SPARK

D2.1

TECHNOLOGIES AND TECHNIQUES – STATE OF THE ART UPDATES

Approval Status

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1 EXECUTIVE SUMMARY

This deliverable describes the outcomes of the activities of task 2.1 "Technologies and techniques - State of the art updates" of the SPARK project. The objective of the deliverable is to report the reviewing activity conducted on the state of the art of SAR application and related technologies and techniques, as planned in WP2. The review activities involved the most relevant SAR applications developed in these last years, as well as, EU projects and patents concerning the topics addressed by the SPARK project. The material documented in this deliverable will allow the SPARK Consortium to identify and then select the best hardware and software solutions for the implementation of the SPARK platform modules, the requirements and the targeted performances beyond the state of the art.

The deliverable starts with a brief introduction on the activities conducted during task 2.1 and provides a detailed structure of the document. Then, it provides a brief description of the platform architecture and its modules and presents a use case, which has been elaborated in order to highlight technical criticisms that could occur during the functioning of some of the modules of the SPARK platform. This use case ensures to bound technology requirements but does not stand as final SPARK use cases, which will be defined within the activities of WP1.

In addition, the deliverable presents a discussion on the potential of SAR in the field of the product design supported by the overview of the latest research advancements in SAR. Moreover, a review on hardware and software solutions that could be integrated in the SPARK platform is presented. In particular, the issues related to the SAR technologies, such as visualisation, interaction and tracking have been addressed. Particular attention has been paid to the specification and performance of the devices, which can mainly influence the realism of the SAR simulation.

Eventually, the last part of the deliverable provides a synthesis of the information and the discussions collected during the task 2.1 and provides the final remarks that can be considered as a starting point for the subsequent tasks of WP2.

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2 INTRODUCTION

This deliverable describes the outcomes of task 2.1 of the SPARK project. The objective of task 2.1 is to investigate the state-of-the-art technologies and techniques that could be the best candidates for the implementation of the modules of the SPARK platform. The importance of these outcomes could sensibly influence the decisions that will be taken within the WP2. Consequently, some of the technical solutions, which have been hypothesized in the proposal with the definition of the draft of the SPARK platform architecture, could be further discussed in order to achieve the SPARK objectives in the best possible way.

2.1 Scope of the activities and of the deliverable

The scope of the activities carried out in task 2.1 is to identify the candidate technologies and techniques suitable for the development of the modules of the SPARK platform. The first activity of task 2.1 has concerned the discussion about the architecture described in the proposal. The discussion led to the identification of the technical and technological elements that must be taken into account during the implementation of the prototypal modules constituting the SPARK platform. To highlight technical criticisms, which can occur to the modules during their functioning, a use case has been defined. The use case has been elaborated in order to generalise the possible use of the SPARK platform and according to the outcomes of task 1.1, which were described in the deliverable D1.1 "Case studies and Evaluation Criteria". Then, a critical analysis of the latest researches conducted in the field of SAR has been carried out. This activity allowed deepening the knowledge on interesting SAR applications, whose technical solutions or ideas could be used as starting point for the development of the SAR module of the SPARK platform. Finally, candidate hardware and software suitable for the SPARK platform development have been analysed and evaluated in order to get a complete overview of the possible solutions.

In the deliverable, all the activities conducted in task 2.1 have been clustered according to the main issues to be addressed by the SPARK platform, in order to obtain a document the Consortium can refer to, during the subsequent activities of WP2.

The deliverable has been organized as follows:

Chapter 3 shows the preliminary SPARK platform architecture. In addition, a brief description of the elementary modules is provided to detail their technological components. The chapter also describes the potential of Synaps in relation to the SPARK project, the expected technological advancements and the possible integration modalities of this module.

Chapter 4 presents the use case elaborated according to the outcomes of task 1.1.

Chapter 5 discusses the potential of SAR in the field of product design. In addition, a section of the chapter overviews the latest research advancements in SAR. The overview describes the most relevant SAR applications developed in these last years, including EU projects and patents.

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Chapter 6 proposes the candidate hardware and software solutions that could be integrated in the SPARK platform. In particular, the issues related to the SAR technologies, such as visualisation, interaction and tracking have been addressed. Particular attention was dedicated to the specification and performance of the devices, which can mainly influence the realism of the SAR simulation.

The deliverable ends with a synthesis of the information and the discussions collected during task 2.1 and provides the final remarks that can be considered as the starting point for subsequent tasks of WP2.

3 SPARK MODULES

The SPARK project aims at developing *an ICT responsive platform* integrating diverse modules to provide the user with an *intuitive* and *easy-to-use* co-design environment. The platform will be interfaced with external hardware and software commonly used in the design process. Figure 1 shows the preliminary architecture of the SPARK platform as presented in the project proposal.

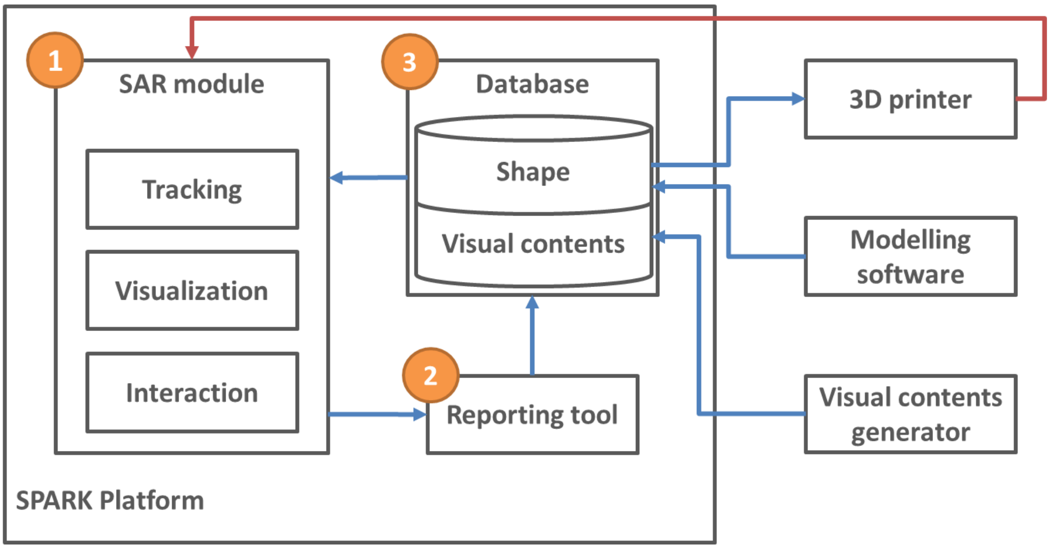

Figure 1: Preliminary architecture of the SPARK platform

The modules constituting the platform will be mainly:

SAR module. It will enable the collaborative "creation" of a mixed prototype of the proposed creative concepts, by allowing the combination of 3D shapes, textures, images and sketches on a physical object. The latter can be:

- the former version of the device/package under study, suitably whitened to allow for projections on it;

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- an indicative shape resembling the object under discussion in the co-design session (the design company might have a collection of shape primitives frequently occurring in their design activity);
- a rapid prototype obtained by additive manufacturing or even simply by modelling clay.

The SAR module will include state-of-the art technologies for tracking, visualisation, interaction, while innovative techniques for using these technologies will be implemented to address typical issues of SAR. SAR technologies and techniques will be selected by taking into account also the outcomes reported in this deliverable.

Reporting tool. It will enable to record, and hence keep track of, all the actions developed within the creative sessions. The reporting tool will translate the modifications applied to the mixed prototype to store them into the database of the platform.

Database. All data used to develop the mixed prototype will be stored into a specific database. The nature of these data will concern: 3D shapes, textures, images and sketches. The database will be populated with external data, which could be generated by using professional software or downloaded from internet, or with data generated with the SAR module during the brainstorming sessions.

All modules will be managed by or integrated into the already-existing collaborative platform named Synaps, which has been created and is distributed by Viseo [1].

Synaps is a communication tool that allows agile networking within a company by enabling the share of ideas, information and processes in an extended collaborative perspective. The Synaps platform also intuitively enables the collaboration (in this project, the co-design activity) from a distance, thus making the SPARK platform ready to be ubiquitously used if appropriate equipment is available in the different locations to be connected. Synaps will be used in the project as an underlying platform of SPARK. It will act as an interface between the SAR module, the data provided by designers and stakeholders, and external software. Under these expectations, Synaps will provide two of the modules described above, i.e. the database and the reporting tool. In addition, Synaps will also provide a task management module to prepare the brainstorming creative session.

Depending on the results of the WP1, an interaction module could be also developed. This module would aim at enriching the SAR interaction, as discussed in section 3.1.7. In this way, Synaps will be involved before, during and after the brainstorming creative sessions.

3.1 Synaps

As mentioned above, Synaps will be used as the underlying platform of SPARK. Technically, it is a Rich Internet Application (RIA) based on a client/server architecture.

The back-end application uses recent and effective server technologies, such as:

- language: Java 8 [2];
- main framework: Spring [3];

- database: Neo4J [4].

The client application is executed inside a web browser and it is based on the most recent standards of the web (HTML5, CSS3) and JavaScript framework and libraries such as Backbone [5], jQuery [6], threejs [7], etc..

A web application offers many advantages compared to desktop application. It is natively cross-platform, i.e. the application can run on every device regardless the OS. It only requires the use of a modern web browser such as Chrome or Firefox. Thus, it is possible to use it through various devices, such as computers or tablets without the need to compile the application for each supported platform. Furthermore, since the client application is delivered to the user device by the server, the upgrade and the deployment of a new release of the application are very transparent for the user.

It is important to notice that user expectations and needs are decisive in the choice of the technologies and features. A lot of improvement will be required to use Synaps as the underlying platform for SPARK. The platform already provides some very convenient features that will be enriched whereas some others will be developed from the ground.

3.1.1 Preparing for brainstorming sessions

An important ingredient of Synaps is its project management feature, which includes task assignments and reporting of the overall progress. Figure 2 shows an example of a list board, used for task management. Each card in a column corresponds to a task.

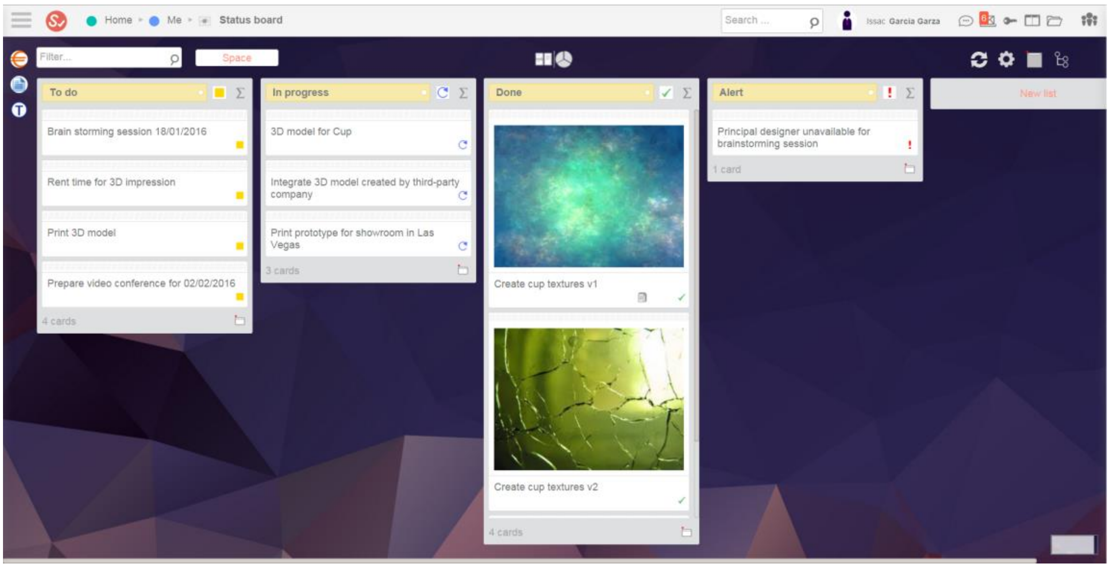

Figure 2: Synaps - an example of a list board, used for task management; each card in a column corresponds to a task.

Since a lot of task management happens in electronic correspondences, Viseo is enhancing this feature by an extraction module, currently under development, which operates on emails to extract tasks using machine learning and natural language processing (NLP) techniques.

These features could be used to prepare for a brainstorming session, as well as to coordinate tasks between colleagues/stakeholders. Examples of tasks to be handled before a brainstorming session are:

1. Create a model or a texture file;
2. Select and upload texture files to the system;
3. Send mail to participants;
4. Print 3D models;
5. Organize a meeting;
6. ….

3.1.2 Collaboration

Synaps offers convenient features for multi-users interactions, such as real-time notification (using WebSocket), shared workspace and group authorization etc. While preparing a workshop session, it will be easy for many users to share their assets in order to use them during the design session. In the event of indirect interactions provided by Synaps, every user could also be able to manipulate the "on-screen mock-up".

3.1.3 Database

The database used in Synaps is Neo4J. It is an open-source graph database implemented in Java. The platform database schema will be upgraded to meet the requirement of SPARK, both for the models and the assets management (3D models, textures, sketches, etc.) and for the workshop reporting tools.

3.1.4 Viewers

Synaps provides document viewers inside the client application. Some are already implemented (pdf, ppt, image, notes/rich text, etc.) and new ones will be developed specifically for the SPARK platform, for example 3D object viewer, texture and/or material viewer (from a rendering point of view), etc.

3.1.5 Reporting Tool

The reporting tool aims at keeping track of every action made during the workshop session. The entire history of the session, i.e. the actions that have been done, as well as the complete evolution of the mixed prototype, will be saved in the database. This will offer the possibility to come back to a previous version of the prototype. A Snapshot feature will also be implemented to allow users to save a particular improvement of the design, or even just to save the current state of the prototype before going back to a previous version.

Another module could be a "session player". It will act like a video player by showing a virtual evolution of the prototype during the past session. Therefore, it would be possible to replay the entire session and watch every modification applied to the prototype.

3.1.6 Indirect Interactions

The SPARK platform is expected to provide direct manipulations of the mock-up during the workshop session through the SAR modules. However, waiting for the results of the WP1, we think that an external HCI (Human Computer Interaction) would probably be required to extend the possibilities.

These possibilities could be various, but here are some examples:

- **Assets explorer**: designers would like to prepare many assets before the session. During the session, users should probably be able to select the assets to apply to the mock-up by using an assets database explorer.
- **Snapshot tool**: a "snapshot" tool would allow workshop participants to save the current state of the mock-up and to be able to come back to a previous version in one click. An "Undo/Redo" feature could also be implemented outside of the SAR module.
- **Comments and annotations tool**: Improving the session history with comments and annotations.

All these features and needs are strongly related to the results that we will obtain during WP1.

3.1.7 Communication with the SAR module

Some features of SPARK require an important communication between Synaps and the SAR module. These communications could be described at two different levels. A technical low-level communication and a "semantic" high-level communication.

Low-level communication: networks and protocols: Since the backend Synaps application is located on a server, it is accessible through the network. It provides the possibility of running the SAR module, many instances of the Synaps client, and the Synaps server on many devices and/or different locations.

A bidirectional communication between the Synaps server and the SAR module will be required. A good solution would be to use existing web protocols:

- Http requests (GET/POST/PUT/DELETE) provide an easy and efficient way for the SAR module to request and send information to the Synaps backend.
- WebSocket technology is a good candidate to allow the server to push messages to the SAR module without the need that the SAR module request for it.

An initial step needs to be done in order to synchronize the SAR module with the Synaps platform. This is needed in order to identify the resources that Synaps have to share with the SAR module. This can be achieved, for example, by providing the SAR module with a unique key session that Synaps will create to establish the communication.

High-level communication: a shared language: At a higher level of communication, we need to define a "shared" language between the SAR modules and Synaps. This language must describe the different actions that can be performed by the whole SPARK platform during a

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session, starting from the selection of the assets (shapes, textures, materials, colours) up to every interaction made by the users with the prototype.

Having such a language could provide some advantages:

- lightweight communications: sharing action/interaction instead of full prototype "state";
- knowledge of the prototype "state" in real-time in Synaps;
- indirect interaction for the SAR module;
- possible implementation of useful features, such as "undo/redo" feature;
- pertinent data for the reporting tool;
- virtual reproducibility of the workshop session through a session player.

Finally, the results of WP1 are fundamental in order to steer the selection and definition of the communication protocol between Synaps and the SAR module.

4 DEFINITION OF THE USE CASE

Technology cannot be fully specified without taking into account the use case and vice-versa. As a consequence, the partners involved in the activities of WP2 have decided to define a use case enabling them to discuss the technologies. In the following, the description of the use case is provided. This use case has to be considered as a first way to investigate the key characteristics to be taken into account when selecting the technologies. Anyway, it is important to keep clear in mind that the activities of WP1 will lead to the identification of the users' expectations, while in the context of WP2, the technological constraints will be highlighted.

In fact, the activities of WP1 will end up with a finer analysis and with a definition of the expected specifications for use cases. Therefore, the following use case is just a representative example for SPARK applications.

Use-case scenario: let us imagine one or two creative designers who plan to run a co-creative session together with their customers, starting from a selection of previously defined design concepts. The design concepts integrate a selection of potential product shapes plus a selection of product decorations. The customer expects to discover the proposed concepts and to compare the various options proposed by the designers. Thereafter, they are going to build on those initial proposals to produce a preferred design concept.

Use-case roles: we assume in this scenario to involve one designer and a second person from the design office in charge of design sales. The project responsible of the customer is in charge of assessing and selecting the right option and to propose refinements. He/she is likely to be accompanied by an assistant.

Use-case process: the creativity innovation process is here conceived in 3 main steps:

- Step 1: In an asynchronous mode, and prior to the use of SPARK SAR module, an overall specification of the product has been exchanged between the customer and the design team. The designers have worked on several concepts and have prepared material for presenting these concepts. Currently, without the SPARK SAR module, they prepare drafts, pictures, videos but also physical non-functional mock-ups. The SAR information module, based on Synaps will provide a solution also to support step 1.
- Step 2: Then, during a synchronous meeting, the material previously prepared, is presented to the customer and several options are discussed together. The discussion (negotiation) takes place in order to fix the selection of options, to ask for some changes in the design, or to validate a solution. During this meeting, the participants sit down around a table in a traditional office room.
- Step 3: Depending on the decision made during the meeting, the product may pass to the final development phase or go back to a new definition of concepts or to a refined definition of look and feel.

Use-case goals: with the SAR module, we will provide support to all steps of the creative innovation process.

Use-case product: in the considered scenario, the product will be a human easy-to-be-handled product: its maximum size will fit inside a bounding box of 40cm x 40 cm x 40 cm. Its minimal size will provide almost a sub-part containing a box of 60mm x 40mm x 25mm. Smaller and bigger artefacts are likely to be tested in the project, but it must be highlighted that sharpness, relative position of projectors will be impacted by size setup. Smaller size will usually expect to pull projectors towards objects and may disturb actors' motions. A bigger size will push back projectors: this is not a big issue, but it will lead to less precise and less sharp images.

Use-case situation: The normal situation will be around a table of standard dimension. The potential four simultaneous users will be placed around the table (see Figure 3). The environment lighting may be adapted with curtains to avoid direct external light, but the natural ambient light must be present. Here, again, we describe a situation that should be updated with WP1 observations. However, it must be noted, that the table size and shape, as well as the number of people involved and sitting around the table, might influence the number of projectors, their setup, and, depending of the selected technology, the tracking solution for interaction. The overall cost of the SAR module will directly depend on the number of expected viewpoints.

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Figure 3 A collaborative creativity meeting around a physical mock-up.

The SPARK platform will enable the designer to present the proposed options of a product concept by superimposing the virtual image on several physical white mock-ups. Coloured mock-up could be used, but this solution requires a more complex treatment on the visualisation side.

The control of projected options may be both a direct or indirect control. Indirect controls are activated from a computer or a tablet while direct controls are activated by direct interaction with the SAR mock-up. It could be by gesture recognition or by usage of tools as tracked pointers. The duration of such a session may vary between 10 minutes and two hours.

Use-case input: material to present mock-ups in a SAR environment

- white physical mock-ups. The 3D model of the mock-up will be also available;
- every texture option;
- controls: light, design line shape controls.

Use-case output: several kinds of decisions will be the main outputs of the activity with the SPARK platform. WP1 will study and report the main outputs. However:

- detail expectation about a concept, or design line;
- edition of a design line;
- agreement about a concept;
- rejection of concepts and/or design line.

It is unclear at this step what will be all the users' requests and features to be implemented in the SPARK platform. Further details will be obtained after the completion of the activities of WP1.

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5 SPATIAL AUGMENTED REALITY: APPLICATIONS OVERVIEW

Spatial Augmented Reality (SAR) augments the perception of the real world through the addition of digital graphics onto physical objects. Compared with classical augmented-reality environments, SAR does not use special displays but uses projectors to display digital contents onto the real world. In this way, the display is separated from the user and, consequently, the user is not constrained to see the augmented world through a digital "window" (monitors) and does not have to wear or bring other devices (head mounted displays or hand-held devices). Therefore, in many situations, SAR displays could be able to overcome technological and ergonomic limitations of conventional Augmented-Reality display systems [8].

The use of physical objects for the projection also provides the users with a passive haptic feedback, which increases the perception and the awareness of the augmented object. This statement is corroborated by a study [9], conducted in 2002, where the authors have concluded that: *"Projection-augmented models offer a unique method for presenting visual and haptic information in the same spatial location. The visual information is projected onto a physical model that supports all physiological depth cues and the ability to touch the object under investigation, allowing a user to naturally access information."*

This feature of SAR naturally fosters the collaboration between users, as assessed in the research [10] conducted in 2014. The authors highlight how *"SAR participates perfectly in group cohesion by creating intermediary spatialities between augmented presence and virtual co-presence. It aids and equips the student in learning how to collaborate. It encourages peer-to-peer sharing between learners, trainers and experts, but at the expense of independent work and the creation of private conversations."*

These motivations led to consider SAR as a "key" element to support co-creative activities in the SPARK project. The application examples, proposed in this chapter, will show how SAR can be effectively used for this aim. Actually, since the early 2000s, SAR applications, including Shader Lamps [11], iLamps [12], Extended Virtual Table [13], Smart Projector [14], have been suggesting product design as one of the most profitable application fields for SAR.

In 2010 a study [15] demonstrated the real effectiveness of SAR in this field. The authors carried out some tests in order to compare how users evaluate products interaction both in a real context and by using SAR. Tests results show that in both contexts users were able to evaluate interactive aspects of products and were able to contribute in changing their design.

Further confirmation of SAR potential in product design is highlighted in the research [16] conducted in 2013, where the authors propose a prototyping system named SARventor. This system was developed to conduct a qualitative review process with three experts within the area of architecture and industrial design, who were not involved in the research. The experts concluded that SAR could effectively assist the collaborative process during product design

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sessions, by offering a high fidelity, transparent application, presenting an enhanced insight into critical design decisions to the projects stakeholders.

To have an overview of the advancements that worldwide research centres did in the SAR field and in particular to support product design, this chapter proposes a discussion about the most significant applications developed in these last years. In addition, the chapter also describes other applications, EU projects and patents, whose technical solutions or ideas, although not specifically related to product design, are deemed significant for the development of SAR module of the SPARK platform.

5.1 Applications for product design

The design review of products seems to be the natural outcome of the possibility to augment physical objects through SAR techniques. In the last years, in fact, academic and commercial applications have been made with the intent of exploiting this feature.

An interesting application, which was presented at the RTT Excite 2012, shows the integration of a real-time rendering software RTT AG, now called DELTAGEN [17], with SAR technologies. The application can use prototypes of real products, realized with 3D printing technologies, or real prototypes, with monochromatic white surface finishing, to projected real-time texture by using a HD 3D laser projector. The tracking system consists in some markers printed on the plane on which the products are positioned and that provides the dynamic projection of digital contents onto the real objects. Tracking and object mapping was implemented by Extend3D [18]. Figure 4 (left) shows how textures can be displayed onto a shoe while Figure 4 (right) shows the visualisation of a car seat including an interactive monitor.

Figure 4: Projected Augmented Reality Prototype by RTT AG and Extend3D, pictures extracted from video [19]

The same real-time rendering software has been used in 2013 to implement another interesting SAR application. The application "Projection Mapping Design Prototype", which was presented at SIGGRAPH 2013, demonstrates the technological improvements of SAR technologies in making a quasi-realistic prototype to evaluate car design. This application was developed in collaboration by two important hardware companies NVidia [20], which is one of the best-

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known graphics card manufacturers, and Christie [21], which produces and commercialises professional projectors.

Further improvements of the prototype rendering quality have also been addressed in the research carried out in 2015 [22]. The authors propose a method to project the high quality rendered image considering the optical property of the product material. In addition, they conduct a projector-camera calibration to compensate a colour distortion according to the projector, the projection surface and the environment lighting.

An important example, which shows a professional use of SAR, is provided by Vizera [23]. Vizera is an application that allows the customization of products directly in the sale point through the real-time projection of graphics, colours, textures etc. The product is initially mapped by 3D scanning to identify its position within the projection area. The customer can control the application by making real-time changes to the design of the product through a mobile device (tablet, smartphone). If the product is moved from its original position, the system updates the projection of the customization elements adapting the new location after a few seconds. The user, thanks to the system, is able to choose his/her preferred product solution among several variants with greater awareness and simplicity. On the other hand, also the dealer can benefit from this application, since he/she can use the shop space in a more effective way. As a consequence, the selling process becomes more effective and efficient. Figure 5 shows the SAR visualisation provided by Vizera.

Figure 5: Two visualisation examples provided by Vizera, pictures extracted from video [24]

Other applications, instead, extend the use of SAR by adding the possibility of interacting directly with augmented objects in order to make modification directly on them. Physical-Virtual Tools for SAR [25] allows the user to paint with an augmented airbrush, create stencils on the surface of physical object and view the result in SAR. BuildMyKitchen [26] is a SAR system to improve kitchen design and other interior architecture tasks: room sized modelling tasks, viewing and modifying pre-set designs, and modifying materials and surface finishes.

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5.2 Other applications

SAR techniques have also inspired important research centres in developing interesting applications that exploit SAR features to make more natural the interaction of the users with the digital contents. Although these applications do not directly relate to the product development processes, they have also been taken into account for the proposed technical solutions that could be reused for the development of SAR module of the SPARK platform.

HideOut [27] is an application developed by Disney research centre that uses mobile projectors to create new forms of interaction with digital contents. These contents are projected on everyday objects such as books, walls, game boards, tables, and many others. The interesting aspect of this application is the use of specially formulated infrared-absorbing markers. These markers are hidden from the human eye, but visible to the camera embedded in the compact mobile projection device, as shown in Figure 6.

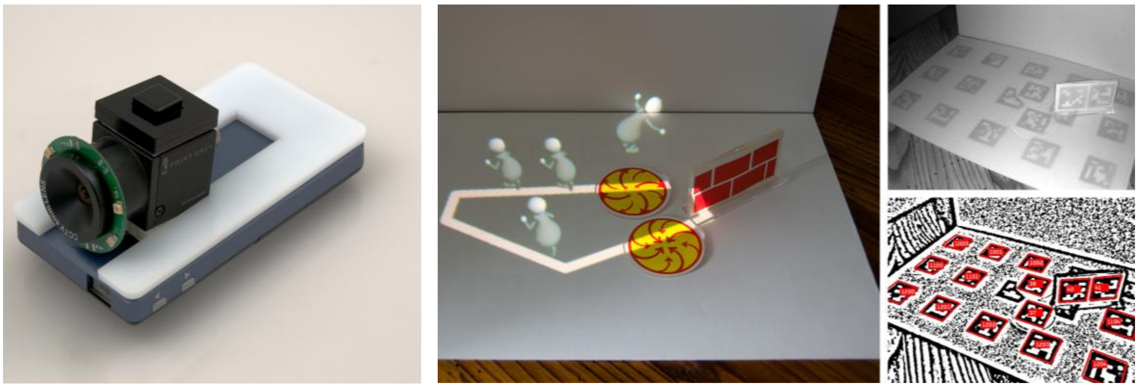

Figure 6: Mobile projector, camera and infrared illumination source (left); hidden markers tracked in the infrared spectrum (right), from [27]

The Disney research centre has also implemented another application, which enables a live object texturing from coloured drawings in AR [28]. The user can colour a 2D drawing on paper and in real time update the corresponding 3D model displayed in AR, as shown in Figure 7. The texture of the 3D model is changed in real time without any delay and even if the page of the colouring book is deformed by the user manipulation.

Figure 7: Live Texturing of Augmented Reality Characters from Coloured Drawings, from [28].

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The Microsoft Research Centre proposes, instead, two interesting SAR applications that transform every room in an interactive virtual experience. The first application, which is named RoomAlive [29], integrates high-definition projectors, with wide fields of view, and depth cameras (Microsoft Kinect) to enable the user to interact with digital contents by touching them directly onto the wall or on furnishings. RoomAlive initially performs a scan of the room (Figure 8, left), by using the depth cameras and then uses the point cloud of the room to project the digital contents coherently with the real space (Figure 8, right).

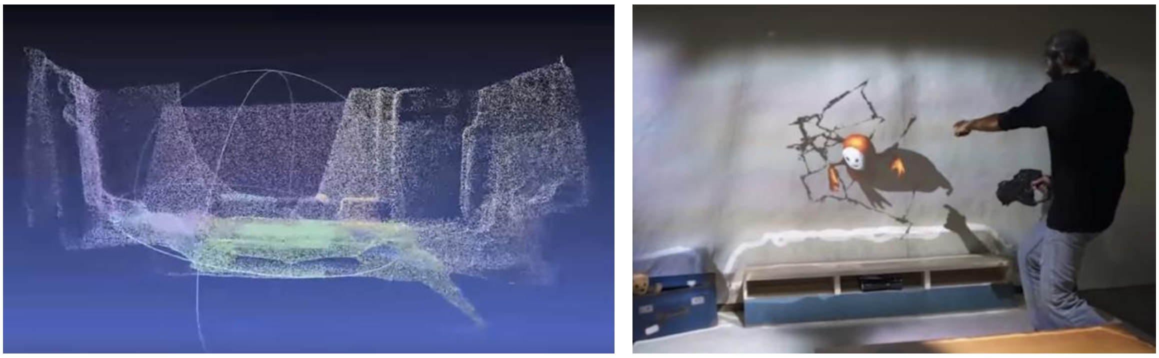

Figure 8: Microsoft RoomAlive, pictures extracted from video [30]

Mano-a-Mano [31] uses technologies similar to those implemented in RoomAlive, but it also includes face-to-face, or dyadic, interaction with 3D virtual objects, multiple perspective views coupled with device-less interaction. Figure 9 shows the application functioning.

Figure 9: Microsoft Mano-a-Mano, pictures extracted from video [32]

Another interesting use of depth cameras coupled with SAR is provided by AR Sandbox [33]). This system was developed for educational purposes and it is able to project digital contents onto the sand, which can be modified in real time by the user, as shown in Figure 10. Although the purposes of this application are very far from the aim of the SPARK platform, the proposed technique, which is used to interact and to control the digital contents, could be borrowed to manage the projection onto possible deformable objects.

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Figure 10: Sandbox AR, pictures extracted from video [34]

Depth cameras and projectors have been also integrated to develop the Mirror Mirror application [35]. This application presented at SIGGRAPH 2015 allows users to customize appearance (graphics, textures, designs, colours, pattern, etc.) of their clothes in front of the mirror. The user holds two targets that track their location and allow him/her to interact with the interface placed in front on the area of a screen-mirror, as shown in Figure 11.

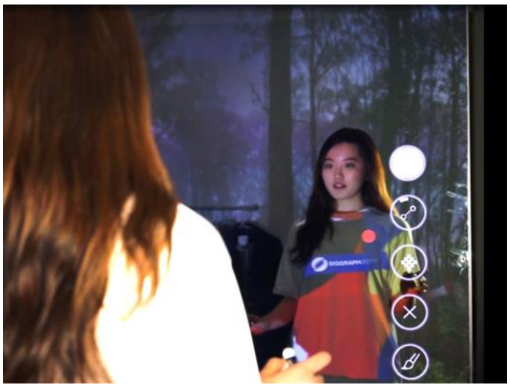

Figure 11: The functioning of the SAR application Mirror Mirror, from [35]

5.3 EU PROJECTS ADDRESSING THE SPARK TOPICS.

The development of systems and platforms for enabling the cooperation of the users without limiting them has been of great interest also for the EU as witnessed by the great amount of EU contributions granted to projects dealing with issues related to the SPARK topics. In the following, the most significant EU funded projects, since the FP5, are presented, so as to provide the reader with an overview of the research conducted in the field. A section of the chapter is, instead, devoted to the projects which are still on going and whose results will be monitored by the SPARK Consortium in order to have a clear view of the updates in the fields addressed by SPARK research activities.

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5.3.1 Former projects

In 2000 a project funded under the aegis of the FP5 – IST named WORKSPACE, has investigated the possibility of creating a novel workspace, mainly for architects and designers so to enable them to work in a collaborative space without the need of using keyboards and screens. The idea was to use spatial positioning technologies to improve the capabilities of the design professionals to work with information and digital spaces that can be related to geographic location [36].

In 2006 a Marie Curie - Reintegration Grant project named ARTEMIS, has developed an intuitive interface for displaying Spatial relevant information to the user [37]. The aim of the project was, among others, to enable the transition between cooperative and non-cooperative environments. In addition, the final goal of the project was the establishment of foundations for the further development of AR technologies, which should have been consumer-oriented, easy to be used and applicable to a great variety of case studies (art, AR games, …). The final report of the project states that the fellow granted with the EU contribution, decided to focus on two main fields: light aircraft maintenance and medical field. Moreover, he focuses his activity on the domain of Mixed Reality and Ubiquitous Computing and on the interaction with geo-centric interfaces.

ManuVAR [38] is a project that started in 2009 (FP7 – NMP-2007 – LARGE 1), whose aim was to apply the AR and VR technologies in order to improve communication flows between people and systems, therefore improving ergonomics, safety, work assistance and training in the manufacturing and service industries. Using this technology, the consortium intended to enable the two-way flow of knowledge, its accumulation, reuse and sharing.

The main aim of the FP7 – PEOPLE – IEF-NIPUI project [39] consisted in the development of ways of interacting more naturally with computers, using projected user interfaces. The scientists have developed controllable projection units for the projection of virtual documents on to real paper, by using a high-resolution projector, and interaction modalities for the projection of virtual characters (in that case cartoon animals that crawl on walls) combined with a speech output. The idea was that thanks to these interfaces, it could be possible to increase the interest in diverse kinds of meetings, such as business meetings and meetings in creative industries and exhibitions.

In 2009, the EU funded a FP7 – PEOPLE – IRSES project, whose acronym was MARCUS [40], aimed at conducting a research on how mobile augmented reality and context aware applications can be used to improve the urban experience.

The ARtSENSE project [41] was funded in the context of the FP7 – ICT- 2009 and aimed at bridging the gap between the digital world with the physical so as to allow for a novel, adaptive cultural experience by using cutting-edge technology (low weight bidirectional see-through displays) that allows the overlaying of the reality with digital information.

Funded in 2011 under the FP7- ICT 2011, the SCOOP project [42] aimed at improving the competitiveness of European industry as well as the scientific one in the field of OLED and thin film encapsulation, which can be useful for many applications, informative eyewear or augmented reality glasses. More important, the results of the project can be applied to many OLAE devices as for instance biosensors, small to large size direct view displays, lighting devices, or solar cells.

The FP7 – ICT 2011 CultAR [43] project aimed at developing a mobile platform to increase users' awareness of their cultural surroundings and users' social engagement with culture. To reach these goals, CultAR combined mobile 3D, augmented reality and tactile technologies in a platform able to provide the users with an enhanced representation, hybrid space mediation, social engagement and awareness.

5.3.2 On-Going projects

In 2013, the COMPEIT project (REF 10) was funded under the aegis of the FP7 – ICT – 2013. COMPEIT aims at developing interactive, personalised, shared media experiences on the Internet for enabling the users to feel present while interacting remotely with other people so as to enjoy media together. COMPEIT will provide virtual eye contact, augmented reality and other features.

In the same context, the FP7 ICT BRIDGET project [44] aims at opening new dimensions for multimedia content creation and consumption by enhancing broadcast programmes with bridgets. A bridget links the programme the user is watching with interactive media such as web pages, images, audio clips, different types of video and synthetic 3D models. Among the different solutions, which will be investigated, there is the possibility for the users of enjoying the bridget on the common main screen or a private second screen, in a user-centric and immersive manner. Within 3D models allowing the users to place themselves inside an Augmented Reality (AR) scene at the exact location from which the linked content was captured. In order to achieve the goals, the project will develop:

- a hybrid broadcast/Internet architecture;
- a professional Authoring Tool (AT) to generate bridgets and dynamic AR scenes with spatialised audio;
- an easy-to-use AT for end users;
- a player to select bridgets, and consume and navigate the resulting dynamic AR scenes.

The FoF – NMP – 2013 PROSECO [45] project aims at developing a novel methodology and a comprehensive ICT solution for collaborative design of product-services (Meta Products) and their production processes. The Meta Product/process development platform will be provided, including a set of new engineering tools to support collaborative work (simulation, configuration etc.) on new product-services, enhancing existing tools for product/process design.

An ERC Advanced Grant funded on 2014, the WEAR3D project [46], aims at addressing the two fundamental scientific challenges of wearable displays so as to make them as natural as wearing a pair of eyeglasses: (i) Eliminate the relay lenses; (ii) Provide all the essential 3D depth cues to avoid perceptual errors and viewing discomfort

It is important to highlight that the solution under development of this project has been funded also as ERC –PoC (proof of concepts) in order to exploit the commercial potential of the Wear3D display technology [47].

In 2015, a project named DBR live has been funded under the aegis of the H2020 – SME instrument. The project aims at accelerating the scaling of a unique and innovative technology platform, the platform, DBRLive. It is a software- and hardware- based technology system bringing together near infrared physics, advanced camera optics and integration techniques with television broadcasters to enable the real time replacement of physical advertising signage in sports broadcasts with virtual content targeted simultaneously at multiple audiences (e.g. different regional language versions) [48].

An ICT project targeted for the creative industries is the FURNIT SAVER project (H2020 – ICT 2014) [49]. The FURNIT-SAVER project aims at taking advantage of the VR/AR technologies, recommendation engines and a user interface to produce a smart marketplace for furniture customisation. This system will allow customers to make accurate 3D plans of the rooms they wish to design, recommend, customise and visualise different furniture, before visualising it in their home environment by using Augmented Reality.

The ICT 37 – SME instrument phase 1 - IMERSO project [50] aims at introducing on the market a VR system for the enterprise market. The aim is to produce a system, which is affordable for everyone. This will modernise the multimedia aspects of product design and prototyping, customer engagement, and workforce training. In addition, it could help the EU in modernising education and training systems, as well as the industrial field.

Another ERC project, which has been funded by the EU in 2016 is an ERC Consolidator Grant named SEED [51]. The project aims at advancing the methodology of computer vision by exploiting a dynamic analysis perspective in order to acquire accurate, yet tractable models, that can automatically learn to sense our visual world, localize still and animate objects (e.g. chairs, phones, computers, bicycles or cars, people and animals), actions and interactions, as well as qualitative geometrical and physical scene properties, by propagating and consolidating temporal information, with minimal system training and supervision. The methodology could affect diverse kinds of fields as for instance automatic personal assistance for people, video editing and indexing, robotics, environmental awareness, augmented reality, human-computer interaction, or manufacturing.

In the field of projects addressing the creative industries' needs, the H2020 –ICT 2015 - REPLICATE project [52] aims at satisfying the creative industries' growing demand for high-quality content by developing a user-centric, mobile-based, 3D-acquisition tool to transform the real-world into new forms of creative-assets by recruiting and encouraging the involvement

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of everyone. The results of the project will enhance the human creative process through the integration of novel Mixed-Reality (MR) user experiences, enabling experimental solutions as 3D/4D storyboarding in unconstrained environments and the ad-hoc expression of ideas by disassembling and reassembling objects in a co-creative workspace.

The H2020 –ICT 2015 first.stage project [53] aims at developing an easy to use and natural interface for fast previsualization of the Narrative Visual Art.

5.4 Patents

In order to explore SAR solutions concerning recent inventions, which have not had the chance to emerge in the market yet, a patent search has been carried out. This has allowed the SPARK Consortium to improve the coverage of the review of existing SAR technologies and techniques.

This patent search has been scoped to gather the relevant information available in public patent databases. In detail, the patent search has been carried out by exploiting the set of patents collected by the European Patent Office (EPO) in the so-called "worldwide" database, which is a collection of patent applications from more than 90 countries, including the ones where the patenting activity is more intensive. Firstly, the patent query was defined to capture the patent applications that include the terms "Spatial Augmented Reality" OR "SAR" " in the title or in the abstract.

This kind of search yielded a very large amount of patents (5k+) with probably an almost satisfactory recall but a very poor precision, considering that most of the retrieved patents included in that set were about technical solutions not concerning any Spatial Augmented Reality application, but sharing the same acronym (e.g.: Specific Absorption Rate, Synthetic Aperture Radar,…). A second and simple patent query was then just focused on patents having the keyword "Spatial Augmented Reality" in the title or in the abstract of the patent itself. This specific search, even if less performing in terms of the recall index, was much more precise: 8 out of 8 patents were relevant to the purposes of the SPARK project. It is worth mentioning that the retrieved patents were not filed earlier than 2009.

In order to achieve more satisfactory results both in terms of precision and recall, the patent retrieval process has been, then, carried out through "Orbit"; a patent search engine that allows exploring the patent databases with more complex queries. The final patent query aimed at searching relevant terms in the title of the patent (code for the patent query: /TI), in its abstract (/AB/IW), in its claims (/CLMS) as well as in its description (/DESC/ODES) and in, if available, the field describing the object of the invention (/OBJ).

With the purpose of reducing the retrieval of false positives, the keyword used for the search included parentheses and several Boolean operators to exclude patents embedding non-relevant terms: (Spatial_Augmented_Reality OR (SAR AND Augmented_Reality)) NOT radar). This final query is the outcome of progressive refinements. In fact, it was necessary to exclude

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the term “radar” from the search, since the concurrent presence of the acronym SAR and the words “Augmented Reality” within the patent was not sufficient to remove the false positive patents concerning Synthetic Aperture Radar applications. This patent search yielded 45 patents. By reading the content of the retrieved patents, it was also possible to further filter the ones that are relevant from those which are not. The following list summarizes the set of 19 patents that have been considered as potentially relevant for the purposes of the project and, most of all, for completing the analysis of the state of the art for this deliverable. The list includes the information required to identify the patent: title, patent numbers, applicant. A more detailed description of the patent content is provided in the appendix of this deliverable.

KR20090071851	Development of annotation system based on spatial augmented reality
	DONGSEO TECHNOLOGY HEADQUTERS
KR20110107691	Method for display spatial augmented reality-based interactive
	DONGSEO TECHNOLOGY HEADQUTERS
US20100253700	Real-Time 3-D Interactions Between Real And Virtual Environments
	BERGERON PHILIPPE
KR20120113906	System of multi-touch interaction using multi-touch display on an irregular surface, and method of the same
	DONGSEO TECHNOLOGY HEADQUTERS
WO201323705	Methods and systems for enabling creation of augmented reality content
	LAYAR
WO201323706	Computer-vision based augmented reality system
	LAYAR
WO201344983	Feedback to user for indicating augmentability of an image
	LAYAR
US20130162521	Device and method for user interaction
	ELECTRONICS & TELECOMMUNICATIONS RESEARCH INSTITUTE KOREA ELECTRONICS TELECOMM
US20140002498	Apparatus and method for creating spatial augmented reality content
	ELECTRONICS & TELECOMMUNICATIONS RESEARCH INSTITUTE KOREA ELECTRONICS TELECOMM
EP2560145	Methods and systems for enabling the creation of augmented reality content
	LAYAR
US20130069940	Systems And Methods For Projecting Images Onto An Object

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	UNIVERSITY OF SOUTH FLORIDA
WO2014101955	Method of and system for projecting digital information on a real object in a real environment
	METAIO
EP2772885	Barcode visualization in augmented reality
	LAYAR
US20140125577	Distance based modelling and manipulation methods for augmented reality systems using ultrasonic gloves
	UNIVERSITY OF SOUTH AUSTRALIA
WO201432089	Spatial Augmented Reality (SAR) Application Development System
	UNIVERSITY OF SOUTH AUSTRALIA
US20140226167	Method and Apparatus for Calibration of Multiple Projector Systems
	UNIVERSITY OF SOUTH AUSTRALIA
WO201516798	Augmented reality system for projecting an image onto the environment
	IMCOM YAZILIM ELEKTRONIK SANAYI STI
WO201527286	A medical training simulation system and method
	UNIVERSITY OF SOUTH AUSTRALIA
WO201570258	Methods, systems, and computer readable media for improved illumination of spatial augmented reality objects
	UNIVERSITY OF NORTH CAROLINA

6 TECHNOLOGIES AND TECHNIQUES SUITABLE/CANDIDATE FOR SPARK MODULES

6.1 VISUALISATION

Visualisation represents, in addition to the basic haptic sensations of weight and surface texture of a prototype, the main feedback channel during design review and creativity sessions supported by the future interactive SPARK platform. Since appearance aspects are considered to play a key role in purchase decisions of customers, it will be critical to the SPARK platform to create realistic visual experiences during design sessions as well. A number of technical visualisation requirements have therefore to be taken into account, such as:

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- Realistic shapes (the geometric form of an object);
- Realistic textures (any surface painting or label);
- Realistic shading (material-based light reflection);
- Realistic lighting (types and numbers of light sources).

In addition, the collaborative design review and creativity context will require that the visual experience can be shared across participants, whether in place (around a table) or remotely, whether directly (overlaid on a physical prototype) or indirectly. A variety of visualisation technologies and techniques, including high quality rendering engines, can readily be employed, others will have to be adapted or developed in the course of the SPARK project. The sections below will discuss the state of the art with respect to the aforementioned requirements.

6.1.1 Photorealistic real-time 3D rendering

Thanks to the availability of engines for photorealistic real-time 3D rendering, such as Unity 3D [54], the Unreal Engine [55], Blender [56], or 3Dexcite's Deltagen [17], we will immediately be able to respond to most of the visualisation fidelity needs. Lighting and shading options allow producing real-time graphics at the required quality. However, object shapes and textures or labels have to be acquired or generated before they can be integrated as assets into a 3D scene. If not already available in digital form, shape information can be obtained, for instance, using 3D scanners. Textures or labels to be painted on the surface of a product are usually provided by the design group. Their integration will thus be straightforward in our case.

Whether 3D shape or texture data, their real-time optimisation will be important because, in interactive systems, noticeable lags can dramatically affect user experience. Methods for reducing geometry complexity (e.g., morphology-preserving simplification [57]), or for down-sampling and resizing texture images are often part of dedicated software suites, or even rendering engines.

However, given that, our modes of inspection can range from viewing product designs on desktop screens, having them video-projected onto physical prototypes or mixed with the real world using special glasses, colour calibration/balancing [58] of the rendering output may be required. The main motivation for this step is to assure colour consistency across the display systems being used in order not to bias user judgements.

6.1.2 On-screen visualisation and augmentation

A common way to review designs is to visualise them on any kind of display. This can be the display of a handheld device, a desktop screen, a power wall, or even a projection. What a participant would see essentially is a remote or tele-representation of the product (see Figure 12).

Figure 12: On-screen design review, Microsoft's Perceptive Pixel.

In fact, these visualisations would not even need to be combined with real world elements, although user experience may benefit from reviewing the design in a natural context [59]. In order to integrate both 3D product visualisation and natural context, a standard Augmented Reality (AR) based on live video data [60] could be used (see also Figure 13).

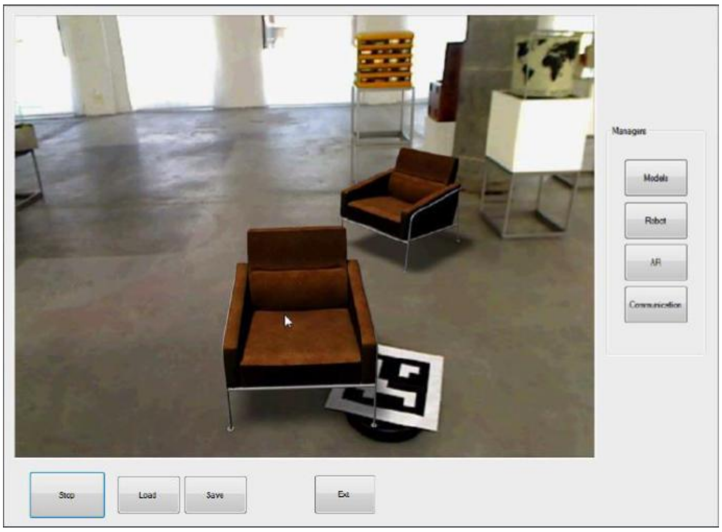

Figure 13: Desktop AR interior design, from [60].

At this point, we are not talking of Spatial AR (SAR) yet. Rendering of the virtual content (i.e., the product / design) is done from the viewpoint of the video camera, which lends (some of) its intrinsic (e.g., focal length, aspect ratio, principal point, and lens distortions) and extrinsic characteristics (i.e., camera centre and heading in world coordinates) to the "virtual eye", the rendering camera. The intrinsic parameters of the video camera must have been determined beforehand in a separate calibration step [61]. The extrinsic parameters are computed online with respect to a known reference (e.g., a marker; see also the Tracking section 6.2), and allow

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positioning any 3D object as if it was located at and oriented like this reference. This position and orientation information can then be fed into the rendering engine of choice.

Advantages:

The general advantage of this AR approach is that the rendered content will always be synchronised and geometrically perfectly aligned with the live pictures of the real world. System response delays will, if ever, be less noticeable. Moreover, colour calibration can be done more easily, since display properties typically do not change during a design review and creativity session. The full range of on-screen visual effects can be applied to the rendered content, which in many cases offers the required compelling look. It would further be possible to modify the "real context" at varying degrees, spanning different video backgrounds to fully controllable virtual worlds, and even to add geometric features not present in the real object. Another advantage, in particular, in the purely virtual case (which would then no longer be called AR, but Virtual Reality – VR), smaller registration or tracking offsets will not affect the general experience. Users are more likely to automatically compensate for such "errors".

Disadvantages:

However, manual manipulation (i.e., moving the object of interest around or turning it with the own hands) will always resemble a remote or tele-operation task. Look and haptic feel at perceptual level are not taking place within the same space. User experience may thus be less realistic as compared to co-located interaction [62]. It will depend on the type of product to review whether this kind of presentation can satisfy specific design review and creativity needs.

6.1.3 Video-projection-based augmentation

When added visual content will be displayed directly onto the physical objects, we talk of SAR [63]. There will be no need for an external "indirect" display. Therefore, whatever appearance modification (e.g., surface texture/painting and labels) we wish to demonstrate, it will immediately be visible on the object's surface. An example of SAR is the video-projection of the desired content directly onto the object(s) of interest, as shown in Figure 14.

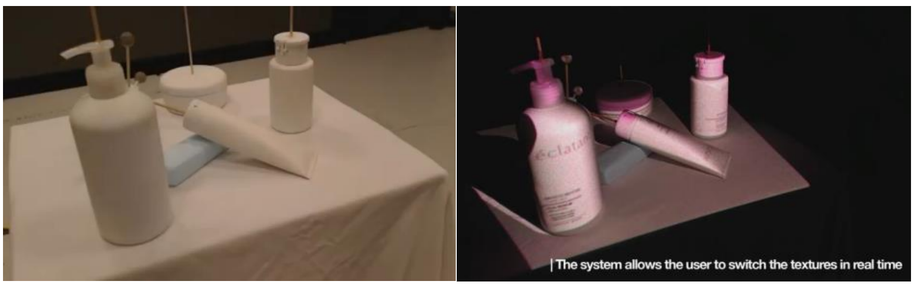

Figure 14: SAR example applied to industrial packaging design, pictures extracted from video [64]

Despite the advantage of having in-place augmentation, it is necessary to cope with a number of technical challenges to fully benefit from a physical object being augmented in real-time:

- Precise overlay of the projected content on the object of interest;
- Illuminating the entire object surface, including potentially concave parts;
- Appropriate texturing, shading, and colour/material mixing;
- Handling of display lags leading to augmentations being "late".

Correct projection onto a physical prototype, which moreover can be moved freely in 3D, requires the shape of the projection volume to be known, mainly for the following two reasons:

- To compute a rendering frustum (i.e., the projection matrix) that matches the projection volume. This step allows to exactly superimpose virtual 3D geometry on its real counter-part without any pre-warping. One way to determine projection intrinsic and extrinsic is to inverse the pinhole camera model as described in [65].
- To locate the object inside the projection volume, or, in other words, inside the rendering frustum. This can be achieved by computing the 3D homogeneous transformation between the object tracking and the projection frames of reference.

Illuminating the entire object surface via projections, notably in cases where viewers are sitting around a table, can be difficult. There may be regions that do not receive any light from a projector. If multiple projectors are being used, projection seams have to be handled in order not to oversaturate or skew colour properties of certain regions. The issue of colour blending and radiometric compensation for single and across multiple projections, including camera-induced colour biases, have been extensively discussed in [63, 66]. Colour correction transformations have to be performed at pixel level to resolve colour inconsistencies.

An important aspect of an ergonomic interaction with display systems is a low response time, at best below inconvenience or even perceptual thresholds [67, 68]. However, there are many possible sources for response delays (e.g., image processing for marker detection, complex geometry and shading, system event handling, data flow, computing performance). As a consequence, to reach a satisfying overall end-to-end performance, it is necessary to analyse and then to take adequate measure in any of these domains. Fortunately, various guidelines and best practices exist that can help inspire possible actions of optimisation.

Advantages:

The main advantage of projection-based SAR is that the surface appearance of volumetric objects can be manipulated in place. This allows to directly integrate look and feel, even at perceptual level, and to deliver the most natural experience, notably when interacting with the mixed prototype. Visual stimuli have to be faithful/convincing enough not to break the illusion of presence, while taking the potential risk of Uncanny Valley effects into account. Further, multiple viewers (or participants of a design review and creativity session) can simultaneously look at the augmented object at its real size, and from (nearly) all angles. All this will be possible without wearing glasses or employing any other complicated view multiplexer (e.g., a holographic display like REALFICTION's DREAMOC HD3). Longer-term use should be unproblematic under these beneficial ergonomic conditions.

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Disadvantages:

The biggest advantage also is the biggest disadvantage of projection-based SAR. The fact that the computer-generated content will be physically co-located with the real object induces a number of issues: a) Object tracking and overall system calibration have to be very precise, b) colour-mixing will be complex for the surface design to look reliable from multiple viewpoints, c) even small system delays will immediately lead to visible gaps (i.e., the projected content will not appear as if it would actually "stick" to the surface), in particular, if the augmented object is being moved, d) other objects (as for instance the hands of a person) may cast shadows or spuriously receive projected images, e) the perceived visual quality will, of course, depend on the projector's properties, but certainly be considerably lower than any real packaging print. All this is to say that the design simulation can unfortunately fail easily, if any of the above issues cannot be handled appropriately. Moreover, design variations are limited to surface painting or shading variations. That is, geometric shape manipulations will not be possible due to them a) being view-dependent (i.e., for each viewer, a dedicated image has to be rendered), and b) requiring projection support (i.e., a surface that can receive the image).

6.1.4 Projection-based display

For the visualisation technology of the SAR module, the choice of the projection-based display devices will be fundamental in order to allow designers to perform correctly the brainstorming creative sessions. This section provides useful information and consideration that will enable the SPARK Consortium to choose the best devices available on the market. The choice of the visualisation device will have to satisfy both the requirements of WP1 and the need to implement a cost effective solution, as claimed in the project proposal. The section includes a complete overview of the current projection-based display technologies and their specifications, a hypothesis of the best-performance specifications for the SAR module and reports the information collected during the technical visit to the premises of one of the most important digital projectors manufacturers.

Projection-based display technologies

LCD projector using LCD light gates. This is the simplest and most common technology, making it one of the most common and affordable for theatre and business use. Its most common problem is a visible "screen door" or pixelation effect, although recent advances have reduced the severity of this effect.

DLP projector using Texas Instruments' DLP technology. This projection display technology uses one, two, or three microfabricated light valves called digital micromirror devices (DMDs). The single- and double-DMD versions use rotating colour wheels in time with the mirror refreshes to modulate colour. The most common problem with the single- or two-DMD varieties is a visible "rainbow" which some people perceive when moving their eyes. More recent projectors with higher speed (2x or 4x) and otherwise optimised colour wheels have lessened this effect. Systems with 3 DMDs never have this problem, as they display each primary colour simultaneously.

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LCoS projectors (liquid crystal on silicon). LCoS projector technology often processes light in the Fourier domain, which enables correction of optical aberrations using Zernike polynomials. Some commercially available technologies include: D-ILA JVC's Direct-drive Image Light Amplifier based on LCoS technology. SXRD Sony's proprietary variant of LCoS technology.

LED projectors use one of the above-mentioned technologies for image creation, with a difference that they use an array of Light Emitting Diodes as the light source, negating the need for lamp replacement.

Hybrid LED and laser diode projection systems developed by Casio. This projector technology uses a combination of Light Emitting Diodes and 445 nm laser diodes as the light source, while image is processed with DLP (DMD) chip.

Laser diode projectors have been developed by Microvision and Aaxa Technologies. Microvision laser projectors use Microvision's patented laser beam-steering technology, whereas Aaxa Technologies uses laser diodes + LCoS.

Projection-based display specifications

Picture Brightness - ANSI Lumens: The international industry standard measurement of a projector's brightness is ANSI Lumens. Depending on lamp, optics and projector design, ANSI lumens on projectors range from 200 to 10,000. The more light in the room or the farther away the projector, the brighter your projector should be.

Contrast Ratio: The contrast between the brightest white and the darkest black. Higher contrast ratios offer brighter colours and better details. Contrast Ratio works hand in hand with lumens. A projector with a 1000:1 contrast ratio will look brighter than one with 400:1, even though they have the same lumen rating. This is particularly true in a darkened room. For the SAR visualisation module of the SPARK platform, it is recommended to specify a projection technology with a minimum contrast ratio of 1000 to 1.

Display resolution: Display resolution is the number of distinct pixels in each dimension that can be displayed by the projector. Display resolution is quoted as width × height, with the units in pixels: for example, "1024 × 768" means the width is 1024 pixels and the height is 768 pixels. Figure 15 shows most common display resolutions with the colour of each resolution type indicating the display ratio (e.g., red indicates a 4:3 ratio):

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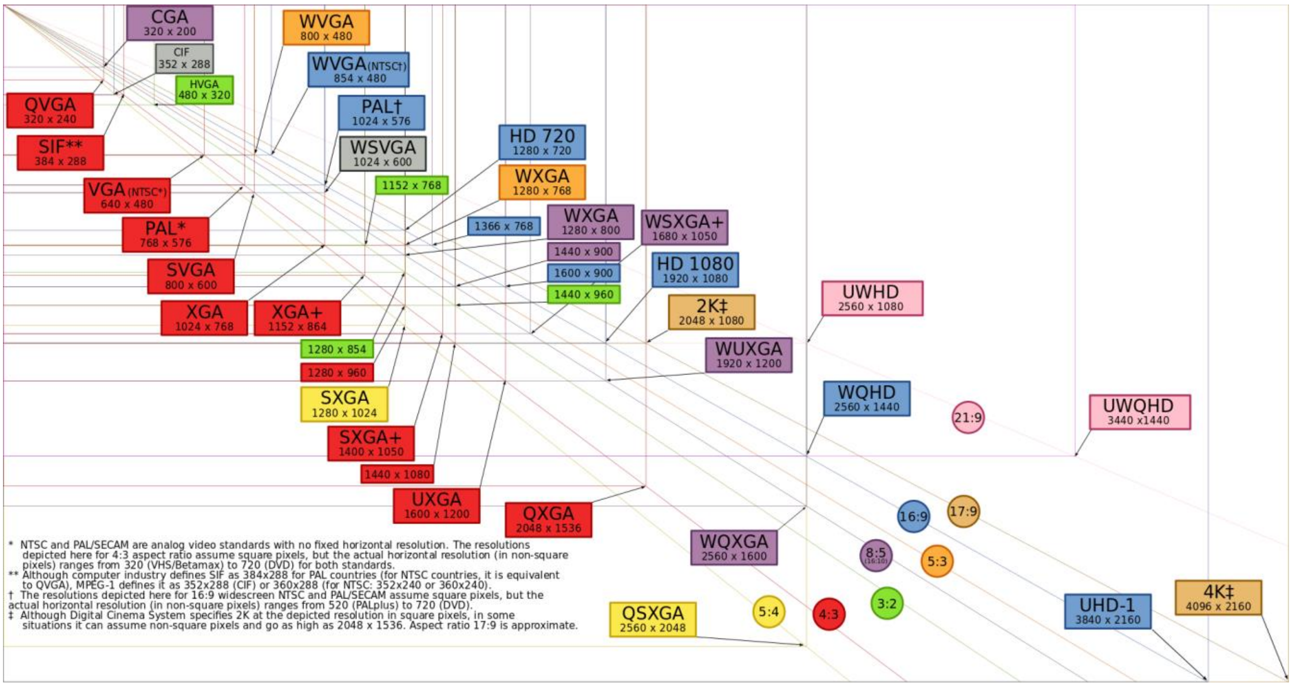

Figure 15: Most common display resolutions with the colour of each resolution type indicating the display ratio

Colour Dynamics: "The whitest whites, reddest reds, etc.". High colour dynamics are a result of dynamic range/contrast ratios. When we describe a unit as having excellent colour dynamics, the practical description might be "rich colours, excellent definition, and high contrast".

Digital Keystone Correction: Keystone correction makes a projected image rectangular. This can be accomplished by positioning the projector to be perpendicular to the screen. Since this is not always possible, most projectors are equipped with keystone correction that allows the image to be keystone corrected (made rectangular) by adjusting optics, making mechanical adjustments, or applying digital correction to the image. Keystone correction can be one or two dimensional and manual or automatic depending on the projector and the manufacturer.

Scanning Frequency: Different image generator outputs have different vertical and horizontal scanning frequencies. For example, VGA (640 x 480 resolution) can be as low as 32 Hz Horizontal and 60 Hz Vertical, and SXGA can be up to 81 Hz Horizontal and 76 Hz Vertical. In order for the projector unit to be compatible with the image generator unit, it must have a range of scanning frequencies, which covers the SAR visualisation module requirements.

dB Rating: This refers to the amount of fan noise the projector produces.

Throw Distance: The throw distance or projection distance is the distance from the projector unit to the projection surface or the physical object of the mixed prototype in the SAR visualization module of the SPARK platform.

As the performance of the SAR visualisation module of the SPARK platform will not only depend on the projector unit but also on the nature and characteristics of the physical object of the mixed prototype on which will be projected and the room lighting conditions, it is

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recommended to add following specific specifications for the SAR visualisation & projector technologies:

Luminance: Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light that passes through, is emitted or reflected from a particular area, and falls within a given solid angle. The SI unit for luminance is candela per square meter (cd/m^2). A non-SI term for the same unit is the "*nit*". The CGSunit of luminance is the stilb, which is equal to one candela per square centimetre or 10 kcd/m^2.

Pixel size on the projection surface: In digital imaging, a pixel is a physical point in a raster image, or the smallest addressable element in an all points addressable display device; so it is the smallest controllable element of a picture represented by image or video projection on the physical tangible object of the SPARK mixed prototype.

Colour Space: A colour space is defined by its colour model (a way of representing colours as tuples of numbers) and its colour gamut (a subset of colours which can be accurately represented). The most common colour spaces used in displays are based on the RGB colour model where red, green and blue light are added together to produce a colour.

For the SAR module of the SPARK platform, it is recommended to specify a REC.2020 Colour Space. Rec. 2020 is an ITU Recommendation, first introduced in 2012, that sets out the standards for UHDTV (UHD 4K and UHD 8K). Included in these standards is the Rec. 2020 Colour Space, which is an RGB colour space that has a colour gamut that is wider than almost all other RGB colour spaces (Figure 16).

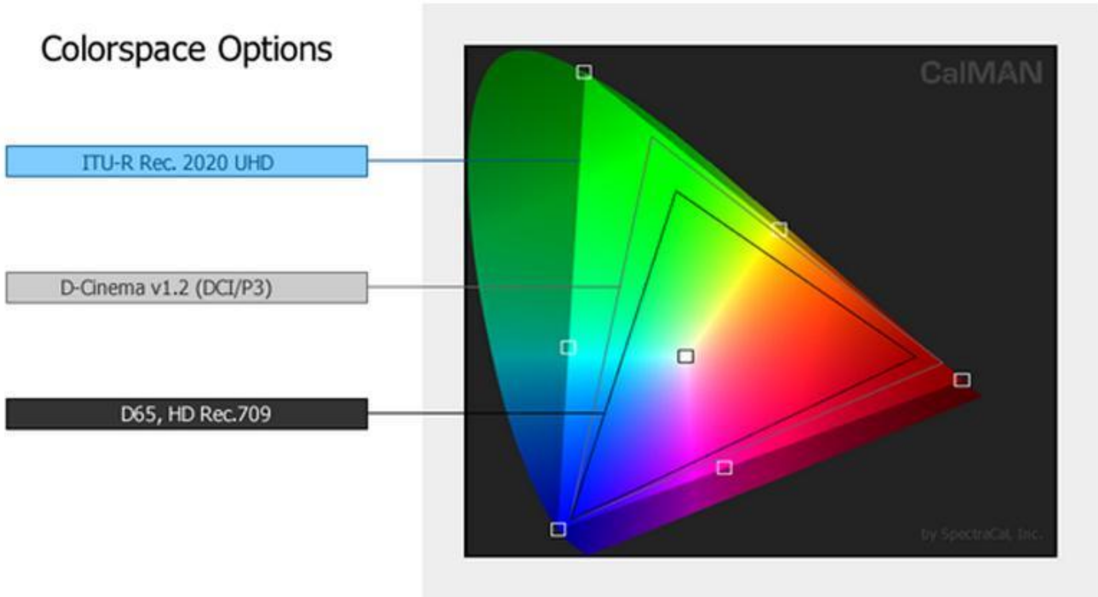

Figure 16: Colorspace options

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Best-performance specifications for SAR module

Projector Illumination Technology: For the SAR visualisation module of the SPARK platform it is recommended to specify a projection technology based on **solid-state illumination (SSL) technology (laser or LED).**

Luminance: For the SAR visualisation module of the SPARK platform it is recommended to specify a minimum perceived brightness on a white object of **100 NIT.**

Pixel size: For the SAR visualisation module of the SPARK platform it is recommended to specify a **maximum pixel size of 0,75mm** on the physical tangible object of the mixed prototype in the SAR module of the SPARK platform.

Colour Space: For the SAR visualisation module of the SPARK platform, it is recommended to specify a **REC2020 Colour Space** for optimal colour reproduction on the SAR object

Visit @ BARCO

To improve the knowledge on the projection-based display technologies, a technical visit was organised at BARCO [69], which is one of the most important digital projectors manufacturers. During the visit, many technical issues related to the projection have been discussed. Barco's people have provided us with their opinions about the specifications, which have been reported in the previous paragraph.

They still consider LED technology as not powerful and bright enough for the purposes of the project (projection in environment with natural light). RGB laser projectors could provide the best lighting source but they are very expensive, cumbersome and cannot be used, for safety reasons, if users can be directly exposed to the light (possible occurrence during the use of the SPARK platform). Laser-phosphor illumination could represent a good solution even if the brightness of current midrange laser-phosphor projectors cannot be compared with the lamp-based correspondents. Laser-phosphor illumination technology is constantly improving so BARCO's people suggested using lamp-based for the first implementation of the platform and then moving to the incoming laser-phosphor projectors.

The image sharpness does not depend solely on the resolution of the projectors. In actuality, also optics and the distance of the projection play a fundamental role. During the first testing sessions, these features have to be taken into account in order to identify the best combination between resolution, optics and distance of the projection.

Finally, they consider the fidelity of colours an issue that can be influenced by factors that go beyond the colour space of the projector. External lighting and the colour of the projection surface are two of these factors. Software algorithms could be used to compensate the influence of these factors. Consequently, also this aspect has to be carefully considered from the first implementations of the platform in order to constantly check and control the rendering of colours.

In addition, possible multi-projectors layouts were discussed. The number of projectors and their arrangement will significant influence the cost and the complexity of the SPARK platform. While technical issues, such as the overlap of multi-projected images, can effectively be managed via software, the placement of projectors has also to satisfy usability and ergonomics aspects. Some layouts have been discussed and the most compelling hypotheses will be implemented and tested since the early implementations of the platform.

6.1.5 Augmentation using see-through glasses

The third technological branch we would like to discuss in the light of design reviews is called "see-through glasses". As opposed to the other two modes of presentation described above, Head-Mounted see-through Displays (HMDs) are typically strictly private. Only one person can see visual augmentations at a time in her or his display. That is, multiple simultaneous viewers would have to be coordinated by the future SPARK platform; while each participant's viewpoint has to be tracked at 6 degrees of freedom [70] (see also Figure 17).

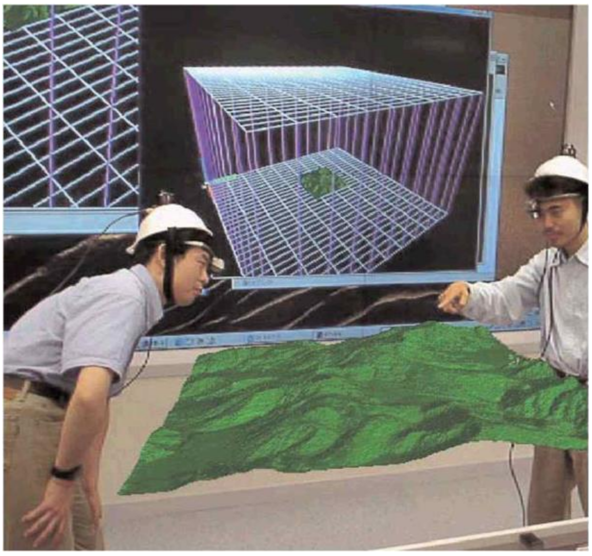

Figure 17: Collaborative AR, from [70].

We can divide HMDs into, at least, three groups of devices:

Opaque HMDs (e.g., Sony HMZ or Oculus Rift): These devices are usually equipped with one integrated display, or an array of displays (e.g., Sensics' piSight), for each eye allowing to render contents, if needed, in stereo. The distance between these displays can be adjusted such that it matches the eye distance of the wearer. This kind of device would allow design reviews under VR conditions.

Video see-through HMDs (e.g., Trivisio's SXGA HMD series): In addition to the opaque base device, this group of HMDs has one or two built-in or attached video cameras pointing in the user's view direction. There is no direct, but indirect see-through via video. Since the real environment (incl. the own hands) will be captured before it will be displayed, any modification

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to the visual content will be possible, just as in the case of on-screen AR or VR. Augmentations will thus always be synchronised with the image of the reality.

Optical see-through HMDs (e.g., Google Glass or the Vuzix glasses): As says the name, these HMDs allow to directly see through the device's optics and look around the real environment. Sometimes, cameras are integrated for basic interaction. However, in most cases, these devices are monocular (a stereo alternative is Trivisio's AlphaBino). What is common to this type of display is that images appear translucent which means that real objects (incl. markers etc.) will always shine through.

Specific calibration procedures are necessary to register the built-in displays of HMDs with the real world frame of reference. Many devices are "wired", notably those with bigger resolution and better optics. However, autonomous options exist, some of which requiring wearing a backpack. Even smart-phone-powered optical see-through HMDs have been proposed (e.g., Seebrigt's Wave or Microsoft's experimental Reality Mashers).

Advantages:

Opaque and video see-through HMDs come with nearly the same visualisation benefits as on-screen displays, although at a lower resolution: Visual augmentations or modifications of the object of interest (even at geometric level) are practically unlimited. It would further be no problem to share the experience across different places. Real size 3D reviews are possible, also in stereo. Optical see-through HMDs allow directly seeing the real world, and so offering a stable perceptual reference, making the experience generally more ergonomic (and less prone to cyber sickness side effects [68]. Given that these devices are often considerably lighter and consume less energy, they may be more appropriate for longer-term use. Geometric shape modifications of a design are possible in optical see-through configurations as well.

Disadvantages:

Despite the benefits of HMDs, the need for wearing special equipment, even if it was lightweight, can present a serious burden, in particular, if heavier devices are being used. Moreover, each participant of a design review and creativity session has to wear her or his own device. This would make the final platform more complex when sharing a common scene, and require additional tracking technology in order to locate each participant's viewpoint. In addition, the resolution of HMDs is generally lower than that of on-screen displays or higher fidelity projectors. Optical see-through devices suffer from disadvantages comparable to those of video projectors, since augmentations will be overlaid on the real environment, and not only on its image. Since the augmentation is translucent in optical see-through HMDs, it is important to take care of the final appearance of the object of interest.

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6.2 Tracking

Tracking is a major and sensitive component of a SAR system. We can augment the physical world as soon as we can capture this world or if the components of this world are pre-defined if we can capture the position of these components.

6.2.1 Accelerometers, gyroscopes, and magnetometers

Accelerometers allow measuring accelerations relative to the free fall. In a3-axis configuration, such sensors can be used to compute a sensor unit's orientation with respect to the direction of gravity. That is, rotations perpendicular to this direction cannot be determined. Moreover, when sensors are moving, there will always be a mixture of forces, making it difficult to separate acceleration components.

Gyroscopes exploit inertia by measuring angular velocity along the rotational axes. Given a known initial orientation, integration over time allows tracking a sensors orientation – with some drift, though. Further sensors can be used to compensate this drift, or to perform recalibration, e.g. in combination with 3-axis accelerometers. Movea's InvenSense products fall into the domain of such coupled sensors in order to offer 6 degrees of freedom motion tracking.

Magnetometers are "compasses" measuring the yaw rotation (which would not be possible with accelerometers, for instance). They can be combined, just as the former sensors, in x-y-z-setups, and so complement them in a way to resolve ambiguities and compensate for drifts. Movea's 9-axis MPU-925x family is equipped with such a combination of sensors, making them precise and robust at the same time.

Most of these sensors, both combined or not, are available as wireless solutions. Several candidates are listed below:

- http://www.invensense.com/motion/
- http://www.trivisio.com/trivisio-products/colibri-wireless-inertial-motion-tracker-3/
- http://inertia-technology.com/promove-mini
- https://www.xsens.com/products/mtw-development-kit/
- https://www.xsens.com/download/pdf/documentation/mtw2-awinda/MTw2-Awinda.pdf
- http://www.stt-systems.com/products/inertial-motion-capture/isen/

Advantages:

Accelerometers, gyroscopes, magnetometers, and their various combinations exist in self-contained and, often, in wireless form of a few cm in size. This makes them relatively easily deployable. Although drift effects during position recognition can still occur, a time-limited use, even in larger spaces (up to 20m indoors), makes this kind of tracking technology an interesting option for SPARK. For most of the tasks envisaged so far, accuracy and latency would be largely satisfying.

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Disadvantages:

On the other hand, the sensors themselves have to be integrated with the objects being manipulated. They could potentially be put inside a physical prototype, if this prototype is large enough. Otherwise, sensors have to be attached to the object of interest, which, given the form factor of these sensor devices, may result in a somewhat bulky appearance. User experience may be affected by that. Finally, an absolute reference will be needed (which can be the known initial object location).

6.2.2 Electromagnetic sensors

Electromagnetic sensors measure position and orientation with respect to a reference magnetic field emitted by an active component of the tracking system. Different sizes of tethered sensors exist, as shown in Figure 18. Housings of wireless solutions, important for the SPARK project, are typically much bigger (8.9 x 4.2 x 2.5 cm).

Figure 18: Versions of electromagnetic sensors from Ascension with diameters from 8 to 0.56mm.

There may be difficulties to equip smaller size objects with wireless electromagnetic sensors. The max distance of remote connexions should not go beyond 5 to 7 meters. Latency (20 ms or below) and precision would be sufficient in terms of SPARK requirements.

Hereafter, we list the references to a set of currently available electromagnetic sensors:

- http://polhemus.com/motion-tracking/all-trackers/
- http://www.ascension-tech.com/products/

Advantages:

The benefits of electromagnetic sensors are similar to the advantages described in the previous section. In addition, thanks to these sensors, it is always possible to obtain absolute tracking measurements with respect to the calibrated tracking reference. Given the extremely small size of tethered sensors, it is likely to integrate them into nearly any objects.

Disadvantages:

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The form factor advantage only holds for tethered solutions. Wireless sensors are considerably bigger, even than comparable combinations of inertial, acceleration, and magnetic sensors. Moreover, perturbations of the electromagnetic reference field, for instance, due to massive ferroelectric components in the environment, can require complicated calibration procedures or, if non-static, be impossible to compensate for.

6.2.3 Image-based tracking

The main property of image-based tracking is that video cameras are used to track specific structures or features. "Optical tracking", as a special form of image-based tracking, relying on the identification of known tracking objects (or "bodies") typically made up of at least 4 spherical markers, will be addressed in the IR Tracking section. Here, we want to focus on the detection and tracking of binary patterns and arbitrary image patches in live video streams.

Most marker-based systems use binary patterns [71] (see Figure 19), first, because the detection of candidate zones (typically black squares or other characteristic shapes) is simple, fast and reliable, and second, the evaluation of each of these candidate zones benefits from the prior knowledge of the algorithmic structures they may contain (e.g., Hamming encoding). Fixed arrangement of multiple markers are called marker boards representing markers themselves [71]. Such a board can still be detected, even if some if its markers are occluded. In order to estimate the pose of a marker with respect to an observing camera, this camera usually has to be calibrated [61].

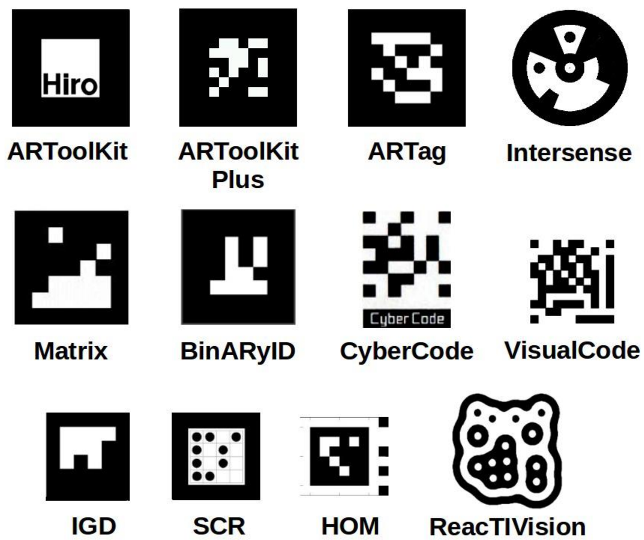

Figure 19: Examples of binary marker patterns; from [71].

The standard marker detection process would operate as follows:

1. Register all markers or structural marker models to the pattern/marker detector;
2. Scan the incoming video, frame by frame, for potential marker candidates;
3. Try to identify these candidates, and retrieve geometric feature information;
4. Using these features, estimate each marker's pose with respect to a calibrated camera.

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Arbitrary image patches can also be used as markers (see Figure 20). In this case, their detection is not based on algorithmic structures. Instead, rotation-invariant multidimensional features (e.g., ORB features [72] will be extracted for each registered image patch, and then be matched with those extracted from the incoming video frame. If certain matching constraints are fulfilled (i.e., quality and quantity of matches), then an image patch will be considered detected. As with binary markers, geometric features will be used for pose estimation.

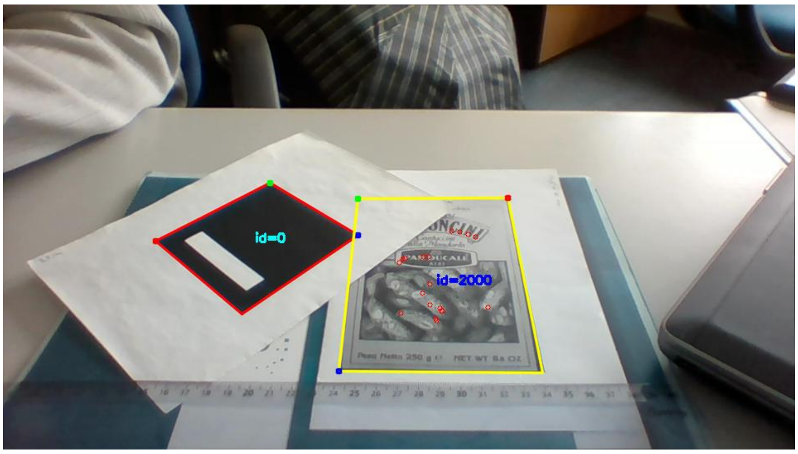

Figure 20: Binary marker (left) and partially occluded image marker with matched features (right).

In addition to single frame pose estimation of planar marker, the detection of 3D textured objects would also be possible. Their pose could be estimated from learned pose classes [73] or via 3D feature matching [74]. For the latter to work, the shape of the object to track has to be known, just as in the case of optical marker body tracking (or IR Tracking).

Advantages:

Image-based tracking, in the sense of marker or image patch tracking has the big advantage of not requiring more than one calibrated camera to work. In addition, this camera can even be a simple webcam. Therefore, cost and system complexity are extremely low. Binary markers are very easy to detect. Their highly reliable versions [71] are easier and more robust. Image markers can be detected, even if they are partially occluded. Because they rely on features distributed over the whole image patch. Whatever type of marker, their creation is simple, and they can be printed out in order to equip a scene or any objects of interest.

Disadvantages:

First, markers have to be planar, although different sides of a volumetric object could be equipped with multiple markers. However, neither curved nor any other non-planar marker shapes are currently supported by this approach. Given that the entire recognition is based on image processing, visual noise or perturbations, a matter of face in natural settings, can drastically compromise detection performance. In addition, if visual content will be projected onto markers, their appearance will be altered, and so the ability to actually detect them. Image processing routines are often costly and it is often necessary to optimise inputs, algorithms, and hardware. Finally, markers have, at least to some degree, to be visible to the observing

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camera. Therefore, if a marker is leaving the (typically small) field-of-view of the camera, it will be lost. Using multiple cameras may help solve this issue, even if the computational load could dramatically increase.

6.2.4 IR tracking

IR tracking is a specialisation of image-based tracking. It relies on the pursuit of active or passive (i.e., reflective) IR markers, which often have the shape of small spheres. A marker body is a cluster of at least four markers, rigidly connected, but sufficiently separated to allow tracking. At least two cameras (in theory, even one would be enough) are usually put around the room-size space of interaction. IR flashlights illuminating the physical space are typically integrated into the cameras; but could also be placed elsewhere.

After thresholding the IR camera images, it is possible to fit known tracking bodies into the 3D locations of detected marker spheres. This way, position and orientation with respect to a common calibrated reference system can be obtained. Principal professional vendors of IR tracking systems are OptiTrack and A.R.T. IR tracking offers high precision and low latency with only a few cameras.

Advantages:

Precision and low latency are clearly the biggest advantages of optical IR tracking. Calibration is simple, and cameras can be arranged almost freely in order to maximise the observation space and to minimise occlusion problems.

Disadvantages:

However, the system will have difficulties with parasite reflections in the scene. Moreover, cameras should not point towards fixed or moving light sources. As with any optical tracking system, IR tracking will have to deal with the risk of (partial) occlusions of tracking bodies. To improve robustness, the number of observing cameras could be increased. Probably the biggest disadvantage is that tracking bodies have their marker spheres mounted on (fragile) pins of several cm in length. This can provoke issues during manipulation and limits there usability.

6.2.5 Range/depth sensing

Range or depth sensing is a technology that allows producing depth maps of the scanned environment. The point clouds generated through any of these methods offer the basis for object recognition or shape matching, opening the way to object or even skeleton tracking.

Three prominent approaches are being used in the consumer and the professional domains:

1. **Structured light**: Structured light at a band invisible to humans (e.g., IR) is projected into the environment. A calibrated camera, integrated and calibrated with the projection unit, captures the resulting image. Rules of size and other spatial characteristics known about and retrieved from structured light patterns lead to more or less precise 3D maps.

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Practically useful tracking distances range from 1.2 to 3.5 m. Examples are the Asus Xtion PRO [75] device or former Kinect devices [76].

2. **Time-of-flight (ToF)**: This method is based on the direct or indirect measurement of the time a light pulse need to travel from the emitter to the receiver. The Kinect v2, for instance, employs an indirect method. As a result, after spatial scanning, a depth map can be generated at a distance of up to 8 m. Professional devices using laser pulse scanning seem inappropriate for SPARK.
3. **Stereo reconstruction**: Depth maps can also be computed from pixel correspondences across multiple images. In its simplest form, stereo image pairs are being used. A critical requirement for efficient 3D reconstruction is that the observing cameras are well calibrated, intrinsically and extrinsically. Triangulation then allows the actual estimation of a depth map for all parts of an object observed by at least two cameras. The Leap Motion controller [77] is a device, which relies on stereo reconstruction for near space range sensing. Its resolution is superior to that obtained via structured light as well as via most of the consumer ToF technologies.

Whatever approach will be taken, reconstructing the observed volume (more or less precisely) in 3D is solely one-step of the processing needed to make sense of the range data. Most of the devices listed above are provided with their own SDKs, and therefore, it is possible to link tracking with interaction (e.g., skeleton or hand / fingertip tracking). Tracking custom objects is, instead, another question. 3D features have to be extracted and matched with the known 3D geometry of a physical object. It will thus be necessary to identify software products offering generic 3D object tracking.

Advantages:

Most, if not all, commercial devices are shipped with their SDKs. This allows easily developing applications making use of integrated and highly optimised tracking features. Good examples are the MS Kinect or the Leap Motion controller (although there are various other devices with similar properties). Mainly developed for game applications, these products are tailored to manual or corporal interaction. Usually, all components are integrated into one single fully calibrated tracking unit.

Disadvantages:

One of the main disadvantages is related to the simultaneous tracking of human gestures and other objects. Indeed, the human body and the objects that should be tracked would form a unique shape meshing.

6.3 Interaction

Interaction refers to actions between two or more objects, which have some impact on these objects. Here interaction refers to the signal exchange between the human participant and the SPARK platform. Visualisation is then an action from the SPARK platform towards human actors

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and is part of the SPARK interaction model. Tracking solutions are also part of the interaction system since they capture positions of either artefacts or human beings, which must be used by SPARK to adapt visualisation. However, tracking and visualisation may be completed by other modalities issues to get a full interaction capacity. This section focuses on tools and methods that could be used to enable control of the SPARK platform by human users. The following classification is proposed:

- Indirect control refers to usual computer graphic user interfaces;
- Direct control refers to technologies capturing events in the spatial augmented reality space.

6.3.1 Indirect controls

Any computer user interface may be developed to select or adapt the behaviour of the spatial augmented reality system. The window-based system with mouse and keyboard events remains the main used solution even if it competes with tactile interfaces. Tactile displays can be integrated easily in the overall SPARK framework. All indirect control applications will create an extra virtual space. It is here recommended to get a fine analysis of the expected spaces [78, 79, 80, 81].

- The SAR is by default a shared space: involved users share the same content.
- A control display could be either shared, if any actor can interact with it or semi-private if a single user can act on the display but everybody sees the content, or also fully private if a single user views and interacts with the corresponding content.

The development of such interfaces are common and many libraries could be used for this task. Here two kinds of libraries should be differentiated respect to multi-platform capacity.

- Qt, wx, GTK [82, 83] are well known to be multi-platform and work fine on either windows, linux or macintoch operating systems. They both have an android dedicated module but remain poorly used.
- Kivy [84] is another GUI system, which natively works on windows, linux, macintoch and android.
- Javascript [85] is a web-oriented language, which allows definition of user interface independent of the platform since it expects a web renderer (browser) to work.
- Java language [86] is an integrated basic user interface module.
- Some OS vendors (Microsoft, Apple, Android) provide dedicated graphic user interface development tools and are usually non multi-platform solutions.

Finally, the Synaps platform described in section 3.1 is another source of potential interaction control at the condition it integrates new modules dedicated to the SPARK platform.

6.3.2 Direct capture of gestures

Using gestures is considered one of the most intuitive ways to interact with information or presentation systems [87]. The widespread use of gesture-based interaction in the domains of

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mobile computing or gaming demonstrates how efficient and accessible direct gesture input can be. In the following, we will discuss touch-based and 3D (or "air touch") gestures.

Tactile gestures performed on any kind of touch-sensitive surface can be used to select or manipulate SAR scenes [88] (see also Figure 21). Although viewed through a "window" and so being "indirect", control may still be felt as "direct", since the user is operating directly on the object of interest. Touch-based interaction can cover a wide range of even more complex gestures. Participants of a design review and creativity session could demonstrate or evaluate design options using their private UI, or pass on a semi-private shared tablet computer. In order to use such a device, it is necessary to locate it with respect to the augmented workspace. This can be achieved just as any pose estimation by relying on calibrated cameras.

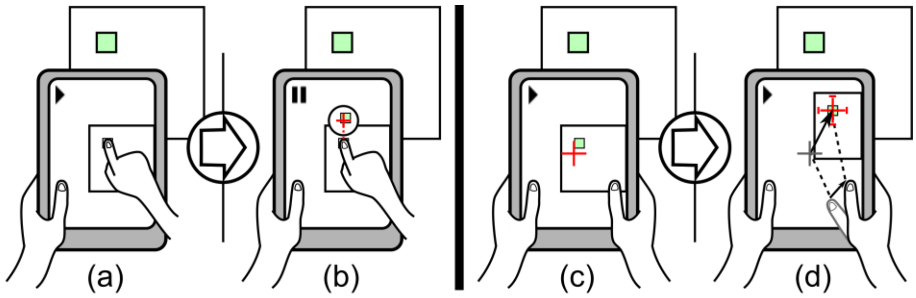

Figure 21: Handheld AR selection techniques: a) Direct Touch on the live video, b) Shift&Freeze, c) Screen-centered Crosshair, and d) Relative Pointing with cursor stabilised on the physical object; from [88].

3D gestures performed either near to or directly on the surface of an object would represent an alternative, but this requires additional specialised gesture capturing hardware. Techniques for free air 3D gesture recognition include classical optical tracking (e.g., ART's Fingertacking device), range sensing (e.g., the Leap Motion controller), or image-based tracking [89]. However, none of these techniques actually allows for surface contacts, but puts the tracked element in relation with the object being manipulated. An essential prerequisite for doing this is that the additional gesture-tracking unit has to be previously registered with the SAR workspace.

Advantages:

Gesture-based control is direct and intuitive. Interactions are spatially aligned with the object being manipulated. Therefore, it could be hypothesised that learning and using such tools will be relatively easy, compared with indirect modes of interaction. However, usefulness may also depend on how creative designers work. Many tasks can still be accomplished more precisely and more quickly in a standard point-and-click environment [90]. Apart from this, transitions between viewing and manipulating the object, if well designed, will be smooth, allowing for a continuous workflow in co-location.

Disadvantages:

The overall system will become more complex, notably if an additional tracking system has to be installed. Whatever this device would be, it has to be registered with the rest of the SAR

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environment. This requirement can be challenging, because accuracy will be a key requirement when interacting directly with an object. Furthermore, gestures may cover important parts of the object of interest, and, although thought to be the most natural and intuitive way of interaction, using the hands may not be as precise as are other modes of interaction. Finally, a gesture-based system has to deal with the risk of confusions with actions such as grasping, holding, or turning the underlying prototype.

6.3.3 Direct capture of tools motions

Rather than capturing human gestures, it may be sharper to capture the motion of a tool. Another great advantage in using tools is that it is possible to reduce the risk of masking a part of the scene with hand (occultancy issues) and to offer sharper pointing capacities. A tool will be a physical artefact, which can be tracked by any solution described in section 6.2. It can be an active tool if it has some actuators to send remote events. A laser pen including a USB remote for power point presentation may be easily adapted to become a 3D pointer/selector/(or whatever) active tool in a spatial augmented reality system. The laser light could also be used to point sharp positions on the mock-up. This expects to fix to it either a magnetic sensor or a trackable image or a marker body.

7 CONCLUSION

The activities conducted during task 2.1 of WP2 have allowed the SPARK Consortium to collect useful information about the state-of-the-art technologies and techniques that will be used for the implementation of the SPARK platform.

The initial discussion on the platform architecture (Chapter 3) clarified the roles of the modules constituting the SPARK platform and steered the activities of the task, which mainly focused on the SAR module. As a consequence, the state-of-the-art updates have concerned aspects related to the SAR. In addition, the modalities for the integration of the already-existing collaborative platform, named Synaps, have been preliminary discussed. This discussion has been considered as useful by the SPARK Consortium in order to identify, since the beginning, the technical implications between Synaps and the SAR technologies, which will be used during the project.

The definition of a general use case (Chapter 4) opened, instead, the fundamental discussion between end users’ expectations and technical limitations. Some of the outcomes of task 1.1 have been used to start clarifying this aspect and to define a general use case. Conversely, some of the outcomes of the task 2.1 will be used to organize the activities of task 1.5. In this way, the planned interviews of task 1.5 will foster a better identification of the information necessary for the implementation of the SPARK platform.

After this initial part, an overview of SAR applications useful for the project has been proposed (Chapter 5). Many of these applications have demonstrated the effectiveness of SAR to evaluate

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mixed prototype and, hence, made SAR ready to be used in some of the design review activities. Other applications, while not specifically related to the purposes of the project, have equally provided useful insights. However, the fundamental issue, which emerges from this overview, is the lack of applications that directly use SAR also to make and to modify the mixed prototype in an interactive way. We believe this lack will be filled by the SPARK project.

The overview of EU project (Section 5.3) related to SAR and the search of patented SAR applications (Section 5.4) allowed the SPARK Consortium to increase the knowledge on SAR applications and research lines in a wider perspective and to identify other possible targets that the SPARK project could reach. In addition, the patent search could help the Consortium to protect new ideas, which will be developed during the SPARK project.

The analysis of technologies and techniques suitable for the SPARK modules (Chapter 6) has allowed deepening the knowledge on the current solutions for the visualisation, tracking and interaction for SAR. During the analysis, advantages and disadvantages were discussed in order to compare the different technological solutions.

Visualisation represents the technology that mainly will influence the realism of the mixed prototype. The discussion on the visualisation technologies led the Consortium to identify the specifications that the projection system will satisfy. Illumination, resolution, optics, noise are some of the requirements that will mainly influence the final choice. In addition, some layouts of multi-projector system have been discussed in order to start identifying the most interesting ones.

The overview related to the tracking technologies have shown that there are no solutions directly satisfying the requirements of the project. The Consortium has taken into consideration the hypothesis to merge different tracking technologies (such as electromagnetic and optical) to overcome their limitations and obtain a reliable tracking that is also compatible with the purposes of the project.

Finally, the discussion on the possible techniques, which should be used to interact with the mixed prototype, led to the definition of two different alternatives: direct and indirect techniques. During the activities of WP2, both techniques will be implemented and tested and, most likely, they could be used in combination into the final release of the platform.

In conclusion, the activities conducted in T2.1 and clustered into this document can be considered not only a review of the state of the art, but also a real starting point for the implementation of the platform.

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9 APPENDIX A – PATENT DETAILS

The following pages present a summary of the content available in the patents selected for the analysis of the state of the art and whose bibliometric data has been presented as a list in section 5.4.

Development of annotation system based on spatial augmented reality

<table>
<tr>
<td>

• **Patent Assignee**
DONGSEO TECHNOLOGY HEADQUTERS
• **Inventor**
AN TAE SUNG
LEE DONG HOON
KIM JUNG HOON
LEE YOUNG BO
YUN CHANG OK
• **International Patent Classification**
G06Q-050/10

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• **Publication Information**
KR20090071851
A 2009-07-02 [KR20090071851]
• **Priority Details**
2007KR-0139775 2007-12-28

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• **Fampat family**
KR20090071851 A 2009-07-02 [KR20090071851]

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• **Abstract:**
A system of guiding exhibits of **spatial augmented reality** is provided to apply a spatial augmented technique to a dynamic object, thereby effectively using the dynamic object in manufacturing various 3D contents. An LCD (Liquid Crystal Display) apparatus outputs information of exhibits. A semi-projective mirror (4) projects the final exhibit guide information. The second display space (1) using an acryl board, a rear screen (5), and a beam projector (10) is formed in a front side of an exhibit guide system based on **spatial augmented reality**. An infrared light emitting diode (8)

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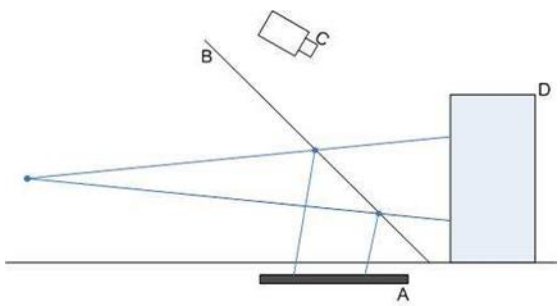

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is installed in a side of the acryl board. A front side of a screen is photographed through a camera (7) capable of infrared photographing.	

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H2020_ICT201_SPARK_688417

Method for display spatial augmented reality-based interactive

• **Patent Assignee** DONGSEO TECHNOLOGY HEADQUTERS • **Inventor** LEE DONG HOON YUN TAE SOO HAN SANG HEON KIM JUNG HOON HYUN SANG KYUN • **International Patent Classification** G06F-003/14 H04N-013/02 H04N-013/04	• **Publication Information** KR20110107691 A 2011-10-04 [KR20110107691] • **Priority Details** 2010KR-0026969 2010-03-25

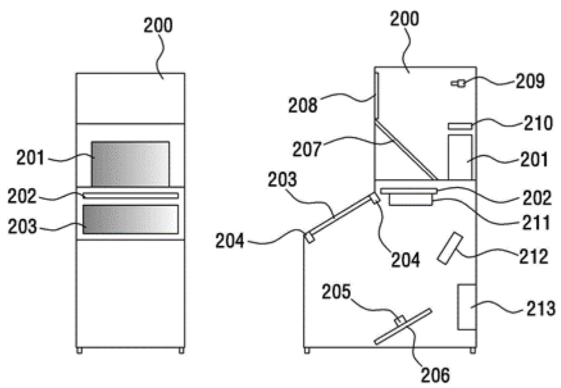
• **Fampat family**

KR20110107691	A	2011-10-04	[KR20110107691]
KR101080040	B1	2011-11-04	[KR101080040]

• **Abstract:**

(KR101080040)

PURPOSE: A method for displaying a **spatial augmented reality**-based interactive is provided to reduce market costs and contribute oversea export and oversea market preoccupy. CONSTITUTION: A display space displays a subject, which stops or moves. A camera (209) photographs the shape of the subject in real time. An image output device (202) outputs guide information of the subject. A translucence mirror enables to see the guide information, which is outputting form an image output device with the shape of the display space. A control PC (213) outputs the guide information, which will be displayed to the subject to an image output device.



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H2020_ICT201_SPARK_688417

Real-Time 3-D Interactions Between Real And Virtual Environments

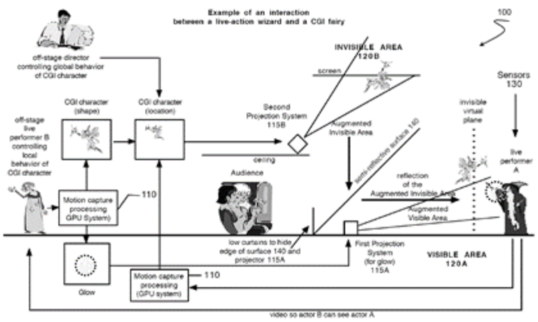
• **Patent Assignee** BERGERON PHILIPPE • **Inventor** BERGERON PHILIPPE • **International Patent Classification** G03B-035/00 G09G-005/00 • **US Patent Classification** PCLO=345633000 PCLX=353007000	• **CPC Code** G03B-035/00 • **Publication Information** US2010253700 A1 2010-10-07 [US20100253700] • **Priority Details** 2009US-61211846 2009-04-02 2010US-12752822 2010-04-01

• **Fampat family**

US2010253700 A1 2010-10-07 [US20100253700]

• **Abstract:**

Systems and methods providing for real and virtual object interactions are presented. Images of virtual objects can be projected onto the real environment, now augmented. Images of virtual objects can also be projected to an off-stage invisible area, where the virtual objects can be perceived as holograms through a semi-reflective surface. A viewer can observe the reflected images while also viewing the augmented environment behind the pane, resulting in one perceived uniform world, all sharing the same Cartesian coordinates. One or more computer-based image processing systems can control the projected images so they appear to interact with the real-world object from the perspective of the viewer.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

System of multi-touch interaction using multi-touch display on an irregular surface, and method of the same

<table>
<tr><td>

- **Patent Assignee**

DONGSEO TECHNOLOGY HEADQUTERS

- **Inventor**

LEE DONG HOON
YUN TAE SOO
KIM CHUL MIN

- **International Patent Classification**

G06F-003/01 G06F-003/041 G06F-003/042

</td><td>

- **CPC Code**

G03B-021/00; G06F-003/01/7; G06F-003/01; G06F-003/03/04; G06F-003/042

- **Publication Information**

KR20120113906

A 2012-10-16 [KR20120113906]

- **Priority Details**

2011KR-0031589 2011-04-06

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- **Fampat family**

KR20120113906 A 2012-10-16 [KR20120113906]

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- **Abstract:**

A multi touch interaction system with a multi touch display for an irregular surface and a method thereof are provided to display images on the irregular surface and supply interaction the displayed images and participators by extending a circular display of a Microsoft Surface. CONSTITUTION: A structure (120) of an irregular surface implements rear side image projection. An infrared LED alignment panel (130) evenly emits infrared light to the whole of a rear side of the structure. A projector (180) projects an image to the whole of the rear side of the structure. An infrared camera (140) catches reflection information of the infrared light when an object or a human body contacts a front side of the structure. A computer obtains location information by using the reflection information.

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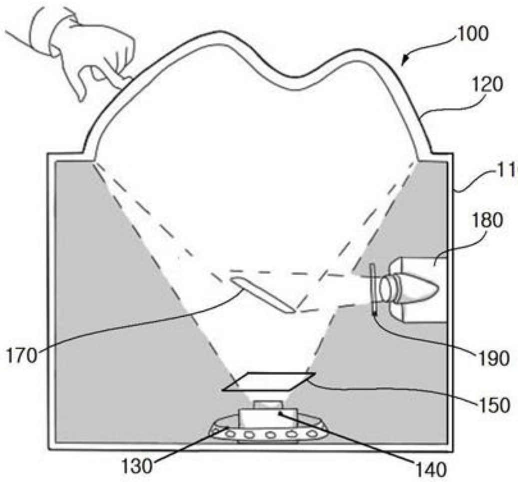

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Methods and systems for enabling creation of augmented reality content

<table>
<tr>
<td>

• Patent Assignee

LAYAR

• Inventor

HOFMANN KLAUS MICHAEL

VAN DER KLEIN RAIMO JAHANI

VAN DER LINGEN RONALD

VAN DE ZANDSCHULP KLASIEN

• International Patent Classification

G06F-003/0481 G06F-003/0484 G06T-011/60 G06T-013/80 G06T-019/00

• US Patent Classification

PCLO=715852000

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<td>

• CPC Code

G06F-003/0481/5; G06F-003/0484/2; G06T-011/60; G06T-013/80 G06T-019/00/6;

• Publication Information

WO2013023705

A1 2013-02-21 [WO201323705]

• Priority Details

2011WO-EP64251 2011-08-18

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• Fampat family

WO2013023705 A1 2013-02-21 [WO201323705]

US2015040074 A1 2015-02-05 [US20150040074]

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<td>

• Abstract:

Methods and systems for enabling creation of augmented reality content on a user device including a digital imaging part, a display, a user input part and an augmented reality client, wherein said augmented reality client is configured to provide an augmented reality view on the display of the user device using an live image data stream from the digital imaging part are disclosed. User input is received from the user input part to augment a target object that is at least partially seen on the display while in the augmented reality view. A graphical user interface is rendered to the display part of the user device, said graphical user interface

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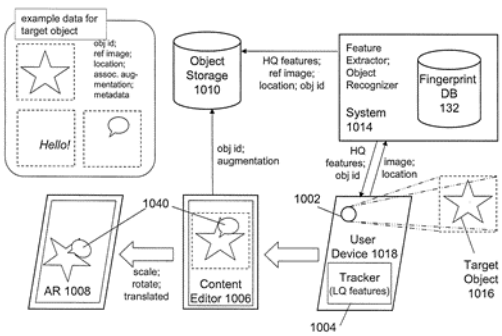

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enabling a user to author augmented reality content for the two-dimensional image.	

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H2020_ICT201_SPARK_688417

Computer-vision based augmented reality system

- **Patent Assignee**

LAYAR

- **Inventor**

HOFMANN KLAUS MICHAEL

VAN DER LINGEN RONALD

- **International Patent Classification**

G06F-003/048 G06F-003/0481 G06K-009/00 G06T-019/00

- **US Patent Classification**

PCLO=345419000

- **CPC Code**

G06F-003/03/04; G06F-003/0346; G06F-003/0481/5; G06F-2203/04802; G06K-009/00/208; G06K-009/00/973; G06T-007/00/42; G06T-007/20/33; G06T-019/00/6; G06T-2200/24; G06T-2207/30244 G06T-2207/30244; G06T-2219/024 G06T-2219/024;

- **Publication Information**

WO2013023706

A1 2013-02-21 [WO201323706]

- **Priority Details**

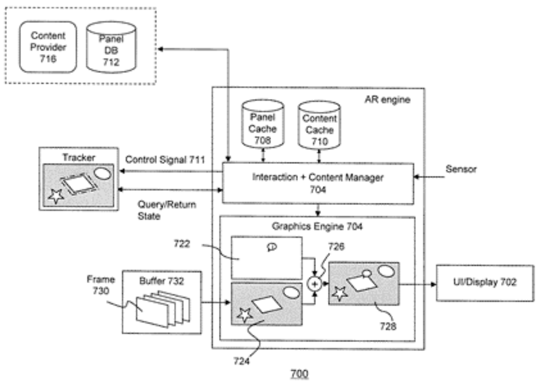
2011WO-EP64252 2011-08-18

- **Fampat family**

WO2013023706	A1	2013-02-21	[WO201323706]
EP2745236	A1	2014-06-25	[EP2745236]
US2015070347	A1	2015-03-12	[US20150070347]

- **Abstract:**

Methods for providing a graphical user interface through an augmented reality service provisioning system. A panel is used as a template to enable content providers to provide configurations for a customizable graphical user interface. The graphical user interface is displayable in perspective with objects in augmented reality through the use of computer vision techniques. (From US2015070347 A1)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Feedback to user for indicating augmentability of an image

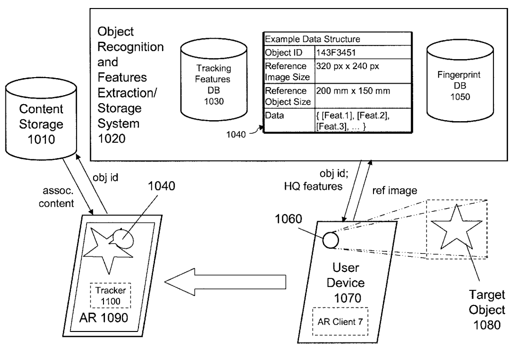
• **Patent Assignee** LAYAR • **Inventor** HOFMANN KLAUS MICHAEL NEDOVIC VLADIMIR • **International Patent Classification** G06T-007/00 G06T-019/00 • **US Patent Classification** PCLO=345633000	• **CPC Code** G06T-007/00/02; G06T-019/00/6; G06T-2200/24; G06T-2207/10004; G06T-2207/30168 • **Publication Information** WO2013044983 A1 2013-04-04 [WO201344983] • **Priority Details** 2011WO-EP67138 2011-09-30

• **Fampat family**

WO2013044983	A1	2013-04-04	[WO201344983]
EP2748795	A1	2014-07-02	[EP2748795]
US2015109337	A1	2015-04-23	[US20150109337]

• **Abstract:**

Methods and systems for determining augmentability information associated with an image frame captured by a digital imaging part of a user device. The determined augmentability score may then be used in the generation of feedback to the user. For example, a graphical user interface may be generated and rendered having a substantially continuous visual output corresponding to the augmentability information.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Device and method for user interaction

- **Patent Assignee**

ELECTRONICS & TELECOMMUNICATIONS RESEARCH INSTITUTE KOREA ELECTRONICS TELECOMM

- **Inventor**

LEE JOO HAENG

KIM HYUN

KIM HYOUNG SUN

- **International Patent Classification**

G06F-003/01 G09G-005/00 H04M-001/02 H04N-005/262 H04N-005/74 H04N-009/31

- **US Patent Classification**

PCLO=345156000

- **CPC Code**

G06F-003/01/7; H04M-001/02/64; H04M-001/02/72; H04N-009/31/73; H04N-009/31/85; H04N-009/31/94

- **Publication Information**

US2013162521

A1 2013-06-27 [US20130162521]

- **Priority Details**

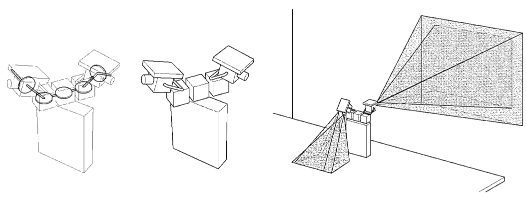
2011KR-0140299 2011-12-22

- **Fampat family**

US2013162521	A1	2013-06-27	[US20130162521]
KR20130072748	A	2013-07-02	[KR20130072748]
US9225950	B2	2015-12-29	[US9225950]

- **Abstract:**

Disclosed are a device for user interaction with a combined projector and camera and a method and a device for user interaction for recognizing an actual object to augment relevant information on a surface or a periphery of the actual object. The device for user interaction, includes: at least one projector-camera pair in which a projector and a camera are paired; a motor mounted in the projector-camera pair and configured to control a location and a direction of the projector-camera pair; and a body including a computer capable of including a wireless network and configured to provide



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

connection with an external device, and a projection space and a photographing space of the projector-camera pair overlap each other.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Apparatus and method for creating spatial augmented reality content

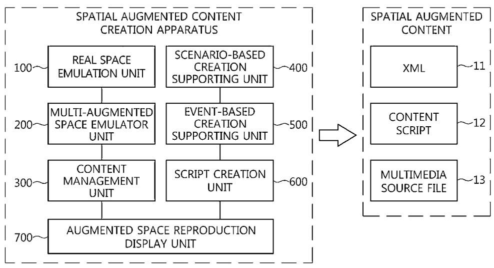
• Patent Assignee ELECTRONICS & TELECOMMUNICATIONS RESEARCH INSTITUTE KOREA ELECTRONICS TELECOMM **• Inventor** LEE JUN-SUP LEE SU-WOONG YOUN JIN-YOUNG LIM SUK-HYUN LEE GIL-HAENG **• International Patent Classification** G06T-017/00 G06T-019/00 H04N-005/262 H04N-021/80 **• US Patent Classification** PCLO=345633000	**• CPC Code** G06T-019/00/6; G06T-019/20; G06T-2219/2016 **• Publication Information** US2014002498 A1 2014-01-02 [US20140002498] **• Priority Details** 2012KR-0069363 2012-06-27

• Fampat family

US2014002498	A1	2014-01-02	[US20140002498]
KR20140001532	A	2014-01-07	[KR20140001532]

• Abstract:

Disclosed herein is an apparatus and method for creating **spatial augmented reality** content, which enable interaction with a user. In the method, a stationary object in a real space in which a user is located is defined, and then a virtual space is generated. A dynamic object in the real space is defined, and the dynamic object is converted into a primitive object. The primitive object is arranged in the virtual space and then spatial augmented content is created. A multimedia object is paired with the primitive object, and then a virtual space object is generated. Interaction



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

between the virtual space object and a gesture of the user is defined in a format of event script. The virtual space object and the interaction are packaged in the spatial augmented content and packaged results are provided to the user.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Methods and systems for enabling the creation of augmented reality content

- **Patent Assignee**

LAYAR

- **Inventor**

HOFMANN KLAUS MICHAEL

VAN DER KLEIN RAIMO JUHANI

VAN DER LINGEN RONALD

VAN DE ZANDSCHULP KLASIEN

- **International Patent Classification**

G06T-019/00

- **CPC Code**

G06T-019/00/6

- **Publication Information**

EP2560145

A2 2013-02-20 [EP2560145]

- **Priority Details**

2011EP-0064251 2011-08-18

2012EP-0180799 2012-08-17

- **Fampat family**

EP2560145 A2 2013-02-20 [EP2560145]

- **Abstract:**

(EP2560145)

Methods and systems for enabling creation of augmented reality content on a user device including a digital imaging part, a display, a user input part and an augmented reality client, wherein said augmented reality client is configured to provide an augmented reality view on the display of the user device using an live image data stream from the digital imaging part are disclosed. User input is received from the user input part to augment a target object that is at least partially seen on the display while in the augmented reality view. A graphical user interface is rendered to the display part of the user device, said graphical user interface enabling a user to author augmented reality content for the two-dimensional image. (see diagram)

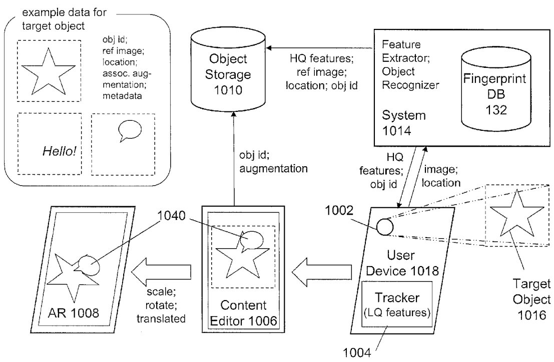


FIG. 1

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

H2020_ICT201_SPARK_688417

Systems And Methods For Projecting Images Onto An Object

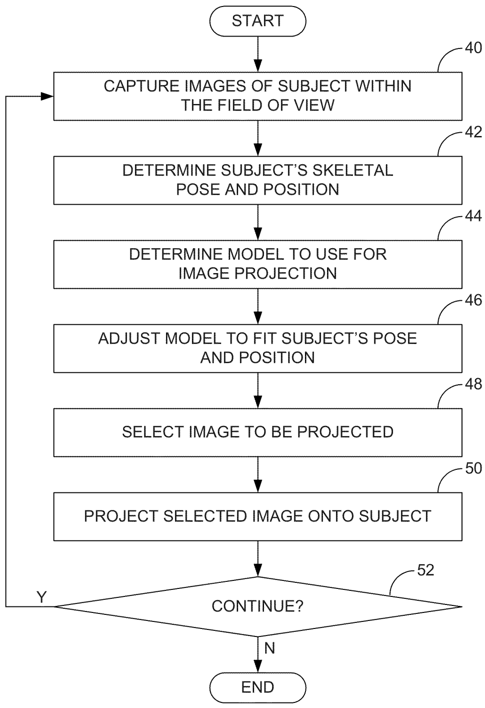
• **Patent Assignee**	• **CPC Code**
UNIVERSITY OF SOUTH FLORIDA	G06T-019/00/6 G09B-019/00/3;
• **Inventor**	• **Publication Information**
SUN YU	US2013069940
JOHNSON ADRIAN S	A1 2013-03-21 [US20130069940]
• **International Patent Classification**	• **Priority Details**
G06T-017/00	2011US-61537311 2011-09-21
• **US Patent Classification**	2012US-13624371 2012-09-21
PCLO=345419000	

• **Fampat family**

US2013069940 A1 2013-03-21 [US20130069940]

• **Abstract:**

In one embodiment, a method for projecting images on a subject includes determining a pose and position of the subject, adjusting a three-dimensional model of an anatomical structure of the subject to match the determined pose and position, and projecting an image of the anatomical structure onto the subject in registration with the actual anatomical structure of the subject to illustrate the location of the structure on or within the subject.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Method of and system for projecting digital information on a real object in a real environment

- **Patent Assignee**

METAIO

- **Inventor**

MEIER PETER

BENHIMANE SELIM

KURZ DANIEL

- **International Patent Classification**

H04N-005/225 H04N-005/33 H04N-009/31 H04N-013/00 H04N-013/02

- **US Patent Classification**

PCLO=345007000

- **CPC Code**

G01B-011/24; G01B-011/25; H04N-005/225/6; H04N-005/33/2; H04N-009/31/85; H04N-009/31/91; H04N-009/31/94 H04N-009/31/94; H04N-013/00/22; H04N-013/00/37; H04N-013/02/57; H04N-2013/0081 H04N-2013/0081;

- **Publication Information**

WO2014101955

A1 2014-07-03 [WO2014101955]

- **Priority Details**

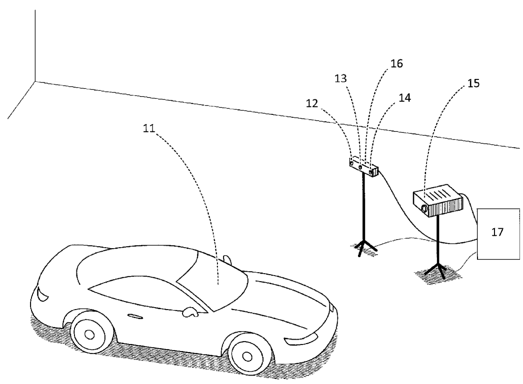
2012WO-EP77060 2012-12-28

- **Fampat family**

WO2014101955	A1	2014-07-03	[WO2014101955]
EP2939423	A1	2015-11-04	[EP2939423]
CN105027562	A	2015-11-04	[CN105027562]
US2015350618	A1	2015-12-03	[US20150350618]

- **Abstract:**

A method of projecting digital information on a real object in a real environment includes the steps of projecting digital information on a real object or part of a real object with a visible light projector, capturing at least one image of the real object with the projected digital information using a camera, providing a depth sensor registered with the camera, the depth sensor capturing depth data of the real object or part of the real object, and calculating a spatial transformation between the visible light projector and the



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

H2020_ICT201_SPARK_688417

real object based on the at least one image and the depth data. The invention is also concerned with a corresponding system.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Barcode visualization in augmented reality

- **Patent Assignee**

LAYAR

- **Inventor**

SAMARA ANATOLIY

HOFMANN KLAUS MICHAEL

GROTEN DIRK

- **International Patent Classification**

G06K-017/00 G06T-011/00

- **US Patent Classification**

PCLO=345633000

- **CPC Code**

G06K-017/00/16; G06T-011/00

- **Publication Information**

EP2772885

A2 2014-09-03 [EP2772885]

- **Priority Details**

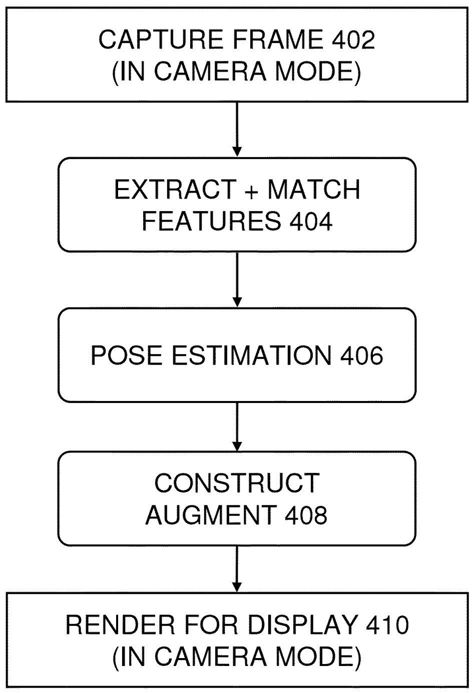
2013US-13781845 2013-03-01

- **Fampat family**

EP2772885	A2	2014-09-03	[EP2772885]
US2014247278	A1	2014-09-04	[US20140247278]
EP2772885	A3	2015-05-06	[EP2772885]

- **Abstract:**

Disclosed herein is an improved method for providing content associated with barcodes in augmented reality in addition or in combination with providing content associated with target objects in augmented reality. The improved method advantageously provides a augmented reality client that a user may use to view the respective content associated with barcodes and target objects while in camera view to improve usability. Advantageously, the user is not unexpectedly taken out of camera view to view the content associated with the barcode and the user experience provided is consistent between barcodes and target objects. Furthermore, the improved method integrates barcodes and a visualization of



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

the barcode within augmented reality, without disrupting the real-time augmented reality experience.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Distance based modelling and manipulation methods for augmented reality systems using ultrasonic gloves

- **Patent Assignee**

UNIVERSITY OF SOUTH AUSTRALIA

- **Inventor**

HOANG THUONG N

THOMAS BRUCE HUNTER

- **International Patent Classification**

G06F-003/01

- **US Patent Classification**

PCLO=345156000

- **CPC Code**

G06F-003/01/4; G06F-003/01/7; G06F-003/0481/5

- **Publication Information**

US2014125577

A1 2014-05-08 [US20140125577]

- **Priority Details**

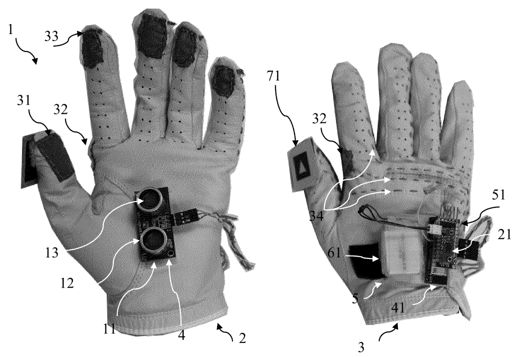
2012AU-0904867 2012-11-05

- **Fampat family**

US2014125577 A1 2014-05-08 [US20140125577]

- **Abstract:**

User input gloves and input methods are described that are well suited to provide input to computer modeling (eg CAD) and **augmented reality** (AR) systems, including wearable AR and spatial AR. Each glove comprises palm mounted ultrasonic transducers, accelerometers, finger based pinch inputs and a wireless communication module. The gloves can be used to measure distances over the natural range of distances that hands can be placed, as well as their orientation, with sufficient resolution to facilitate a range of gesture based input methods to be developed and utilized, including distance-based modeling by measurement. Further the gloves are light weight, allow fast input of modeling measurements, are easy to use, and reduce fatigue compared to existing glove based input systems. The user input gloves, and associated input techniques can be used to measure small and body sized objects using one or two hands,



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

and large objects can be measured using single handed measurements. Further models for both small and large objects can be generated and manipulated through the use of a numeric input technique to obtain an amplification factor to magnify the effective distances measured.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Spatial Augmented Reality (SAR) Application Development System

- **Patent Assignee**

UNIVERSITY OF SOUTH AUSTRALIA

- **Inventor**

MARNER MICHAEL ROBERT

BROECKER MARKUS MATTHIAS

CLOSE BENJAMIN SIMON

THOMAS BRUCE HUNTER

- **International Patent Classification**

G06F-003/01 G06T-015/00 G06T-015/08 G06T-015/10 G06T-019/00 G06T-019/20 H04N-009/31

- **US Patent Classification**

PCLO=345419000

- **CPC Code**

- G06F-003/01/1; G06T-015/08; G06T-015/10; G06T-019/00/6; G06T-019/20; G06T-2215/16; G06T-2219/012; G06T-2219/2008; G06T-2219/2016; H04N-009/31/47

- **Publication Information**

WO2014032089

A1 2014-03-06 [WO201432089]

- **Priority Details**

2012AU-0903729 2012-08-28

2013AU-0308384 2013-08-27

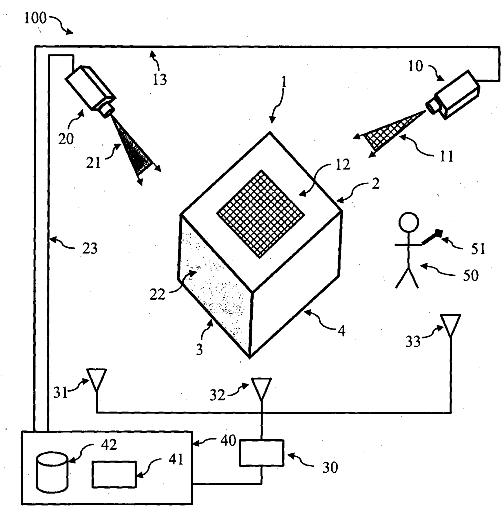
2013WO-AU00952 2013-08-27

- **Fampat family**

WO2014032089	A1	2014-03-06	[WO201432089]
AU2013308384	A1	2015-03-26	[AU2013308384]
US2015262426	A1	2015-09-17	[US20150262426]

- **Abstract:**

A **Spatial Augmented Reality** (**SAR**) system is described. The **SAR** system includes a **SAR** device, such as a computer, and a **SAR** platform such as a set of projectors and object tracking systems that are used for producing a **SAR** environment. The **SAR** device can include a loader for receiving and executing one or more **SAR** application modules and a **SAR** engine for receiving the input data and for interfacing between the **SAR** application modules and the output. The architecture of the **SAR** engine provides a **SAR** environment independent interface between the **SAR** application modules and the projectors and object trackers. The **SAR** engine is responsible for providing perspectively correct projected



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

images in the **SAR** environment and performing coordinate transformations, and providing updates to application modules, as well as automating many common tasks.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Method and Apparatus for Calibration of Multiple Projector Systems

- **Patent Assignee**

UNIVERSITY OF SOUTH AUSTRALIA

- **Inventor**

SMITH ROSS TRAVERS

WEBBER GUY

SUGIMOTO MAKI

MARNER MICHAEL ROBERT

THOMAS BRUCE HUNTER

- **International Patent Classification**

G01B-011/14 G03B-021/14 G06F-003/01

- **US Patent Classification**

PCLO=356614000 PCLX=353094000 PCLX=353121000

- **CPC Code**

A63F-013/00; G01B-011/14; G03B-021/14; H04N-009/31/47; H04N-009/31/94

- **Publication Information**

US2014226167

A1 2014-08-14 [US20140226167]

- **Priority Details**

2013AU-0900409 2013-02-08

2014AU-0200683 2014-02-07

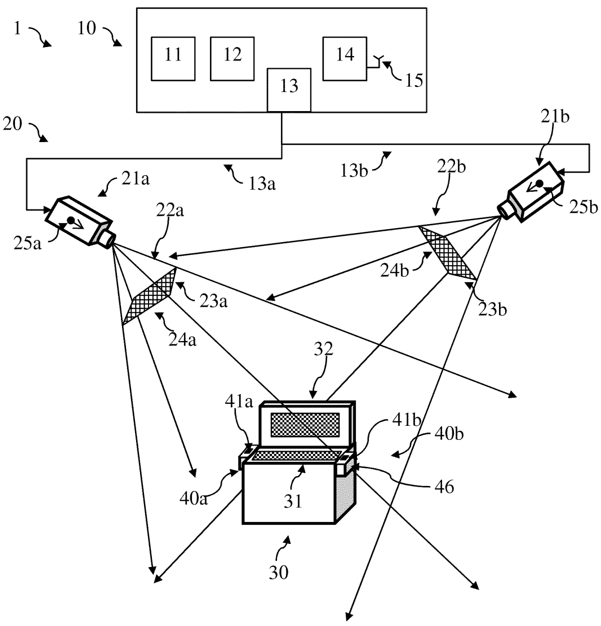
- **Fampat family**

US2014226167	A1	2014-08-14	[US20140226167]
AU2014200683	A1	2014-08-28	[AU2014200683]

- **Abstract:**

(US20140226167)

Disclosed is a method for improving the calibration of multiple projector systems in **Spatial Augmented Reality** systems where multiple projectors are used to project images directly onto objects of interest. The methods and system described herein improve the calibration of multiple projector systems in order to improve the alignment and clarity of projected images by reducing ghosting that can occur with poorly aligned projectors. The system uses a planar photodiode and the projector is used to project a plurality of projection regions, such as scan lines, across the planar photodetector and calculating the position based on weighting measurements by the



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

measured light intensity and projected images in **SAR**.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Augmented reality system for projecting an image onto the environment

<table>
<tr><td>

• Patent Assignee

IMCOM YAZILIM ELEKTRONIK SANAYI STI

• Inventor

KUCUK MERT

• International Patent Classification

G06T-015/06 G06T-019/00 H04N-009/31

</td><td>

• CPC Code

H04N-009/31/85; H04N-009/31/94

• Publication Information

WO2015016798

A2 2015-02-05 [WO201516798]

• Priority Details

2013TR-0092289 2013-07-31

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• Fampat family

WO2015016798 A2 2015-02-05 [WO201516798]

WO2015016798 A3 2015-04-02 [WO201516798]

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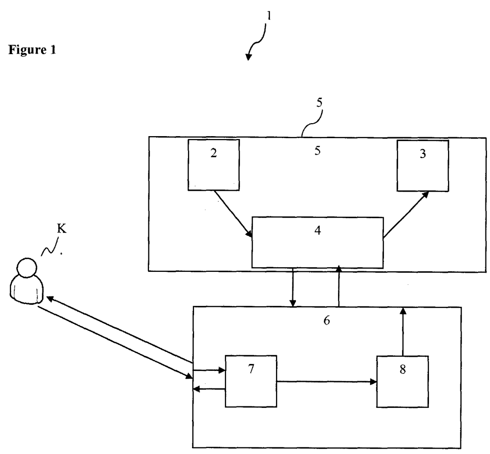
<tr><td>

• Abstract:

This invention is related to a system (1), wherein a depth sensor (2) and a projector (3) are used, which, in general terms, enables an augmented reality application to be provided and, particularly, a **spatial augmented reality** application to be provided. The system (1) of the invention consists of a depth sensor (2), a projector (3), a data interchange unit (4), a stabilizing structure (5), a computer (6), a control platform (7) and a projective overlay platform (8).

</td><td>

Figure 1



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</table>

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

A medical training simulation system and method

- **Patent Assignee**

UNIVERSITY OF SOUTH AUSTRALIA

- **Inventor**

THOMAS BRUCE HUNTER

MARNER MICHAEL ROBERT

SMITH ROSS TRAVERS

WALKER ALEXANDER WILLIAM

WOZNIAK MICHAL

MENON NIRMAL KUMAR

- **International Patent Classification**

G06T-015/00 G09B-023/28

- **CPC Code**

G09B-005/06/7; G09B-023/28; G09B-023/30

- **Publication Information**

WO2015027286

A1 2015-03-05 [WO201527286]

- **Priority Details**

2013AU-0903338 2013-09-02

- **Fampat family**

WO2015027286 A1 2015-03-05 [WO201527286]

- **Abstract:**

A medical training simulation system using a Human Patient Simulation Manikin is described. To increase realism a computational system comprising a computer and a projector (e.g. a basic **spatial augmented reality** (**SAR**) system, is used to project images onto the manikin to simulate a medical condition. The computational system may be also be a sophisticated **SAR** system with multiple projectors and object tracking systems. The projected images can be used to simulate a range of patient body types (age, sex, ethnicity, etc) as well as a range of symptoms, including time varying symptoms. A range of manikins of different sizes can also be provided or formed using a range of materials, and projection can be internal or external. Internal subsystems

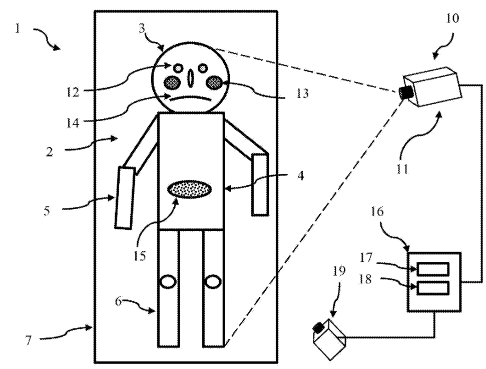

Figure 1

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

such as speaker systems to replicate internal symptoms can also be included. Additional training information and play back facilities can also be provided to assist with learning outcomes.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.688417.
H2020_ICT201_SPARK_688417

Methods, systems, and computer readable media for improved illumination of spatial augmented reality objects

- **Patent Assignee**

UNIVERSITY OF NORTH CAROLINA

- **Inventor**

FUCHS HENRY

WELCH GREGORY

- **International Patent Classification**

G03B-021/12 G03B-021/60

- **CPC Code**

G03B-021/20/53; G03B-021/60/2; H04N-005/58; H04N-005/74; H04N-009/31/82 H04N-009/31/94;

- **Publication Information**

[WO2015070258](WO2015070258)

A1 2015-05-14 [WO201570258]

- **Priority Details**

2013US-61902588 2013-11-11

- **Fampat family**

WO2015070258 A1 2015-05-14 [WO201570258]

- **Abstract:**

A system for illuminating a **spatial augmented reality** object includes an augmented reality object including a projection surface having a plurality of apertures formed through the projection surface. The system further includes a lenslets layer including a plurality of lenslets and conforming to curved regions of the of the projection surface for directing light through the apertures. The system further includes a camera for measuring ambient illumination in an environment of the projection surface. The system further includes a projected image illumination adjustment module for adjusting illumination of a captured video image. The system further includes a projector for projecting the illumination adjusted captured video image onto the projection surface via the lenslets layer and the apertures.

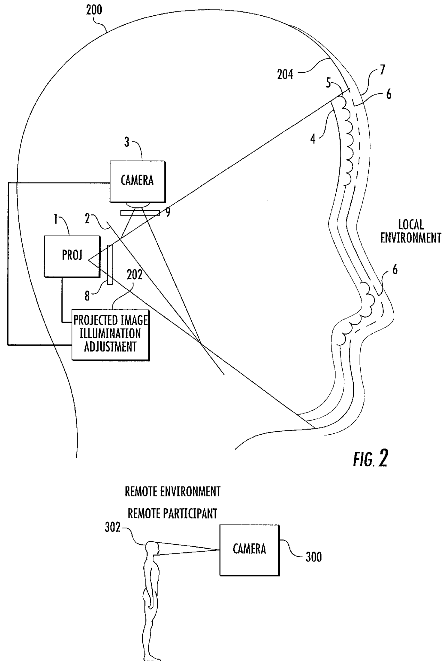

FIG. 2

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