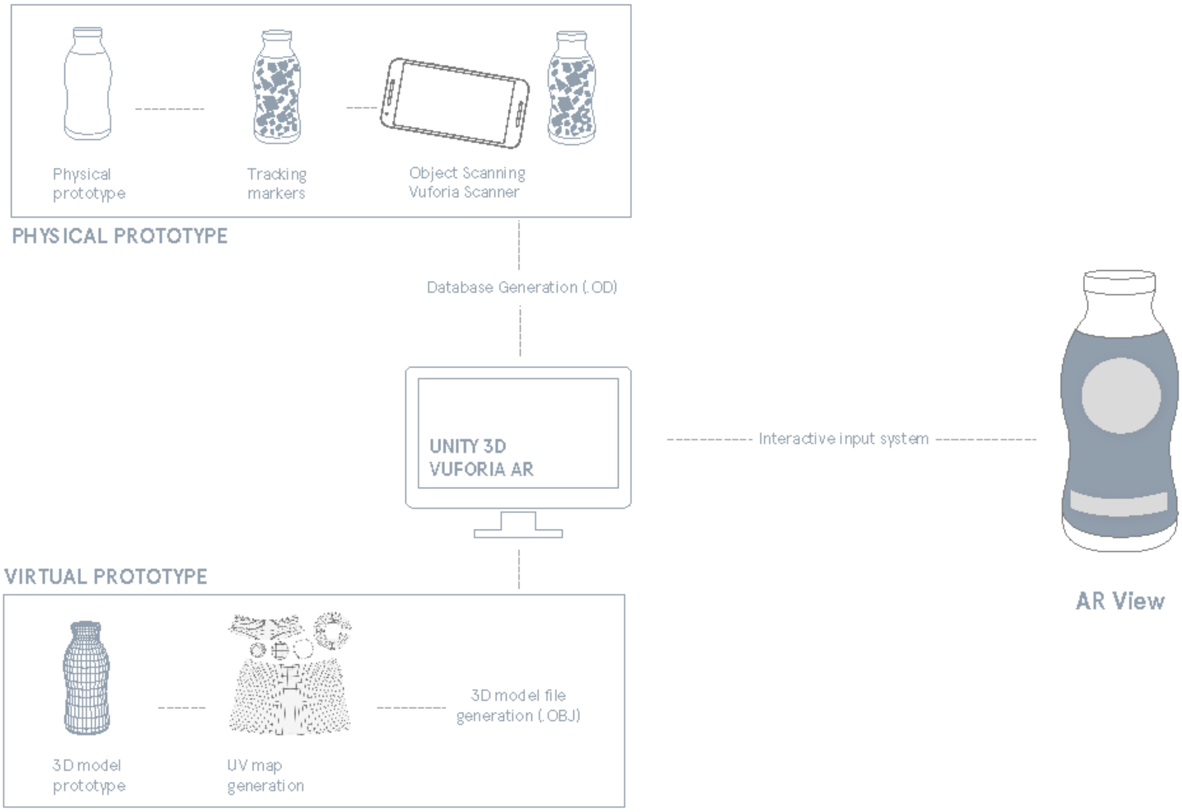

Figure 17: Structure of the AR software application.

6.1.1 Preparation of physical prototype

The preparation of the physical model mainly consists in making it trackable by using a video camera. Starting from a complete white version of the object it is necessary to put some black elements that can be recognised by the application. After a simple scanning procedure with a smartphone application, which is provided by VUFORIA, the object is enabled for the application. Figure 18 shows a sample object after the preparation. The green dots highlight the features that will be used for the tracking. Clearly, the black elements shall be transformed into elements visible only in the infrared field in the final implementation of the SPARK platform, so as to allow the projection of the virtual elements on a white physical surface.

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Figure 18: Sample object after the preparation. The green dots highlight the features that will be used for the tracking.

6.1.2 Preparation of virtual prototype

The 3D models used in the AR software application are mesh objects that need to be mapped into the UV space in order to have a flexible 2D reference that allows the user to move independently the elements of the layout all along the prototype surface. The UV map consists in the 2D representation of the 3D model mesh and it is normally used to apply a colour texture in Computer Graphics (CG) applications. This activity has been performed by using Blender software (https://www.blender.org/). In most cases dealing with basic shapes such as cylinders or boxes, the UV map can be generated automatically in Blender (cube, Sphere, Cylinder and Smart UV Projection). Conversely, to generate the map of complex geometry 3D meshes, the user has to select manually the segments of the mesh in order to identify the line (seam) that represents the opening part of the mesh. The mesh is "opened" through the Unwrap operation and it is consequently represented on the 2D plane (UV coordinates). In case of not-regular and complex geometries, the seam lines allow easing the tensions that exist in the mesh and allow the user to control how the mesh is going to open. Figure 19 shows the influence of the seam lines on the UV map.

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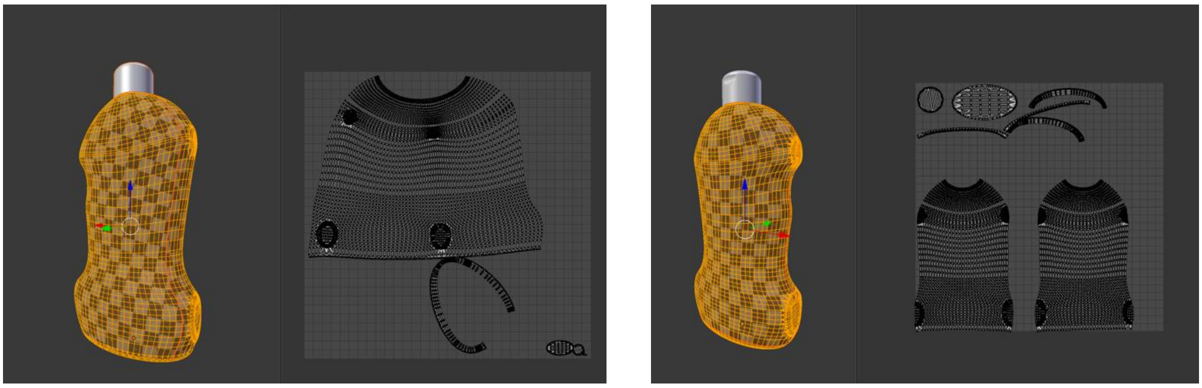

Figure 19: UV map of a packaging. On the right, the mesh is less tense and opened with two seam lines. On the left, there is only one seam line and the mesh resulted more tense and distorted.

Consequently, more seam lines are applied and less distortion is generated in the 2D representation of the mesh. When applying the seam lines on the mesh, there is one aspect that has to be carefully considered: the visual discontinuity of the texture applied to the mesh in that area (Figure 20).

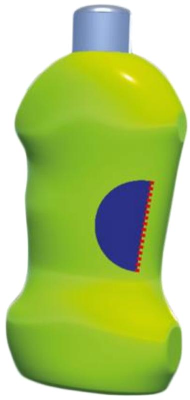

Figure 20: The seam line causes discontinuity in the graphic elements placed across it.

For this reason, the seam lines should be applied in areas where they are less visible and/or where the graphic elements are less likely to be placed. In case of "Shrink Wrap Sleeve" packaging (this is the type of label that is thermoformed and it covers completely the packaging surface) the seam line is applied in the same place where the welding line is positioned in the real packaging. The UV map seam, if positioned in specific area of the mesh, works as a cutting edge and provides also the advantage of dividing the mesh in different parts or cutting the

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elements of the layout applied in that area (Figure 21). In this way, it is possible to achieve a "bleed margin" result.

Figure 21: The seam lines are used to divide the mesh in different parts (on the left) and to cut the images placed across it (on the right).

When the UV mapping operation is complete, the 3D model is exported in OBJ file format. This format contains all the UV-map pieces of information, the mesh groups, nodes and it is ready to be imported in the Unity 3D virtual environment.

6.2 FUNCTIONS OF THE APPLICATION

To import the 3D model into the AR sub-module several OBJ importers have been tested. One of them provides good performance and it is suitable to load big-size OBJ files in a faster manner, with respect to other importers. When the model is imported, the software automatically creates a Standard Shader material for each mesh group that compose the 3D model. The material information (colours, surface finishes, transparency, etc.) that can be created inside Blender are not imported. The Standard Shaders, generated automatically when the 3D model is imported, need to be customized inside Unity. In order to modify the properties of the Standard Shaders that are applied to the virtual prototype parts, a material parameters builder or a selector of template materials (lucid and opaque plastic, metals...) can be implemented in the GUI. In this way before displaying the 3D model in the AR view, it is possible to choose the material attributes and update it. During this operation, a Render Texture is

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applied to the material of the mesh group. The Render Texture is a special texture updated and created in real time that renders, on the 3D model material in which is applied, everything that is placed in front of a secondary orthographic camera (Canvas Camera) in Unity. In this way, it is possible to visualize and independently modify in real time every single element of the prototype layout. The user is able to perform many operations, by means of the GUI, as shown Figure 22.

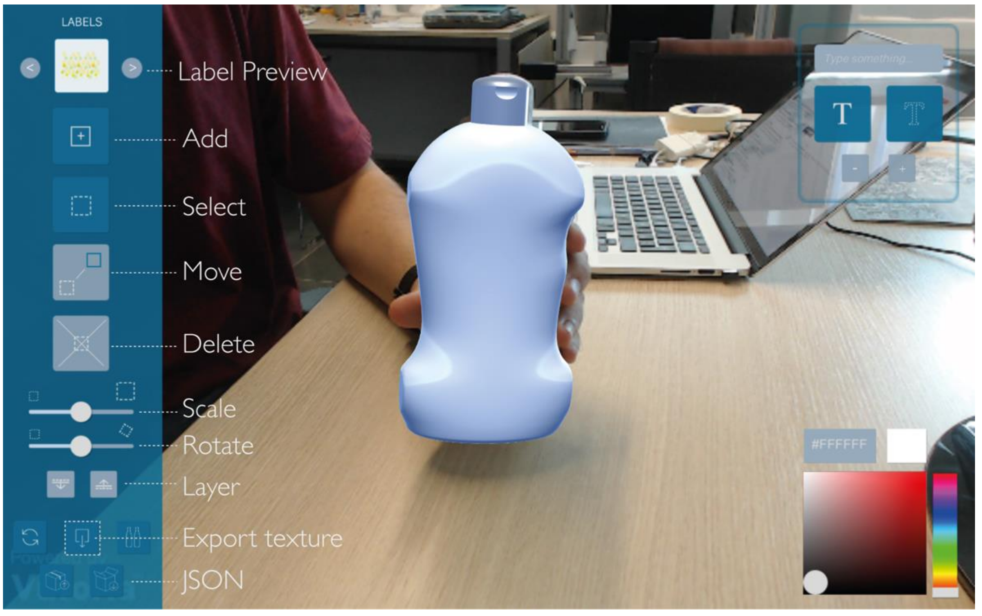

Figure 22: The Augmented Reality view with the interface where the user activate the different functions.

As for instance, the user can start by adding a new element (the file format of the graphic elements can be .png or .psd), then he/she can fix it in the desired position and continue this operation until the layout composition reaches the expectations and it is completed. The operations to add a new element are listed in the following and shown in Figure 23:

1. choosing the graphic element to add;
2. activating the "add" function in the GUI;
3. placing the graphic element in the desired position.

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Figure 23: Adding a graphic element on the 3D model surface.

Every element can be independently selected and modified directly on the model surface. The item selected change the colour, thus acting as a feedback for the user, so that he/she can easily identify it.

Once the selection of the single element is done, the user can modify its scale, position, rotation or delete it. Figure 24, Figure 25, Figure 26, Figure 27 and Figure 28 show how these functions work.

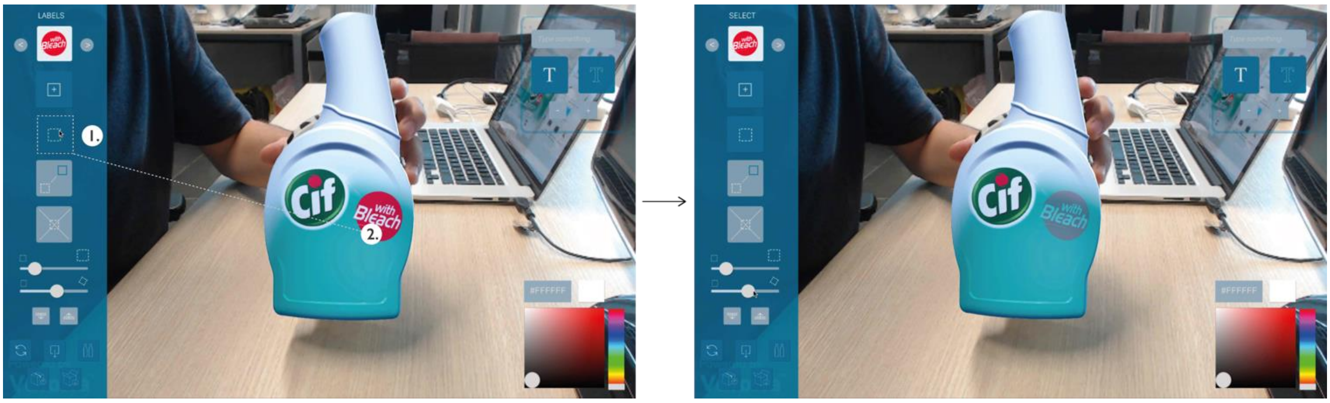

Figure 24: Selecting a graphic element: 1. The user activates the select function; 2. The user selects the single graphic element which, as a feedback, changes its transparency.

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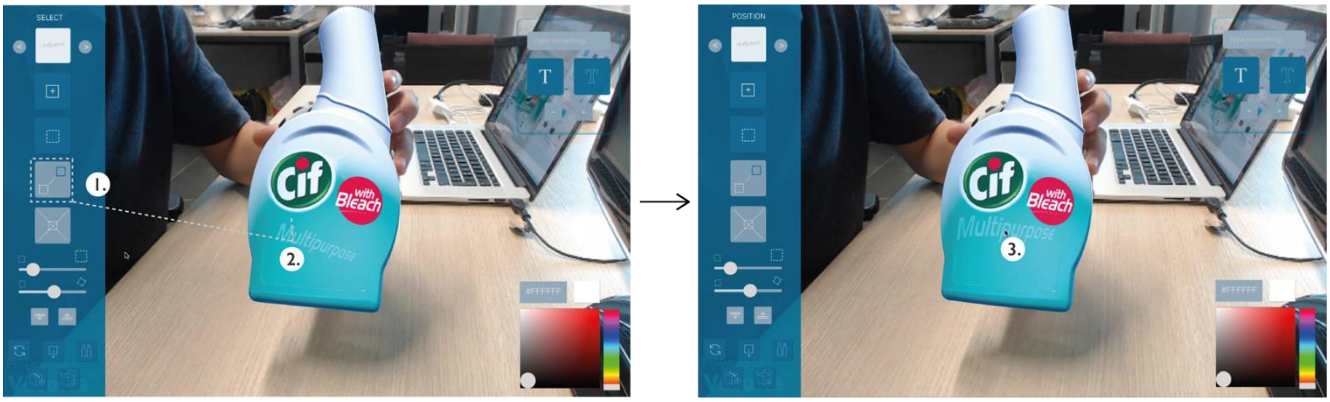

Figure 25: Changing the position of a graphic element: 1. Once the element is selected, the User activates the “moving” function; 2. The user now is free to move the graphic element and place it in a new position (3.)

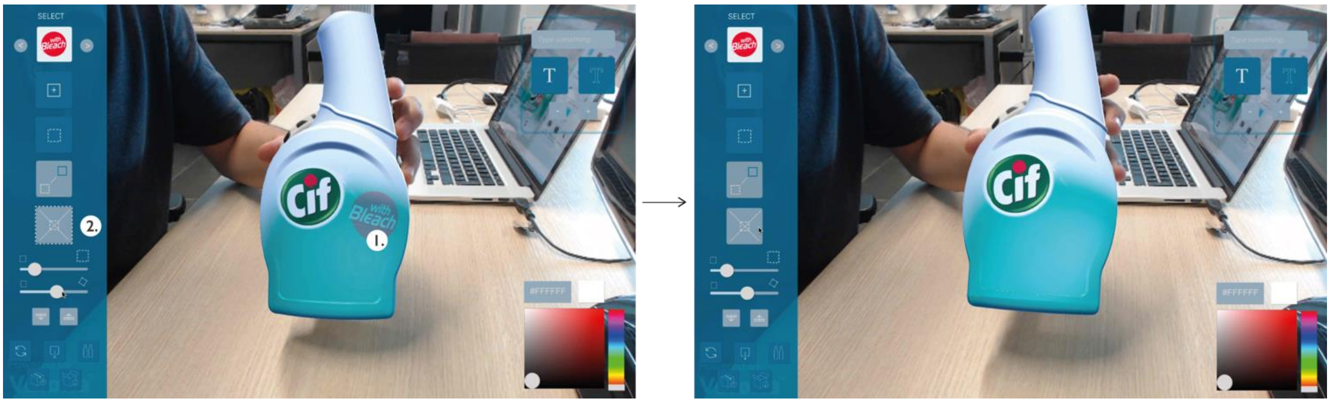

Figure 26: After the selection (1.) of the graphic element, the user can delete it (2.) pressing the dedicated button.

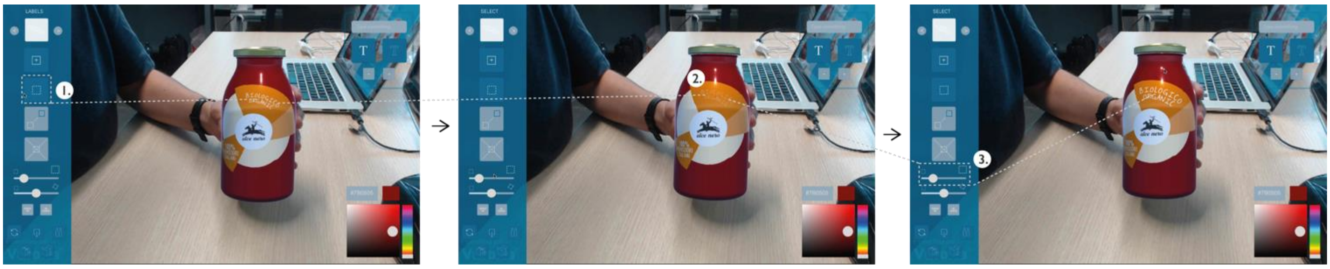

Figure 27: 1-2. The graphic element is selected; 3. The user changes the scale of the selected label using the GUI slider.

Figure 28: 1.-2. The graphic element is selected; 3. The user rotates the selected element using the GUI slider.

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Another function that has been added to the system allows for the management of the rendering layer of each element of the 3D model, as shown in Figure 29. Thanks to this feature, the user is able to control the order of visualization of the graphic elements, by displaying them forward and backward in the layout. It is expected that the latter function enhances the creativity of the users, as well as the number of solutions to propose. In actuality, this function enables the users to add shapes and graphic elements, keeping the whole control on each of them. When the editing operation are completed, the user can clear the previous selection and proceed with the selection of another graphic element.

Figure 29: In order to change the layer visualization of the element, the user select it (1-2) and press the dedicated button (3.) in the GUI in order to move it backward.

The real time text function allows the user to add a filler text, which, after its selection, can be modified, and the user can type any kind of text in a customized manner. In particular, the user can firstly select the text and then modify its font size by means of the dedicated GUI buttons. The user can also change rotation and position through the functions that are used for modifying the graphic elements. In the final version of the software, it will be necessary to add the feature related to the selection of different fonts and other useful functions related to the text creation. Figure 30 shows the steps required to add text element to the 3D model.

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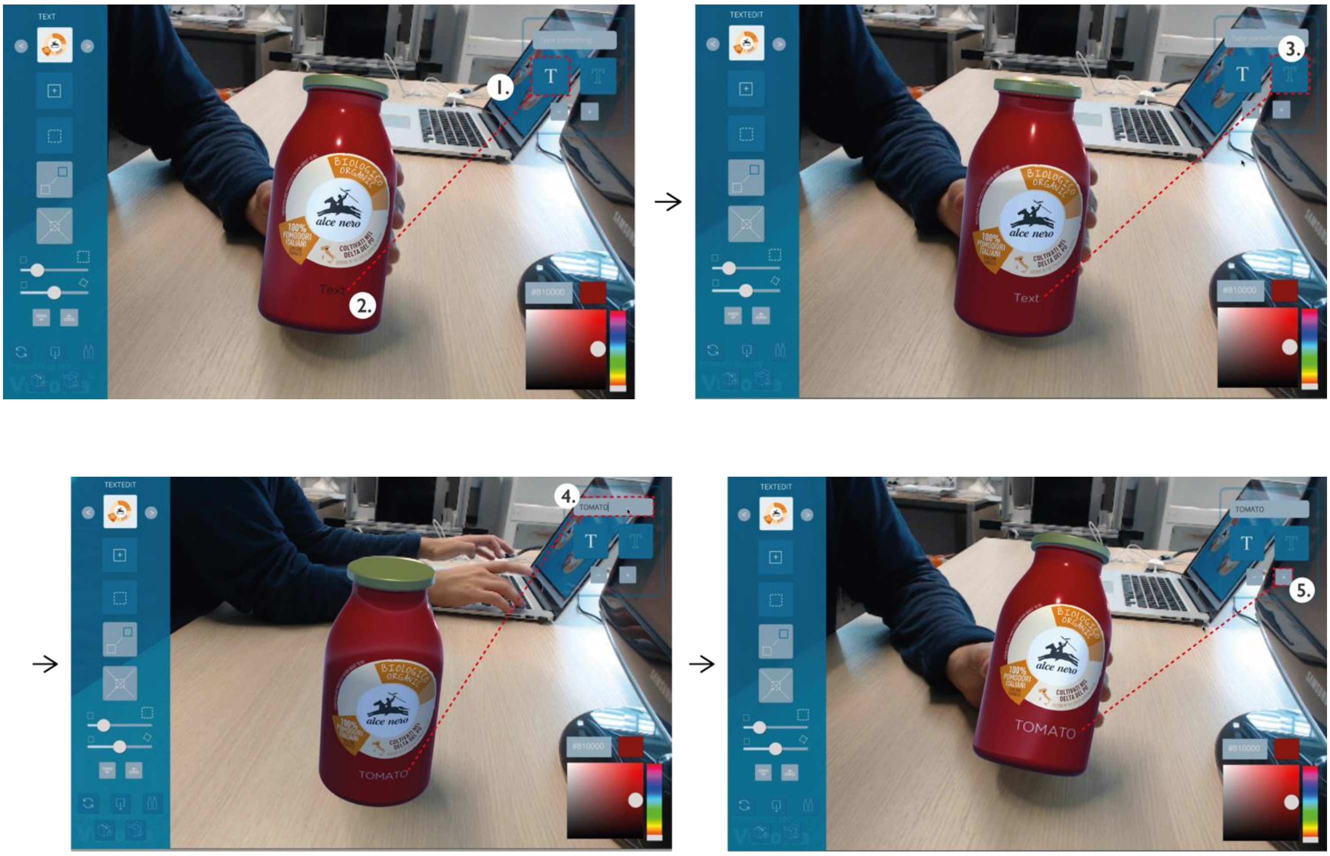

Figure 30: 1-2. The ‘text function’ is activated and the user places the filler text on the 3D model surface; 3. The user activates the ‘select text function’ and adds the custom text (4.) in real time; 5. When the added text is selected, the user can change the font size.

Finally, the colour of the packaging body can be changed through a colour picker positioned in the GUI, as shown in Figure 31.

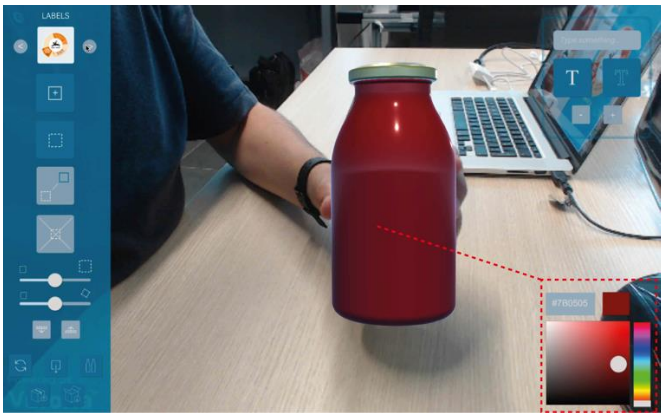

Figure 31: The colour picker allows the user to modify the colour of the packaging 3D model.

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Two videos have been uploaded on the YouTube channel of the SPARK project to better explain the functioning of the developed AR software application. In the following, the links of the videos:

- https://www.youtube.com/watch?v=pDAvuacsO1Y
- https://www.youtube.com/watch?v=LFTdI3Wa3kk

More video will be published, directly accessible from the project web page.

6.3 SAVING AND SHARING DATA

The AR sub-module has been conceived so as to be smoothly integrated in the design and development process also beyond the scope of the SPARK platform. In this perspective, it provides functions to save and load the layout generated by the user during the interaction with the mixed prototype. In particular, graphical elements applied to the 3D model and the attributes of the materials are the data constituting a generic layout. The data related to the graphical elements are:

- position;
- rotation;
- scale;
- z-order.

Besides, the data related to the material are:

- type of shader (standard, standard with specular setup, transparent);
- albedo colour map values (diffuse map);
- specular values and related smoothness values.

These heterogeneous data are stored in a JavaScript Object Notation (JSON) file. JSON is an open-standard format widely used to transmit data in asynchronous browser/server communication. The choice of this file format will allow the easily sharing of this information with the IS module, as well as to forward it to other applications used by the designers.

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6.4 Texture Exporting

In the current version of the software, the individual graphical elements applied can be saved and exported in a single 2D square texture file (.png format) at the end of session. This operation merges in a single texture file all the graphical elements by positioning them according to the UV Map. Consequently, the exported textures can be directly applied to the 3D model by using different 3D software to generate, for instance, a photorealistic rendering. It is important to highlight that the exported texture is different from the one usually adopted by the designers while building and arranging the layout elements using 2D software (eg. Adobe Illustrator). This effect is more evident with meshes that display many tensions and deformations in the UV map. As shown in Figure 32, the exported texture is slightly rotated if compared with the composition derived from the original packaging layout project.

Therefore, even if in the AR view the graphic elements appear aligned, in the 2D view they are not related to the orthogonal reference. In order to reduce the tension of the UV map and obtain an orthogonal orientation of the exported layout, the UV map needs to be split. This can be done by adding more seam lines. The resulting UV map will include more discontinuity areas generated by the seams but, on the contrary, it will have less distortion and it will seem to be correctly oriented, as shown in Figure 33.

Figure 32: Comparison between original packaging layout from Adobe Illustrator (on the top) and the one exported from the AR system, where it's been overlapped the UV structure (on the bottom).

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Figure 33: More seam lines (right image), the mesh is more regular than in the case where there is only one seam (left image) and the UV map is correctly oriented on the 2D space without distortions.

7 INFORMATION SYSTEM

The Information System module for the SPARK platform provides the user with the following three main functionalities:

- setup of the information for the co-design sessions (users, client, and product);
- organize the resources to be used during the execution of the design session;
- visualize the results and generate reports.

This section is divided into four subsections. First a summary of the discussion that the team of WP2 made to identify the communication protocol, which could be used to link the SAR module with the IS module. Then an overview of the current state of the Graphical User Interface (GUI) developed for the IS module.

The third subsection shows the data model identified to store the information within the IS module, and a model, named SPARK model, to be used during the interaction between the SAR module and the IS module. The last subsection shows the first attempts to identify what the platform should provide in order to report the results obtained during a co-design session.

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7.1 Communication Protocol

The SAR module will interact with the IS module during the execution of the co-design session. The SAR module retrieves the state of a given digital model in order to render it onto the physical prototype. In addition, the IS module needs to gather all the modifications applied to the physical prototype in order to store those events and to report them at the end of the session.

This kind of interaction is achieved with these two patterns:

- The SAR module queries the IS module in order to retrieve the state of the digital model (request/reply pattern);
- The IS module sends information, without being queried by the SAR module, to apply modifications by using the IS module user interface (publish/subscribe pattern).

Several approaches have been considered to implement these patterns. The use of pure HTTP, as communication protocol, could be the most suitable solution, since the IS module is a pure web application. However, since the SAR module will be running as a thick client, the publish/subscribe pattern could be limited by the WebSocket or Server-sent events technologies provided by the HTTP communication protocol. The main limitation of using pure web technologies to achieve publish/ subscribe patterns is the reliability. Since they are designed for light applications, there is no default backend approach to check the delivery of the messages. In addition, the development libraries are very reliable for web browser applications while they are not the best solution for thick clients (standalone applications, as the SAR module is). Consequently, for what concerns the publish/subscribe pattern, it has been taken into account the use of a Message-oriented Middleware (MoM). MoM is a server placed in the middle of the server (producing messages), and the client (consuming messages). The MoM server ensures the delivery of messages and it can be more easily scaled than a pure web approach. According to these considerations, the communication protocol will be implemented by using both the above-described approaches :

- Pure HTTP request (GET/POST/PUT) for the request/reply pattern;

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- Message-Oriented Middleware (MOM) for the publish/subscribe pattern.

In particular, the communication protocol will be implemented by using Apache ActiveMQ (http://activemq.apache.org/), which is a well-known and mature open source messaging and Integration Patterns server. Apache ActiveMQ supports a variety of protocols and its clients could be developed in the most popular programming languages.

7.2 GUI

At the beginning of the SPARK project, it was decided to integrate the Synaps GUI in the SPARK platform. However, due to the generic characteristics and nature of Synaps, it was later decided to reuse only some of the existing *Synaps backend* components. While, to accomplish the needs obtained in the deliverable 1.3 within the WP, the graphical user interface (GUI) for the SPARK platform will be entirely redefined.

This redefinition add two major features: first, the possibility to handle high level concepts (*e.g.* the use of client, product and co-design session concepts) instead of mapping them into *Synaps spaces*; and second, a better organization of concepts and resources, obtaining less error-prone usage of the overall platform.

The usage of the user interface could be seen in two major workflows, one for the administration, and the second for the co-design session.

7.2.1 System administration

Users with administration rights can manage the users of the platform and the information in order to organize the co-design sessions. The available administrative operations involve:

- users (only administrators can create new users);
- clients and associate users for each client;
- products for each client;
- co-design sessions for each product.

Each of the administrative operations are organized in a common user interface for users and for clients, as shown in Figure 34.

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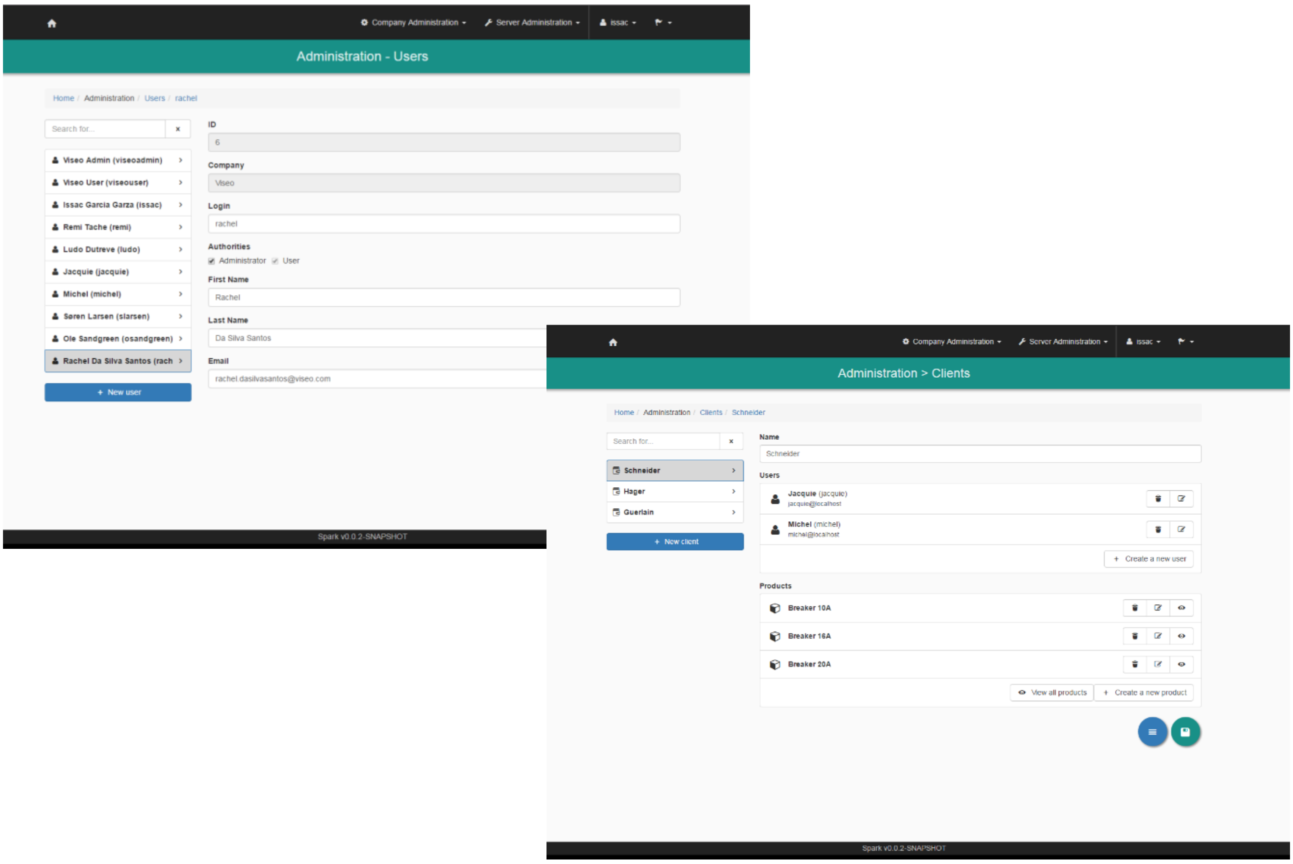

Figure 34: User and client administration interface

The diagram in Figure 35 instead, shows the workflow to accomplish the administration of users, clients, and products. However, this workflow is available only for users with administrative rights. The administration process is not part of the main contribution to the project. However, it helps to organize session and access rights. In addition, this organization could be used to provide in the future the SPARK platform with an advanced system for statistics and reporting. These administration pages are a key feature for the SPARK platform since they allow organizing co-design sessions for a product belonging to a specific client.

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Figure 35: Workflow for administration

7.2.2 Co-design sessions management

The second main feature of the application is the management of co-design sessions. Since the co-design sessions is the most important aspect of the IS module, it was decided to have a user interface entirely devoted to the session.

Therefore, when the user logs in, the main page is a timeline of past and future sessions, with focus on the current date as presented in the Figure 36.

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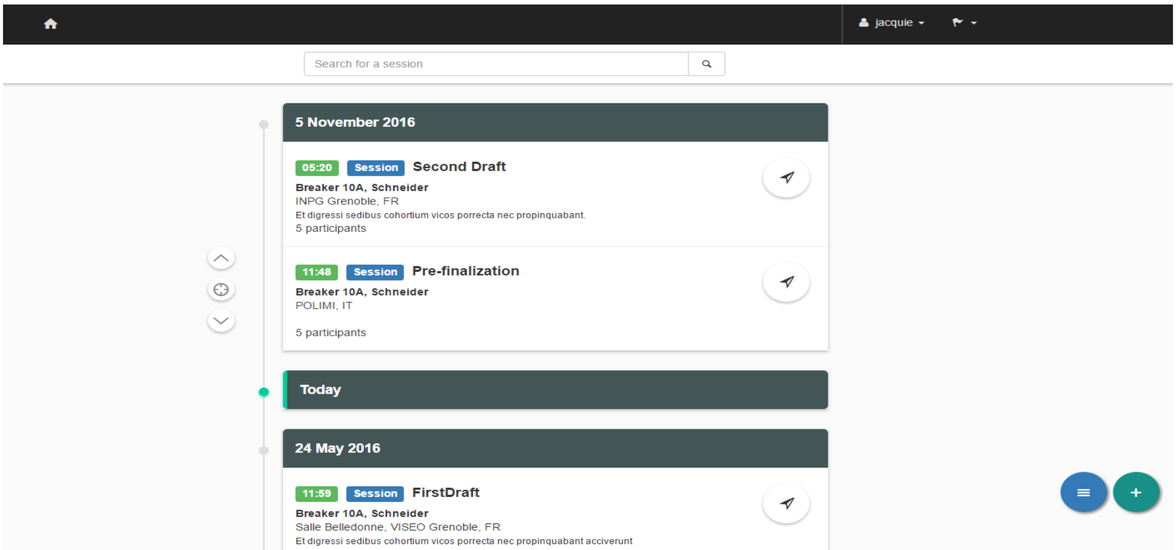

Figure 36: Main page of co-design session

The main page allows navigating and searching to retrieve previous sessions. The list of sessions is filtered according to the connected user; as described in the requirements (Deliverable 1.3), the access rights are per user and per session. Only administrators and session leaders can enable users to access an existing co-design session.

During the preparation of a co-design session, session leader and other enabled users can enrich the information, which will be used during the session. Figure 37 shows the workflow during the preparation. The session leader will grant access to users, as well as assign their role during the preparation and execution of the session.

The enabled users can upload assets by using the asset management page. Each asset is a file with meta-data for each type of file. The platform will support 3D model files, material files and image files and dedicated viewers simplified their management.

During the preparation of the session, the users can also prepare more than one digital model to use during the session. Each model represents an initial state of the mixed prototype. It contains file resources (3D model file, material file, images, etc.), as well as transformation for some images (translation, rotation, scaling) and z-order.

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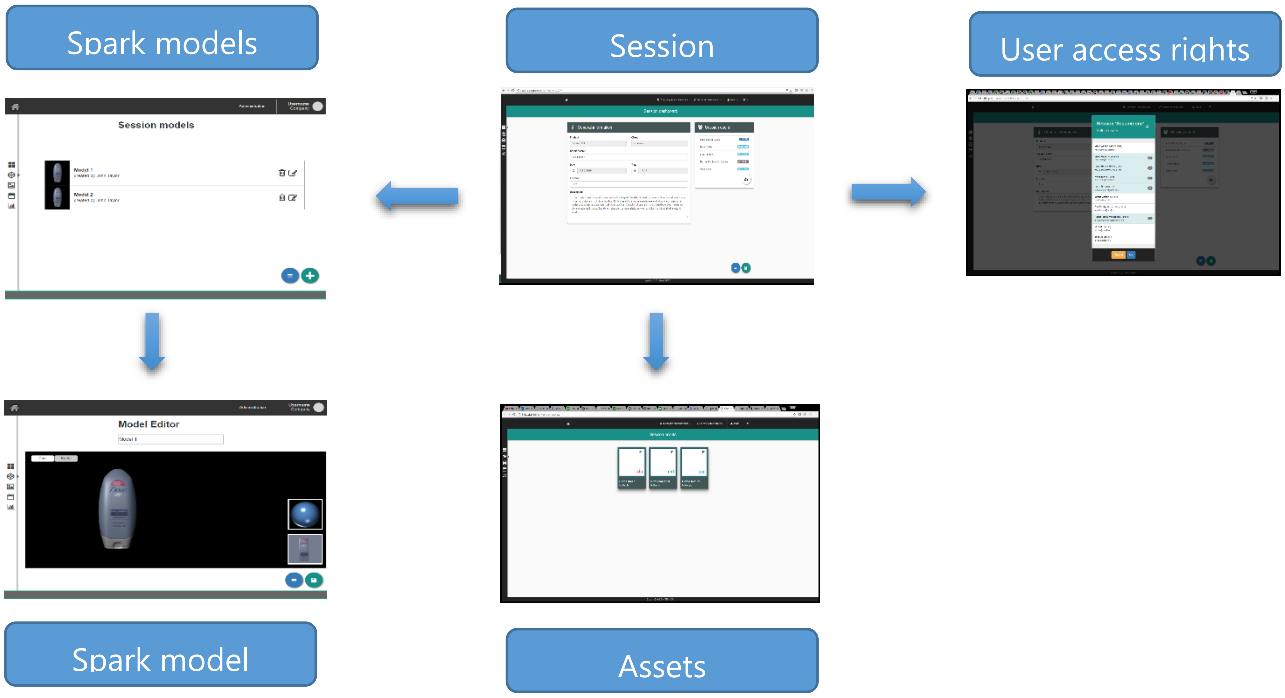

Figure 37: Co-design session preparation

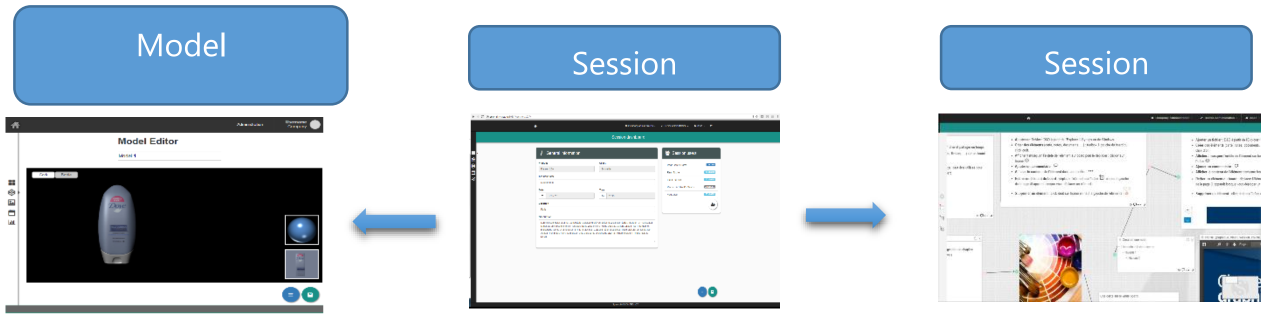

Figure 38: Co-design session execution (mock-ups)

Figure 38 shows the first mock-ups of the design session execution: it contains a model editor, which allows interacting with the mixed prototype and sending the performed changes into the SAR module. During the execution, the whiteboard is available in order to upload and share files, as well as ideas (notes, post-it).

During the execution, the user interface allows the manipulation of the SPARK model by:

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- adding new assets to the model;
- changing visibility order of assets;
- modifying material parameters;
- applying transformation to assets (translation, rotation and scaling).

The final workflow, which is shown in Figure 39, presents two main pages: starting from the session dashboard, it is possible to go to a reporting page to visualize the changes performed to the mixed prototype, as well as to access to the whiteboard and analyse existing notes.

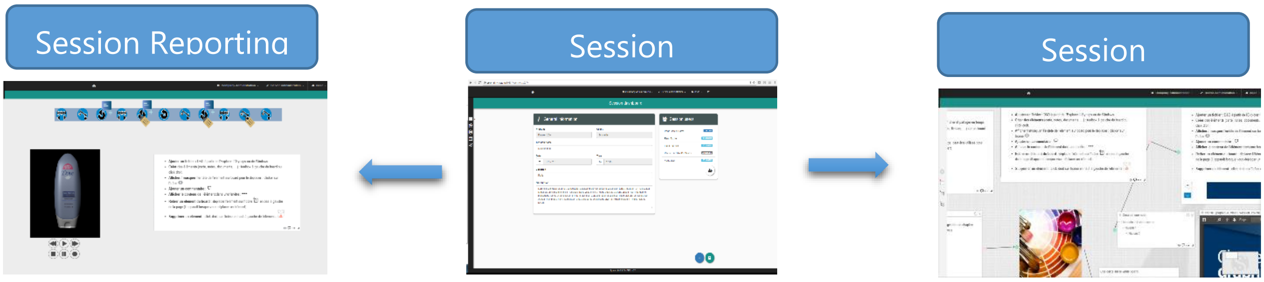

Figure 39: Co-design session reporting (mock-ups)

During the preparation and execution of the co-design session, a 3D window integrated within the user interface allows rendering the digital model into the browser. During the execution, all the interactions made by the SAR module, are sent to the 3D window in order to show a digital model always up to date according to the last modifications.

The 3D window is implemented by using a 3D library based on WebGL. Even though the SAR module is built on top of Unity and it is possible to embed a Unity application into the browser; the use of pure web library like ThreeJS (https://threejs.org/) allows for an easy and natural integration of the web application.

7.3 Database

The results of WP1, as described in the deliverable D1.3 led to significant changes of the user interface and, consequently, structure of the information. As a result, the storing mechanism has been defined from scratch by substituting the graph database, which is currently integrated

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in Synaps, with a relational database combined with the flexibility of a NoSQL database. The software, which has been chosen to implement the storing mechanism, is presented in the following:

- PostgreSQL (https://www.postgresql.org/) relational database; containing structuring entities such as client, users, products, co-design session and resource meta-data;
- MongoDB (https://www.mongodb.com/) NoSQL database; storing events occurring during the co-design session;
- ElasticSearch (https://www.elastic.co) indexing engine; allowing advanced and performant text search;
- the file system of the server to store and share files; binary files, such as images, 3D model files, etc.

The physical model of the first version of the IS module consists of the main objects that the platform has to handle (users, clients, companies and products). Figure 40 shows the physical model of these entities and their relationships.

This diagram shows some important details:

- users can be associated to clients, this allows a fine grain rights management to assign the users that will participate in a co-design session;
- client has a set of products;
- product has a set of co-design sessions;
- right management is for each co-design session.

In addition to this physical model (already implemented), there is a SPARK data model to handle 3D models, which will be manipulated during the preparation and execution of co-design sessions.

The 3D data model will be used mainly to share data with the SAR module, but also it will be interpreted by the IS module in order to render 3D content into the browser and to produce the session reports.

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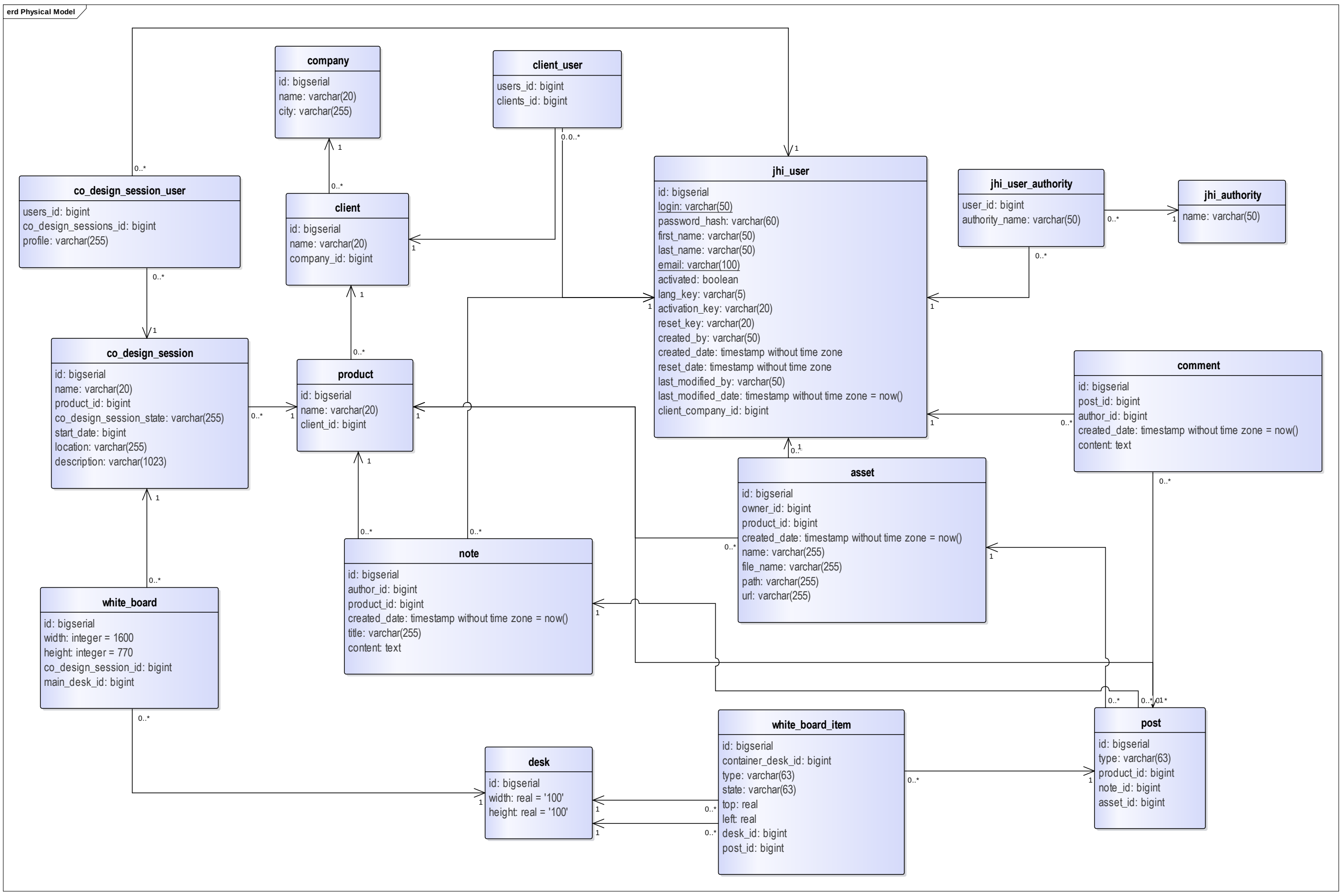

Figure 40: Physical model of main entities

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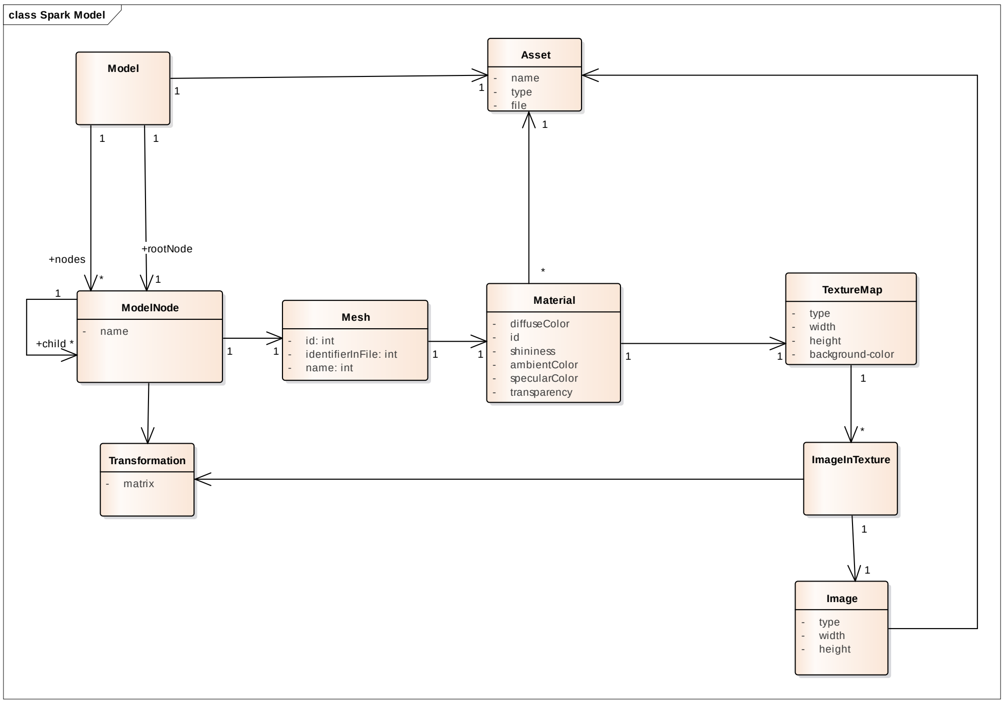

Figure 41: 3D data model

7.4 Reporting tool

The reporting tool is the functionality that allows reviewing the information generated during the preparation and the execution of co-design sessions. This functionality could also support the execution of the co-design session because users can review the previous modifications to generate new concepts.

Based on requirements obtained during the Work Package 1, the reporting tool will provide the following features:

- An interactive timeline of the events gathered during the manipulation of the mixed prototype. This timeline will allow the navigation of gathered events and see the state of the model in a specific point in time. In addition, there will be events that could be previously tagged (during the co-design session execution) highlighting the event as an interesting state.
- Notes associated to a given gathered event. During the execution of the co-creative session, users can create notes and link them to a specific event. At the end of the session, the users can visualize these existing notes.

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- Reports that summarize the session (minutes). Besides the notes attached to a given event, there will be other information that will be collected to summarize all the events of the session. In addition, some notes could be used to brainstorming ideas during the execution of the session. These reports will be available as read-only, and they could help the preparation of further co-design sessions of similar product.
- Replay the session in the browser as sequence of states of the 3D model. All the manipulations done during the execution of a co-design session will be stored into the system. This information will be used to replay virtually the model manipulation.
- Export the final 3D model into an image file. Each saved state could be exported as a PNG image. Before exporting, the user can rotate the 3D model in order to choose the desired point of view to generate the image;
- Export the list of modifications. In order to analyse the modifications, which were applied to the mixed prototype, a list of the modifications will be available. The list will be exported in a file easy to open with a spreadsheet software (e.g. Microsoft Excel).

7.5 Complementary visualizers

The complementary visualizers consist of web-based applications (WebGL), directly built in Unity 3D, which can run on different devices (video monitor in the meeting room, tablet, PC). This alternative visualisation sub-module, complementary with respect to the SAR visualization, allows the participants of a co-creative session to see and interact with the 3D model from the personal point of view. Figure 42 shows two example of complementary visualizers. The one on the left is just a visualizer: a user can manipulate 3D model in order to see the modifications, applied through the SAR module. The other, on the right, instead, includes the same functionalities provided by the application described in section 6.2. Actually, the second visualizer can be considered as a remote interaction system, since a user can apply modification to the 3D model and then show the results through the SAR module.

These complementary visualizers, suitable also for embedding some editing function, are suitable to be accessed with any Internet browser and as such will allow to go beyond the initial goal of the SPARK platform, by enabling collaborative design sessions with participation from distance of some members of the co-design sessions.

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Figure 42: Model visualizer (on the left), model visualizer + GUI (on the right)

8 CONCLUSION

During the activities conducted in task 2.4, the main sub-modules of the SPARK platform have been developed and preliminarily tested.

The implementation related to the SAR visualisation has been focused on the calibration procedures for projectors. The proposed procedures allow an accurate calibration of the projectors, as verified during the first testing sessions. However, the execution of these procedures is still quite difficult and required several steps. It should be simplified and anyone will execute it without the need of a specific skill.

Most of the tracking technologies identified as suitable for the project have been implemented and evaluated. The electromagnetic technology, which seemed one of the most promising for the project, has proved to be highly affected by external perturbation and, as such, it has been discarded. The infrared tracking technology has been tested in its common use: namely with spherical IR markers. It will be used by the WP2 team as the reference tracking system, while the use of invisible IR ink will be further investigated. The limitations, which have been identified for video analysis based tracking, led the team of WP2 to consider it just as a low-cost solution, which could be used for specific use-cases of the SPARK platform. The performance of the

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wireless inertial device, instead, make it an interesting tracking solution that, however, shall be coupled with another tracking technology.

The devices tested for the interaction revealed that still several issues have to be solved in order to provide the SPARK users with a natural interaction system. The functionalities provided by the complementary visualizers, instead, have been considered as an interesting interaction modality to extend the modification tasks to those participants to a design session not directly interacting with the mixed prototype.

The parts concerning the communication protocol, the GUI and the database of the IS module, which have been developed, are almost ready for the first release of the platform. The adopted technical solutions for the implementation are very reliable and envisage further possibilities related to the remote collaboration.

In conclusion, all the developed modules are ready for implementation in the integrated SPARK platform, as planned for WP3, while being improved and expanded according to the outcomes of the experimental campaign which will follow.

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