D6.2 Annex I

Training scenario and Evaluation Plan for Engineering

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Wearable Experience for Knowledge Intensive Training
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D6.2 Training Scenario and Evaluation Plan for Engineering

WP 6 | D6.2

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Executive summary

Engineering domain, particularly when focusing on the healthcare applications, is a very complex environment where knowledge and experience transfer mechanisms involve a large amount of variables, actors and processes difficult to standardize.

Within the WEKIT project, EBIT – Industrial partner in the engineering domain – has the responsibility to identify some scenarios and examples of use cases to demonstrate how the learning processes may be improved by using the WEKIT methodology, in terms of effectiveness, time reduction and user perception.

1. Use Case Introduction

EBIT is the Esaote's Healthcare IT Company dedicated to research, development, manufacturing and commercialization of Radiology and Cardiology RIS (*Radiology Information System*) – CVIS (*Cardio-Vascular Information System*) – PACS (*Picture Archiving and Communication System*) Diagnostic Imaging Software Solutions.

Italian market leader and among the main players in Europe and worldwide, EBIT has developed a mature knowledge in implementing seamless enterprise wide RIS CVIS PACS territorial networks.

Thanks to a deep knowledge of clinical workflows, in WEKIT project EBIT has the task to identify some possible engineering use cases related to the Healthcare domain.

As mentioned in [1], the medical domain is a domain in which complex learning occurs. It involves understanding heterogeneous physiological systems, developing adaptive expertise and acquiring the collaborative skills required in multidisciplinary medical practice. It involves mastery of competencies that enable the individual to effectively perform occupational activities to the standards expected in the professional environment. This requires ample opportunity to practice and the ability to experience all possible variations in contexts and circumstances in order to reach the expert level. Healthcare learning scenarios provide a big variety of use cases as well of different end-users that could benefit from the learning experience. Here are examples of end-users are:

- Health care professionals (doctors, physicians, nurses, clinical engineers, etc.)
- Patients
- Equipment manufacturer technicians
- Medical students

Since training in this real-life context is not always possible for reasons of safety, costs, or didactics, alternative ways are needed to achieve clinical excellence.

Educational technology and more specifically augmented reality (AR) has the potential to offer a highly realistic situated learning experience supportive of complex medical learning and experience transfer. Fundamental idea of real-world object enrichment with 3D holograms activates deeper understanding of learning subject.

AR is a technology that adds virtual content to the physical real world, thereby augmenting the perception of reality.

AR is promising for facilitating meaningful learning and experience transfer; furthermore it may offer organizational advantages because:

- the physical training environment may be very similar to, if not the same, as the professional work environment
- the augmented (virtual) part may visualize the invisible and simulate relevant 3D [7], tactile and other aspects of the real world task
- the AR learning environment may provide the necessary variations in the training task including collaboration which supports authentic learning
- the real time interactive nature of AR provides immediate learner feedback which supports taking control over the learning process
- AR learning environments do not always require an expert or instructor to observe trainee performance

- AR learning environments can provide situated just-in-time and just-in-place learning.

On the other hand, one of the biggest challenges when trying to apply AR and wearable sensors to learning in healthcare domain is the difficulty to specify a model from the real environment and to define precise and repeatable procedures, because the conditions are complex and each situation is potentially very different.

During the first part of the project, EBIT has been collecting requirements (for WP1 and WP6) and describing its scenarios in order to produce at least a complete use case to be tested in the first iteration (see Annex 1 and 2). The applications of interest can be divided into 2 macro-families:

- Learning in surgical and interventional procedures, included minimal invasive surgery, and nursing procedures;

- Support in transferring knowledge from an expert professional to an apprentice in clinical practice.

The second pool of scenarios is surely more ambitious since less standards are available, but at the same time a successful application of AR could revolutionize the way of clinical teaching and learning.

For the reasons just mentioned, to test the WEKIT prototype, an example of clinical training process is proposed, where novel doctors are trained in analyzing patients' conditions combining different data sources with the purpose to get the correct diagnosis.

A flexible training environment is proposed, where trainees can engage with and edit information linked to patient data including various types of medical imagery. A flexible interface will allow the trainee/doctor at a particular section/points of the image to highlight supplementary information and add voice recordings, transcripts as speech bubbles, or any other visual cues, visible only when selected. Similar medical cases may be linked and can be found via keywords.

The training can use existing archive data, which can be constantly expanded and updated. Since with archival data, confirmed diagnosis will be available, the training can use that to assess whether the doctor in training diagnoses correctly and identifies conditions.

For the training, it is suggested the use of a patient manikin that can be enriched with additional imagery data, providing vision into the body, where otherwise imagination has to replace sensory information. Moreover, the manikin can simulate patient reaction, where appropriate, creating a more lifelike experience for the training. In comparison to special purpose hardware simulators, such a manikin with AR software overlay should be cheaper than the very pricy hardware manikins.

2. Use Case Description

In the following, a detailed description of trainer's experience, trainee's experience and training process evaluation methodology is presented.

By way of example, the pulmonary embolism (PE) disease has been chosen as a specific clinical use and a protocol for achieving a correct diagnosis is presented by steps. The presented WEKIT training approach, anyway, can be generalised and applied also to the analysis of different diseases and pathologies.

According to[3], a PE diagnosis process can be summarized in steps by the following diagrams.

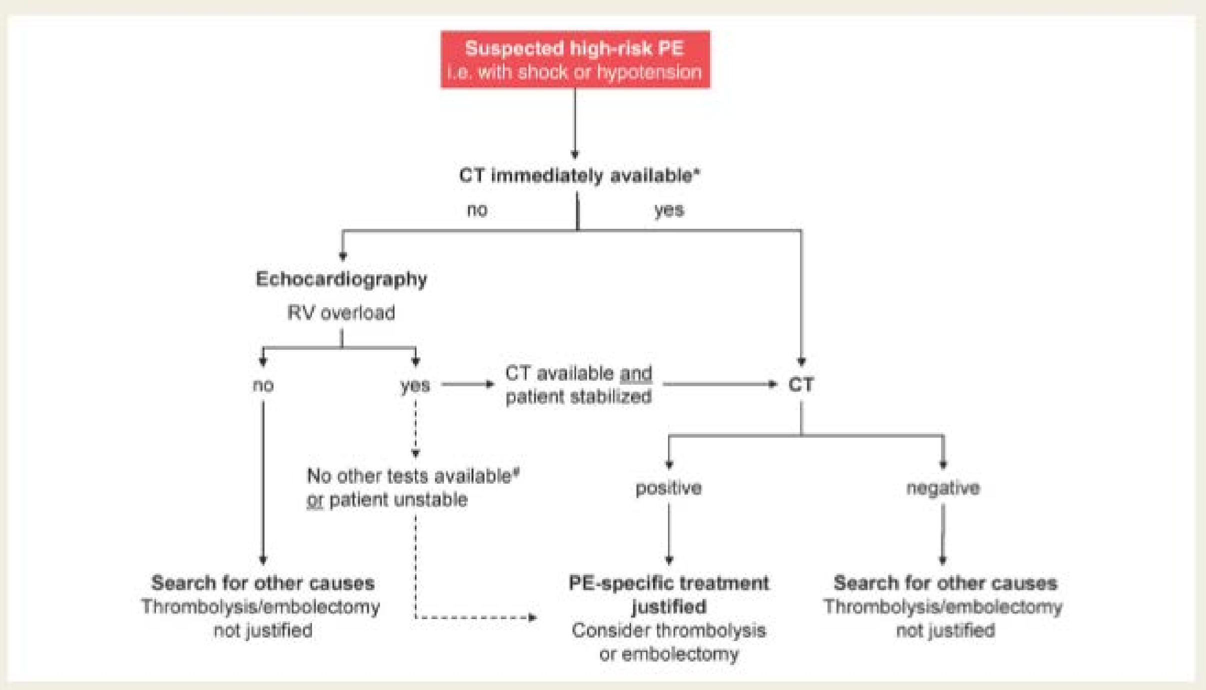

Figure 1. Proposed diagnostic algorithm for patients with suspected high-risk PE, i.e. presenting with shock or hypotension. *CT is considered not immediately available also if the critical condition of a patient allows only bedside diagnostic tests. #Transoesophageal echocardiography may detect thrombi in the pulmonary arteries in a significant proportion of patients with RV (Right Ventricle) overload and PE that is ultimately confirmed by spiral CT; confirmation of DVT (Deep Vein Thrombosis) with bedside CUS (Compression Venous Ultrasonography) might also help in decision-making

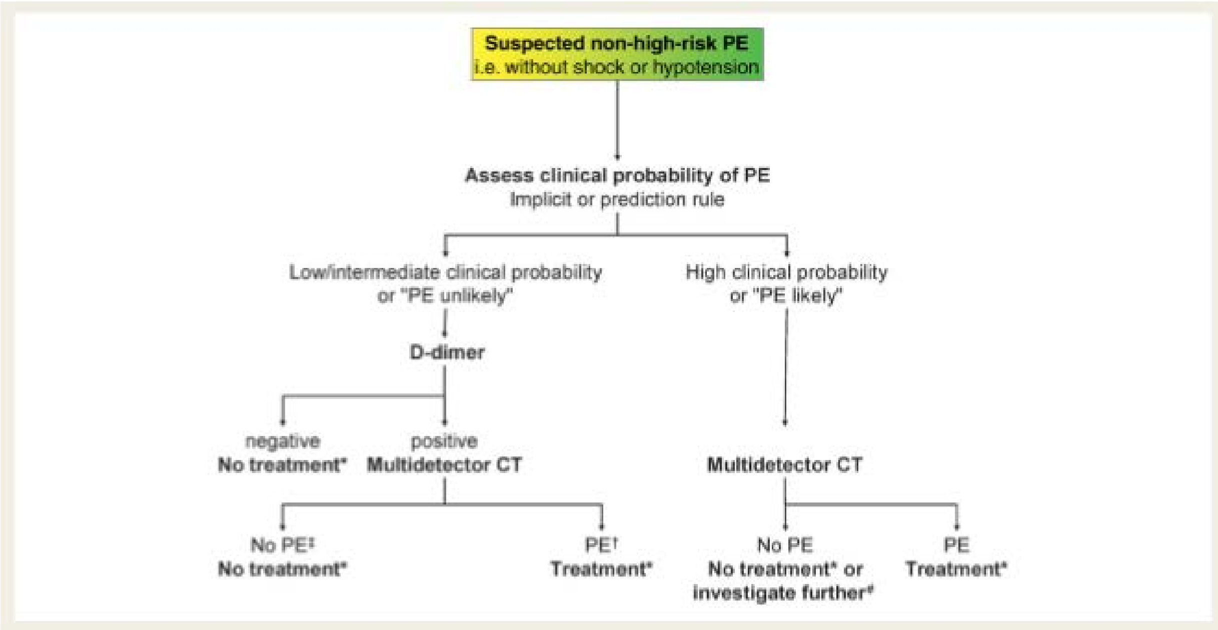

Figure 2. Proposed diagnostic algorithm for patients with suspected non-high-risk PE, i.e. without shock and hypotension.

Capturing Expert Experience:

- Preparation:

1. Deciding the clinical case to analyse. As mentioned before, in the present document the specific case of pulmonary embolism is being analysed [3].
2. Configuring and setting SimMan 3G patient simulator [1] according to the specific clinical characteristic of a patient suffering from the disease under analysis. In case of pulmonary embolism, typical symptoms are: shortness of breath, chest pain particularly upon breathing in, coughing up blood (hemoptysis). Optionally red, warm, swollen, and painful leg may be present.
3. Collecting all the relevant data from the available data sources (results of laboratory analysis, radiological images, anamnestic data, risk factors data, clinical history of the patient, such as previous diseases or interventions)
4. Wearing AR sensors, such as:
    - Microphone and Point of view camera, to record the actions
    - AR glasses
    - Others

- Procedure – the steps that take to PE diagnosis are provided as a practical example , but other pathologies may be explored.

  All the steps described in the following are registered into the WEKIT system.

1. The expert doctor checks the patient (i.e. SimMan) and his physical symptoms:
    - Hemoptysis
    - Heart frequency

- Clinical signs of present DVT (Deep Vein Thrombosis)

Figure 3. Aspect of a patient affected by DVT disease.

He can register by *voice* the results of the check-up. The results may also be translated in a *textual annotation* (flags, numerical values…)

2. The expert doctor queries and retrieves from the clinical database the patient's anamnestic information. This information can furtherly be visualized in any moment also by the trainer by AR glasses as textual information. Examples of anamnestic data are:
    - Previous DVT or PE
    - Recent chirurgical intervention or immobilization
    - Cancer
    - Ongoing Therapy

   The expert doctor can also access to the system database to retrieve previous clinical data or similar clinical data , such as:
    - List of available exams
    - List of reports
    - The doctor can recall the available data by *speech* or *gesture commands* and view them as a textual annotation through the glasses (*virtual post-its*)
3. The expert doctor records his own clinical opinion about the probability of other diseases than PE and assigns a score to indicate the clinical probability (for instance, according to the Wells score [3], reported in the table below)

Wells score[65]

Variable	Points
Predisposing factors	
Previous DVT or PE	+1.5
Recent surgery or immobilization	+1.5
Cancer	+1
Symptoms	
Haemoptysis	+1
Clinical signs	
Heart rate	
>100 beats/min	+1.5
Clinical signs of DVT	+3
Clinical judgement	
Alternative diagnosis less likely than PE	+3
Clinical probability (3 levels)	**Total**
Low	0–1
Intermediate	2–6
High	≥7
Clinical probability (2 levels)	
PE unlikely	0–4
PE likely	>4

Figure 4. Clinical Prediction rules for PE: the Wells score .

4. According to the clinical probability decided at the step before, the expert queries the system to display medical images, such as angio-CT scan or echocardiography. An example of 3D reconstructed volume rendering visualization from CT scan is displayed in the following figure. Such images can be overlaid to the patient (i.e. SimMan) through AR glasses.

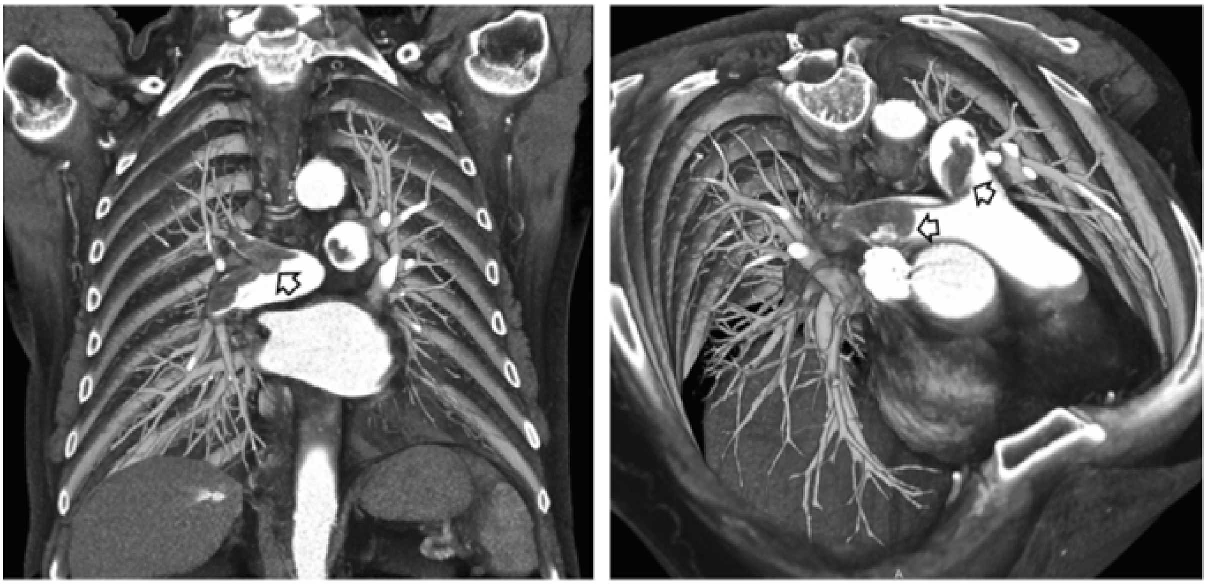

Figure 5. Contrast Material-enhanced 16-detector CT yielded coronal volume renderings in anterocranial and anterior perspective, which allow intuitive visualization of the location and extent of embolus (see arrows) [4].

Figure 6. . 2D CT slice that shows a pulmonary embolus within the posterobasal segment of the right lower lobe artery (arrow). [5].

The type of image visualization (rotation, zoom, MIP/MPR/VR[1] reconstruction) can be chosen by the doctor by a *combination of gestures* (swipe, rotate, hold, zoom in/out) and *voice commands* (load images, close image window, discard images…)

The trainer can register the best display protocol and add *annotations* on the image (such as arrows, circles, etc.) that can be used in the training session to guide the trainee

The trainer can leave *audio comments* on all stages of his performance to integrate different tasks with annotations, which then trainee can activate when needed

[1] MultiPlanar Reconstruction / Maximum Intensity Projection, Volume Rendering. Such 3D reconstructions are produced from the original volume of CT slices

Optionally a previous exam or a similar exam, available in the scientific archive, can be *recalled via keywords*- and a compared visualization can be proposed in order to enhance the possible differences.

5. Optionally, other clinical indexes can be retrieved from the clinical database and displayed.
6. The expert doctor dictates his conclusions by means of a diagnosis code.

Trainee wears Expert Experience

- Preparation:

1. Wearing AR sensors, such as:
   - Head camera and microphone, to record the actions
   - AR glasses
   - Others

- Procedure .

1. The trainee checks the patient (i.e. manikin) and his physical symptoms. The manikin shows:
   - Shortness of breath
   - Chest pain
   - Unilateral lower limb pain

   The trainee has to check:
   - Hemoptysis
   - Heart frequency

   The trainee can:
   - get a *haptic hint feedback* (vibration) from the wristband when he manage to find the pulse
   - annotate by *voice recording* the results of the check-up and decide how to proceed. A message that suggests to consult anamnestic information and previous data can be shown by AR glasses
   - leave *written comments* on all stages of the checking procedure and compare them later with the trainer's conclusion

   The trainee has to try alone to ask and check the correct information. After a short period or through a voice command, a list of suggestions can be displayed on AR glasses.

2. A list of the anamnestic and clinical information displayed by expert doctor is provided to trainee, by audio message or written list. That includes also the evidence of the previous cases that the trainer decided to display from the list of all the available ones. The trainee can call and visualize the related information.

   If the trainer wrote annotations they are displayed to the trainer.

   Also in this case the expert experience will be provided after a period of time if the actions of the trainee do not coincide with the trainer's one, or on trainee's request.

3. The trainee doctor gives his own clinical opinion about the probability of other diseases than PE and try to assign a score to indicate the clinical probability.
   - He can re-play the trainer's remarks to have a suggestion or to compare the conclusions

4. According to the clinical probability decided at the step before, the trainee queries the system to display the medical images suggested by the system. Such images can be overlaid to the patient (i.e. manikin) through AR glasses.

   The types of visualization (rotation, zoom, MIP/MPR/VR2 reconstruction) chosen by the expert as well as the previous images to compare and the action to do to enhance the displayed content can be proposed to the trainee by means of:

   - basic augmentation (symbols, arrows, etc)
   - audio suggestions
   - short videos
   - trainer's annotations

5. If the trainer retrieved and displayed other clinical information, a textual or audio suggestion will inform the trainee.
6. In the end of the session the trainee can activate the menu with a written and visual information about the certain medical condition and explore correct characteristics of chosen disease/ medical aberration
7. The trainee doctor performs his diagnosis by means of a code and a level of gravity and compare it with the trainer's one.

In any moment the trainee can interact with the procedure by means of *voice commands*.

Another feature that could be useful is the tracking and monitoring of the physical state of the trainee by the trainer, in order to evaluate the trainee's level of confidence.

Experience Analysis

The analysis will be performed evaluating the normal execution of the procedure (with the physical support of the trainer) versus the execution of the procedure using WEKIT prototype and approach. In particular, two factors will be taken into account:

- Execution Time (total duration of the procedure, duration of each steps, etc.)
- Amount of the mistakes made during the training
- Speed in getting the correct conclusion

It will be also possible to prepare two different case data sets to analyse, so that:

1. The first set will be object of a training session completely guided by expert experience;
2. The second set will be used to evaluate the progress and the autonomy of the trainee.

Besides, the WEKIT prototype will be evaluated according to the feedback coming from users' interviews and questionnaires. The following aspects will be taken into account:

- Wearability & comfort
- Customizable settings
- User Experience
- Interaction & Usability

[2] MultiPlanar Reconstruction / Maximum Intensity Projection, Volume Rendering. Such 3D reconstructions are produced from the original volume of CT slices

3. References

[1] C. Kamphuis, E. Barsom, M. Schijven, N. Christoph, "**Augmented reality in medical education**", Perspect Med Educ Special Issue, 3:300-11, 2014

[2] http://www.laerdal.com/gb/doc/86/SimMan

[3] The Task Force For the Diagnosis and Management of Acute Pulmonary Embolism of the European Society of Cardiology (ESC), **"Guidelines on the diagnosis and management of acute pulmonary embolism"**, European Heart Journal, **29**: 2276-2315, 2008

[4] U.J. Schoepf, P. Costello, "**CT Angiography for Diagnosis of Pulmonary Embolism: State of the Art**", Radiology 2004 Journal, **230**:329-337, RSNA, 2004

[5] C. Wittram, M. M. Maher, A. J. Yoo, M. K. Kalra, J. O. Shepard, T. C. McLoud, "**CT Angiography of Pulmonary Embolism: Diagnostic Criteria and Causes of Misdiagnosis**", RadioGraphics 2004: 24-1219-1238, RSNA, 2004

4. Annexes

4.1. Annex 1 – Requirements Laundering

Bazar ID	Title	Rationale (from bazaar)	Description	Pilot cases	Notes
3	Use Case: Experience Recording	Active AR in authoring mode is used in a "show and tell" way to extract key steps from existing documentation. User generated content can be used to convert existing technical documentation into augmented documentation.	Capturing requirements: video and audio recording, motion capturing, discipline for the expert (e.g. order of talking and task performance should be standardised, maybe additional moderator needed, manual post processing may be required to cut into steps	EBIT 1 - Training to Physician	may apply to many pilot cases
36	ExplorAr	The main focus of this idea is the collaboration of people that have a certain goal in learning. With a leap motion detector and virtual glasses people can browse between multiple objects that they can inspect. The selected object from the catalog is projected on the table in 3d and via hand detection can be rotated, transformed and exploded into parts that can be examined separately from the group members. From separating in components and examining them individually the group members can change and try different options for the building they are examining. The application can be used mainly in architecture and civil engineering!	Visualization of 3D models on of the human body or part of it and navigation using gesture	EBIT 1 - Training to Physician	nice to have?
36	ExplorAr	The main focus of this idea is the collaboration of people that have a certain goal in learning. With a leap motion detector and virtual glasses people	Visualization of 3D models on of the human body or part of it and navigation using gesture	EBIT 2 - Support to patient for	nice to have?

		can browse between multiple objects that they can inspect. The selected object from the catalog is projected on the table in 3d and via hand detection can be rotated, transformed and exploded into parts that can be examined separately from the group members. From separating in components and examining them individually the group members can change and try different options for the building they are examining. The application can be used mainly in architecture and civil engineering!		understading the images and pathology	
37-38	Assesment and Experience Recording		Record the experience and give on screen sensors feedback	EBIT 1 - Training to Physician	
37-38	Assesment and Experience Recording		Record the experience and give on screen sensors feedback	EBIT 2 - Support to patient for understading the images and pathology	
39	Health learning and health awareness	Combining imaging, wearable sensors, and biometrics to sensitise patients and health professionals to AR-based ways to better understand and communicate the status and anticipated evolution of particular medical conditions, for example, visualizing x-ray or MRI data in situ on the body, using an interactive mirror, helps people understand conditions in a better way. This might help to influence wellbeing, using direct biofeedback to understand and modify own behavior. Likewise for physical therapy for rehabilitation, patient	Probably it would be just a nice to have. See #36	EBIT 2 - Support to patient for understading the images and pathology	

		self-help, Yoga Trainer, etc. all involve the same principles: understand better what's happening inside of you and use it to your advantage.			
44	Training support for radiologist/cardiologist	AS a RADIOLOGIST/CARDIOLOGIST Practioneers and Medical Student I need to have support during my training phase in image based reporting being driven in comparison with 3D body organ model as well with use case found and compared in radiology education digital library. TOOLS: I imagine that using VR techniques, I am guided in the real case image processing analysis and report being projected over my scene the following: a) The 3D body organ model that I'm reporting; b) A relation ship with similar use case that it could be found in the radiology education digital library on the same pathology as well. WHY: To get fast and proper information that help me during learning phase with advanced and automated procedure. CONCERN: Not really on the technology	It can be useful in the re-enactment part	EBIT 1 - Training to Physician	to be better defined how this could be used in training

45	Training support for radiologist/cardiologist (2)	AS a RADIOLOGIST/CARDIOLOGIST Practioneers and Medical Student I need to have support during my training phase in image based reporting having a personalized learning experience. I need to have a guided procedure overimposed on a real scene that both help me in learning and using the proper tool of the reporting application as well compared with my standard protocol used. TOOLS: Using VR techniques, I am guided in the real case image processing analysis with a VR training expert guiding me in selecting the proper tools and protocol looking at the image based on pathology, acquisition techniques and so on. WHY: to get fast and proper information that help me during learning phase with advanced and automated procedure. CONCERN: Not really on the technology	To be understood what kind of re-enactment or training is needed	EBIT 1 - Training to Physician	to be better defined how this could be used in training
46	Image comprehension for patient	AS a Patient When the physician and GP provides me with a CD and an image reporting study I would like to be able to view at the images and report, being guided in the comprehension of the 3D reconstruction and structured reporting that has been applied. TOOLS: I imagine that using VR techniques, I am guided looking at my structured report being projected over my scene the following also: a) a comparison model with not affected organ showing the “process” to my pathology; b) The way in which the VR therapy may help projecting the evolution expected on my image study (that means the next image study I will expect as a result of the therapy).		EBIT 2 - Support to patient for understading the images and pathology	How does it fit the the 3 steps scenarios of learning?

		WHY: To be more engaged and empowered as a patient in understanding an image structured report as well in understanding the way the therapy help and what should I expect.			
47	user feedback for developer	AS a developer of image reporting application during my design phase of a touch screen GUI interface, I need to get feedback on the way the user interact with my application when compared with expected correct use. TOOLS: Having sensor and/or device that collect and get information on the way the user "interact " with my application. WHY: In order to produce an application GUI that could be more effective		EBIT 2 - Support to patient for understading the images and pathology	How does it fit the the 3 steps scenarios of learning?

4.2. Annex 2 – Scenario Definition

The present clinical health use case is designed to provide doctors in training as well as medical students with the opportunity to receive data about the patient and the patient's condition in the most effective and efficient way.

Using Augmented Reality this application displays a variety of medical imagery combined with patient data (medical history, use of medication, etc.) as an overlay on a patient manakin. Doctors can perceive this imagery, as it is superimposed on the body and they are able to switch between methods of scans and data easily. CT scans, Ultrasound, Echocardiography, MRI, 3D imagery, and other medical imagery can be represented at any given time.

The AR interface can provide seamless navigation between various data sets, allowing doctors to focus their efforts on effective decision-making. For training we are proposing an effective method that allows a large amount of imagery to be combined and presented within a patient information-rich context.

Figure 7. WEKIT Medical use case

Training Context:

When training people to understand medical imagery, it is difficult to identify one particular method for training. What is known is that looking at a large amount of image use cases (imagery which describes and explains the medical condition) can enhance our understanding and ability to identify that medical condition. We propose a flexible training environment, where trainees can engage with and edit information linked to patient data including various types of medical imagery. A flexible interface would allow the trainee/doctor at a particular section/points of the image to highlight supplementary information and add voice recordings, transcripts as speech bubbles, or any other visual cues, visible only when selected. Similar medical cases would be linked and can be found via keywords.

The training could use existing archive data, which can be constantly expanded and updated. Since with archival data, confirmed diagnosis will be available, the training can use that to assess whether the doctor in training diagnoses correctly and identifies conditions. Reflection and validated assessment tools can be provided in electronic form to provide independent measures of diagnostic performance.

The patient manakin can be enriched this way with additional imagery data, providing vision into the body, where otherwise imagination has to replace sensory information. Moreover, the manakin can simulate patient reaction, where appropriate, creating a more life like experience for the training. In comparison to special purpose hardware simulators, such a manakin with AR software overlay should be cheaper than the very pricy hardware manakins.

An additional option to this training method could be live expert guidance. This would allow trainees to receive additional information and add their own notes to the existing content. This could include visual and haptic guides for conducting specific procedures (in the style of, for an ultrasound, ‘start measuring the head-size here and measure up to there, where the head ends’).

Eye tracking technology could be an optional sensor source for the training: expert eye-movement could be represented on the display or even, if possible, differences between trainee fixation points and saccades and the expert eye-movement could be highlighted (this could be post analysis or in real time during training action).

Users: Trainees, long-term vision that doctors would use this too.

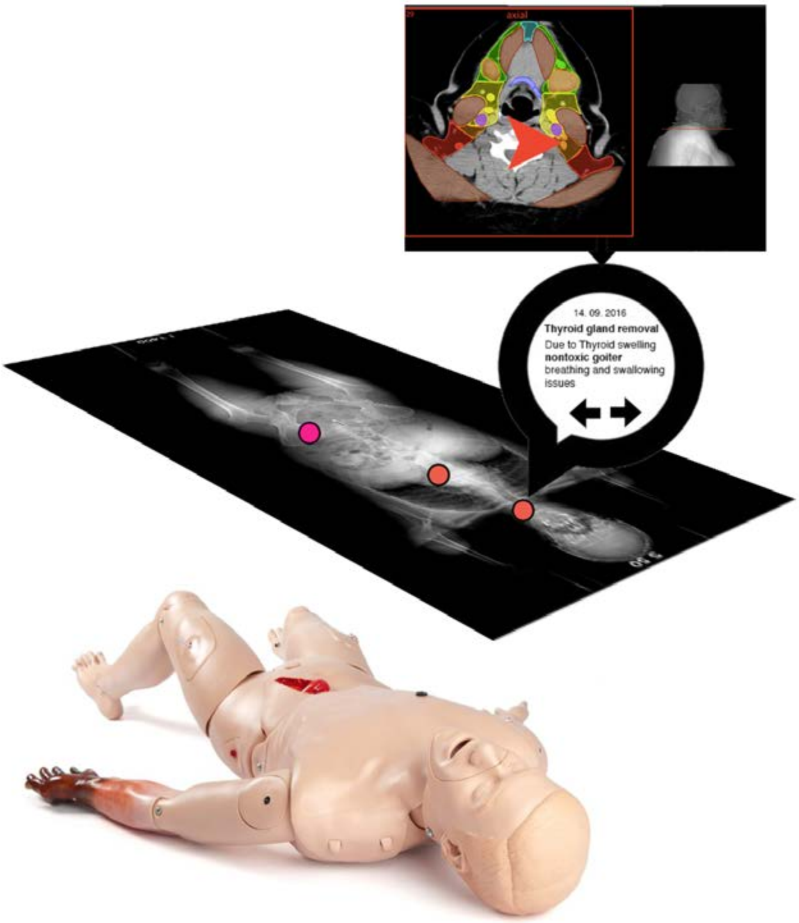

Figure 8. WEKIT Medical use case – concept illustration

Wearable Experience for Knowledge Intensive Training
Project No 687669

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