Supporting Training of Expertise with Wearable Technologies

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Supporting Training of Expertise with Wearable Technologies: The WEKIT Reference Framework

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Abstract. In this chapter, we present a conceptual reference framework for designing augmented reality applications for supporting training. The framework leverages the capabilities of modern augmented reality and wearable technology for capturing the expert's performance in order to train expertise. It has been designed in the context of WEKIT project which intends to deliver a novel technological platform for industrial training. The framework identifies the state-of-art augmented reality training methods which we term as "transfer mechanism" from an extensive literature review. Transfer mechanisms exploit the educational affordances of augmented reality and wearable technology to capture the expert performance and train the novice. The framework itself is based upon Merrienboer's 4CID model which is suitable for training complex skills. The 4CID model encapsulates major elements of apprenticeship models which is a primary method of training in industries. The framework itself complements the 4CID model with expert performance data captured with help of wearable technology which is then, exploited in the model to provide a novel training approach for efficiently and effectively master the skills required. In this chapter, we will give a brief overview of our current progress in developing this framework.

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1   Introduction

"In 2016, keeping the skills of your workforce up to date in this fast-changing world will be more important than ever. Harnessing this peer to peer learning can be an efficient and cost effective way of increasing skills, and the knowledge transferred is likely to be relevant because it is delivered by people who understand your organization's culture." (Matassa & Morreale, 2016)

In a 2016 PwC global survey of more than 1,000 CEOs from all major industries, 61 percent of global chief executives and 78 percent of U.S. respondents said that they were somewhat or very concerned about the speed of technological change in their industry. This creates a challenge for the companies to keep the work force up to date with the new knowledge and skills that are ever increasing. Additionally, the experienced employee retires or leaves the company taking along the vast experience that he/she has accumulated overtime. They are then replaced by the new inexperienced employee who needs to be trained, which requires time and investment.

WEKIT[1] (http://wekit.eu/) which stands for: (Wearable Experience for Knowledge Intensive Training), is a European project supported under Horizon 2020 to develop and test within three years a novel way of industrial training enabled by smart Wearable Technology. In WEKIT, thirteen partners representing academia and industry from six countries in Europe are striving actively to meet the highest degree of standards in the delivery. WEKIT is making significant progress towards meeting the demands of industries by exploring and implementing the best of pedagogical and technological opportunities.

The framework identifies two-fold approaches to address the above mentioned industrial issue. 1.) To capture the expert's performance by means of Wearable Technology (WT) and sensors 2.) To foster efficient training with the help of expert's performance data using Augmented Reality (AR) and WT. Capturing expert's performance should take into consideration what methodologies may be used to capture certain aspects of the expert in a meaningful manner such that they are useful and shareable to the new trainees. Using AR and WT, the trainees can "wear" the expert's performance and track the differences between their own performance and that of an expert. Therefore, the framework posits great potential for efficient training of skills with the help of captured expert's performance to provide new novel approaches to technology assisted apprenticeship.

2   Concept space: supporting training of expertise with wearable technologies

Expertise may be defined as the knowledge and skills behind an expert performance. In Ericsson & Smith (1991), expert performance is defined as consistently superior performance on a specified set of representative tasks for the domain that can be administered to any subject. Representative tasks are structured and managed drills where essential attributes of expert performance naturally occur because of which the consistency of the performance can be replicated and measured. In Ericsson (2006), representative tasks are suggested as an appropriate methodology to correctly evaluate an expert performance under standardized conditions in a controlled setting, such as a laboratory. Also, representative tasks engage the same set of knowledge and skills that are

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[1] Wearable Experience for Knowledge Intensive Training: Project No 687669

used in real world tasks within a domain ensuring that the expert performance is accurately captured. When the expert performance can be reliably reproduced in a test situation such as the representative task, this performance can then be analyzed to assess its mediating acquisition mechanisms.

The basic underlying of attaining expertise is to collect experience. However, the notion of expertise based on the length of experience in a domain (over ten years), which assumed that the novice progressed orderly to an expert under instruction, training and experience (Hoffman, 2014), has been observed to be only partially true. The length of experience has been frequently found to be a weak correlate of job performance beyond the first two years (McDaniel, Schmidt, & Hunter, 1988). Most novices make large gains at the beginning but fail to push further. Only individuals that indulge in deliberate practice achieve the superior expertise (Ericsson, 2006). The notion of deliberate practice dictates that simply executing the skill repeatedly does not account for improved performance. In order to develop expertise, the executions of skills should be aimed at improvement of that particular skill by collecting new experience in every execution.

In Ericsson (2006), Ericson stressed the importance of a mentor for deliberate practice, stating that the apprentice does not engage in deliberate practice spontaneously. An expert mentor would design practice sessions that improve the apprentice's performance gradually which complies with the definition of deliberate practice. By doing so, the mentor "shares" his experience to the apprentice in an explicit manner, ensuring that the apprentice achieves the desired level of performance efficiently. For example, Schulz & Curnow (1988) found that throughout the history of the Olympic Games, the best performance for all events has improved—in some cases by more than 50%. This is because the expert's knowledge and skills have been organized in such a way that facilitates efficient attainment of the expertise (Ericsson, 2006).

In conclusion, an expert is indispensable to the proper efficient training of the trainee. Therefore, the framework, taking the importance of expert into consideration, adapts two-fold approach of: (1). Capturing the expert performance (2). Supporting training with the help of expert performance.

3   Background

Experience may be defined as the knowledge gained through involvement in or exposure to an event. In vocational trainings, the expert "shares his experience" by demonstrating and mentoring the trainee through hands-on experience rather than from written manuals or textbooks. However, Wagner & Sternberg (1990) stated that experience may be shared by sharing the environment in which the expert performed the task. Sharing environment involved sharing not only the workplace but also sharing the environmental stimulus perceived by the expert (Sternberg, 2000). Therefore, in order to share the experience, the expert must not only demonstrate his performance and mentor the trainee but should also be able to share the environmental stimulus. AR and WT have the huge potential to capture and support the re-enactment of the expert's performance and the environment in which he/she performs. The framework leverages on this potential of the technology to envision new training approaches by sharing experience of the expert to the trainee. In the following, we provide review of AR & WT training approaches based on the frameworks two-fold approach.

3.1   Capture of Expert Performance

Numerous studies have presented the potential of sensor-based technology and WT (Schneider, Börner, van Rosmalen, & Specht, 2015) for learning. Similarly, Bower & Sturman (2015) also did a review on affordances of WT and observed that the WT posit new possibilities for supporting trainings. Sensor-based technologies and WT measure the expert's interaction with the physical environment in which he/she demonstrates, enabling the capture of the expert performance. The framework uses the approach defined by Collins (1991) who emphasized two important kinds of performance capture: 1.) Capturing of the expert performance and 2.) Capturing of the process in the world. Capturing of the expert performance includes making the cognitive process of the expert explicit to the apprentice while capturing the process involves making invisible aspects of the task visible. Such an approach would incorporate capturing the physical environment, the expert's interaction with it and the cognitive processes, capturing the essence of a complete process.

However, experts are scarce and becoming an expert is a difficult and time-consuming endeavor. In addition to the shortage of experts in many domains, some expert struggles when it comes to teaching. In Feldon (2007), Feldon stated that an expert is unable to explain his/her superior performance because the amount of expertise inhibits his/her explanation skills. This is because an expert typically has more knowledge than he/she can verbalize (Patterson, Pierce, Bell, & Klein, 2010), which impedes the capability of the expert as a teacher. In addition, an expert is unaware of the factors behind his/her superior performance. For example, an expert is able to notice features and meaningful patterns of information without conscious effort that are not noticed by an ap-

prentice. Due to this, an expert tends to underestimate how difficult it can be for the apprentice (Hinds, 1999), and thus omits the information an apprentice would find valuable (Hinds, Patterson, & Pfeffer, 2001). Therefore, capturing expert performance at the right level of abstraction, while still retaining all relevant details is complex, even from the technological point of view (Fominykh, Wild, & Alvarez, 2015).

Conventional approaches, such as video recording, provide only limited points of view, significantly reducing the wealth of information available from direct experience. In contrary, WT provides a rich multimodal and multisensory medium for the capturing the expert performance as also a multi-perspective opportunity for training. For example, Kim, Aleven, & Dey, (2014) explored different physiological sensors and WT such as eye tracking, EEG sensors and heart rate concluding a strong possibility to use the physiological sensors to be able to record cognitive process. Many recent projects (see (Kowalewski et al., 2016),(Zhao et al., 2016)) have used WT to explicitly capture expert's performance based on physical attributes such as motor movements to provide guidance and feedback to the trainee using AR. AR complements WT by providing a rich multimodal and multisensory medium for the apprentice to wear the expert performance and collect rich experience from the perspective of the expert. In the following, we elaborate on AR as a suitable platform to train expertise with use of expert's performance data.

3.2   Training of Expertise by Expert Performance

In Bacca et al. (2014), a review on affordances of AR, it was suggested that AR along with sensors posit a rich versatile educational potential for training skills. In addition, several studies suggest that technical skills acquired in virtual simulators transfer well into real world and improve performance in areas such as laparoscopic surgery (Haug, Rozenblit, & Buchenrieder, 2014) and anesthesia (Naik et al., 2001). Although the idea to use AR and WT for Training dates back to the early 1990's (Caudell & Mizell, 1992), only a handful of projects have made it successfully into industry. With the technology, still new and major works such as STARMATE & ARVIKA (Friedrich, 2002) focusing on technical aspects, the educational potential of the AR and WT remains unexplored. Now, The WEKIT reference framework aims to exploit the affordances of AR and WT for supporting the pedagogic training approaches to extract the educational potential of the technology.

Zhou, Dun, & Billinghurst (2008) defined the implementation of AR in terms of three main characteristics: (1) The combination of physical and virtual elements (2) interactive in real time and (3) are registered in three dimensional spaces. For the AR to truly fulfill these requirements it must be equipped with sensors and WT to measure and analyze the data from physical environment. Therefore, AR and WT have the potential to create a truly immersive platform which places the trainee in real world context engaging all of his/her senses. Bjork & Holopainen (2004) stated that an immersive environment creates perceptual and cognitive immersion by stimulating the sensory organs directly with relevant stimuli and cognitive content. Therefore, AR and WT have the potential to amplify perceptual stimuli based on the captured expert performance to enhance the trainee perceptions which will allow the apprentice to create new experience similar to the expert's experience.

4   The WEKIT Reference Framework

Most industrial tasks are complex real world problems which are ill structured and require more than an algorithmic approach to be solved. Learning such complex task requires complex learning. Sarfo & Elen (2006) have emphasized the close relation between complex learning and deliberate practice. In order to practice deliberately, the apprentice needs to indulge in extremely targeted practice where new goals are met and learning path is constantly monitored and adapted (Ericsson et al., 1993). This concept is in close alignment with the principles of 4C/ID model (Neelen & Kirschner, 2016). Sarfo & Elen (2006) in their results indicated that the 4C/ID model promoted the development of technical expertise. Therefore, we built the framework upon the 4C/ID model based training methodology by using the captured expert performance to supplement the model, with the help of AR and WT to guide and provide feedback to the trainee. The training will be done in an authentic context with help of AR and WT while supporting the trainee with feedback and scaffolding.

The 4C/ID model is a holistic design model which deals with complex task, without losing sight of the separate elements and the interconnections between them (Van Merriënboer, Clark, & Croock, 2002). It is a non-linear and systematic processing model for designing complex learning environment. Melo & Miranda (2014) investigated the effects of 4C/ID in teaching and concluded it to be effective for acquisition and transfer of knowledge. 4C/ID model consists of four components namely: 1). Learning task 2). Supportive information 3). Procedural information and 4). Part task practice.

1. **Learning Task**: Learning Tasks are authentic, whole task experiences that are provided to the trainee in order to promote schema construction for non-recurrent aspects of the task. It also supports rule automation by compilation for recurrent aspects of the task. Instructional methods primarily adapt induction that emphasizes the importance of task modeling through mindful abstraction from the concrete experiences. Task modeling is the construction of cognitive schemata of the task by the trainee. For example, by first demonstrating examples of how a particular concept is used, the expert allows the trainee to come up with the correct solution using the cognitive schemata that he/she created while observing the expert performance.
2. **Supportive information:** Supportive information is the information provided to support the learning and performance of non-recurrent aspects of learning tasks. Instructional methods for supportive information aim to elaborate the task model by establishing non-arbitrary relationships between new elements and what learners already know.
3. **Just in Time information:** Just in time information is the prerequisite information to the learning and performance of recurrent aspects of learning tasks in a just in time fashion. Instructional methods primarily aim to embed procedural information in rules such as the condition action pairs.
4. **Part-task Practice:** The last component of the 4CID model is the part task practice which recognizes that some parts of the task are automatic and recurrent. In order to develop the automation of the skill it is required that the learner practice the task repeatedly. Part-task Practice items are provided to learners in order to promote rule automation for selected recurrent aspects of the whole complex skill.

The 4C/ID model is acknowledged as an effective instructional design model for designing powerful training environments that facilitate the acquisition of integrated sets of knowledge and skills (Sarfo & Elen, 2006). Evidence about the effectiveness of training environments designed in line with specifications of the 4C/ID model for the acquisition of expertise in training contexts has been documented by Van Merriënboer & Paas (2003) and Merrill (2006). This framework aims to guide the design and development of training applications based on 4C/ID model and the expert in order to train expertise.

After an extensive review of different prototypes designed for training which were identified from the literature from major databases such as SpringerLink, ScienceDirect and SAGE, we identified and extracted instructional methods used by them. We use the term "Transfer Mechanisms" to describe the instructional strategies or methods that exploit AR and WT technology for training purposes. However, only those methods that support or embellish the expert-trainee relationships in a technological platform have been selected. After analyzing the Transfer mechanisms, we have further defined the transfer mechanisms to have 3 general characteristics which are portrayed in Table 1. Each transfer mechanism possesses attributes that answer questions such as what is the type of skill being trained. The other characteristics include requirements for recording such as hardware and software and requirements for enacting by the apprentice which may include

Table 1. Descriptors

Transfer Mechanism
Attributes How can the features be described? What skills are being addressed?
Requirements for recording How is the mechanism enabled during the recording? What types of sensors are required?
Requirements for enactment How is this feature enabled by/for the learner? Which conditions need to be me to allow this feature to be present? Which interaction means does the learner have? What type of sensor/display technology does the learner require?

Table-2 below provides the list of the transfer mechanisms that were identified from the review of studies that exploited AR for training of expertise. We have selected studies performed after 2010 to date to understand the state-of-art in AR and WT based expertise training.

Table 2. List of Transfer Mechanisms

Transfer Mechanism	Attribute	Requirements for recording	Requirements for enacting
Augmented paths	• Augmenting virtual information atop the physical world in a way which allows the trainee to guide his motion with precision	• Tracking of expert's hand motion • Motion sensors • Depth camera	• Visualizing guidance paths using AR • Provide haptic or visual feedback • Comparison to expert data by capturing apprentice movement with sensor
Augmented Mirror	• Augmented display where the apprentice can track his/her body similar to dance rooms	• Record and track body postures • Posture sensor such as Kinect	• Large display where the apprentice can see himself/herself • Posture tracker to provide visual feedback
Highlight Object of Interest	• Highlight physical objects in the focus area indicating to the trainee that the expert found that object of interest	• Eye Tracker • Video recording • Record Gaze behavior of the expert	• Eye Tracker for Formative feedback • AR display to highlight the image
Directed focus	• visual aids for objects outside the visual area	• Eye Tracker and video recording • Record Gaze behavior of the expert • Record the procedure	• Eye Tracker for Formative feedback • AR display • Visual Indicator
Point of view video	• Stream/save video data • Provides unique trainee/expert point of view scope	• Head mounted camera • Interaction Mechanism to initiate, stop recording and Zoom into subject	• Interaction and inference mechanism • Zoom into video
Audio Instructions	• Stream/save audio • Capture of peripheral sound from the environment	• Think aloud protocol to record expert explanations • Microphones • Reduce unnecessary noise	• Audio headphones • Interaction and inference mechanism • Amplify the sound
Cues & clues	• Cues and clues are pivots that trigger solution search	• Take a picture save video & audio or text • Use a physical object in real world as anchor	• Display on demand • Inference mechanism

Annotations	• Allow a physical object to be tagged with virtual information	• Methods to tag media into physical object. • Manual annotation or done by expert on the fly	• AR display mechanism to read the annotations • Mechanism for unobtrusive relay of information
Object Enrichment	• Provide information about the physical artifact	• Use a physical object in real world as anchor • Tags or infrared light emitters and camera	• Object recognition • Control over information displayed • Camera with image recognizer
Contextual information	• Provide information about the process that is frequently changing	• Knowledge of procedure information that depends on the context and required for the task	• Method to know when and where to provide the information
3D models and animation	• Assist in Spatial ability • Complex mental simulation of a phenomena	• Modeling 3d object • Creating 3d animation • Defining Interaction Mechanism	• AR display • Interaction mechanism such as gestures •
Interactive Virtual Objects	• Manipulate to practice on virtually objects with physical interactions	• Realistic 3d objects • Sensors for motion recording	• Haptic and visual feedback • Detecting collision between physical and virtual entity
Haptic feedback	• Force feedback relating to the perception and manipulation of objects	• Fine motor tracking • Defining of criteria for errorless operation • Inertial sensors	• Tracking the trainee motion with inertial sensor • Motors for providing haptic feedback
Xray vision	• Visualizing the internal process or mechanism not visible to the eye.	• Simulation of the Phenomena • Interaction Mechanism	• Visualization of the phenomena • Interaction mechanisms • Object recognition
Feedback	• Provide summative and formative feedback	• Mechanism to infer mistakes in process based on expert data • Mechanism to assess the overall performance	• Measure of performance • Mechanism to evaluate the overall performance

With an aim to support the design and development of the AR and WT based platforms to integrate the 4C/ID model for training, the framework classifies the Transfer Mechanism according to the 4 components of the 4C/ID model. The first component Learning task encapsulates the notion of task modeling along with other attributes such as task scaffolding. Task modeling entails methods for scheme construction by the trainee about the task being performed. Table 3 maps the transfer mechanism that support learning task against the performance attributes they aim to train.

Table 3. Transfer Mechanisms that support Learning task component

Learning Task	Performance attributes				Literature
Transfer mechanism	Fine motor Skills	Cognitive motor skills	Collaborative skills	Perceptual motor Skills	1. Juanes, Gómez, Peguero, & Ruisoto (2015)
Augmented path	1,2,12,18				2. Hahn, Ludwig, & Wolff (2015)
Augmented Mirror	14	3,25			3. Meleiro, Rodrigues, Jacob, & Marques (2014)
Interactive Virtual Objects	15	4,16	5,13,17		4. Ke, Lee, & Xu (2016)
Highlight Object of Interest		2,22		6	5. Lok et al. (2014)
Directed focus		7,33		8	6. Roads et. al 2016
Point of view Videos	20	10,11	17,20	9	7. Jarodzka, Van Gog, Dorr, Scheiter, & Gerjets (2013)

8. Henderson & Feiner (2011)
9. Milazzo, Farrow, & Fournier (2016)
10. Djajadiningrat, (2016)
11. Gallegos-Nieto, Medellín-Castillo, González-Badillo, Lim, & Ritchie (2017)
12. Haug et al. (2014)
13. Nilsson, Johansson, Jönsson, Orn Johansson, & Onsson (2011)
14. Chia & Saakes (2014)
15. Jang, Kim, Woo, & Wakefield (2014)
16. Radu, Doherty, DiQuollo, McCarthy, & Tiu (2015)
17. Datcu, Cidota, Lukosch, Oliveira, & Wolff (2014)
18. Rozenblit et al., (2010)
19. Chang, Kang, Chang, & Liu (2015)
20. Chinthammit et al. (2014)
21. Bordegoni et al. (2014)
22. Sand, Büttner, Paelke, & Röcker (2016)

Table 4 depicts all the transfer mechanisms that have been identified in order to provide supportive information. Supportive information deal with non-recurrent aspect of the task. Supportive information can be declarative information that can be found in books and other resources. Supportive information can be on demand depending on the context or information required for the whole subtask.

Table 4. Transfer Mechanisms that support Supportive information component

Supportive In-	Performance attributes	Literature

formation					23. Martín-Gutiérrez, Saorín, Contero, & Alcañiz (2010)
Transfer mech-anism	Perceptual motor skills	Cognitive motor skills	Collabora-tive skills	Spatial Skills	24. Freschi, Parrini, Dinelli, Ferrari, & Ferrari (2015)
Object Enrich-ments	30			22	25. Kwon, Lee, Jeong, & Kim (2014)
3D models and an-imation		1,25	26	16,28	26. Manuri, Sanna, Lamberti, Paravati, & Pezzolla (2014)
Xray vision	24	23,27 ,29		23	27. Wang & Dunston (2011)
Setting Cues and Clues	30	32,19			28. Buń, Górski, Wichniarek, Kuczko, & Zawadzki, (2015)

29. De Ravé, Jiménez-Hornero, Ariza-Villaverde, & Taguas-Ruiz (2016)
30. Condino et al. (2016)
31. Allain et al. (2015)
32. See (2016)
33. Sabine et al. (2011)
34. Sanfilippo (2017)

The following table 5 maps the transfer mechanisms that support the Just-in-time component. This component deals with procedural information required to perform the recurrent task which must be provided in a just in time fashion. The information can be presented as a step by step instructions or a feedback. It requires the condition action pairs to be identified, that drives the routine behaviors and the prerequisite knowledge involved in the step.

Table 5. Transfer Mechanisms that support Just-in-time information component

Just-in-time Information	Performance attributes				Literature
Transfer mechanism	Perceptual motor skills	Cognitive motor skills	Collaborative skills	Fine mo-tor skills	35. Yarnall et al. (2014)
Annotation			17,35		36. Poelman, Akman, Lukosch, & Jonker (2012)
Contextual in-formation	24	34,10,47	13,36		37. Sano, Sato, Shiraishi, & Otsuki (2016)
Haptic feedback	43,46,29	18,36,38		37	38. Matassa & Morreale, (2016)
Feedback	37	39,40		34,41	39. Lahanas, Loukas, Smailis, & Georgiou (2015)
Audio instruc-tions	33				40. Funk, Heusler, Akcay, Weiland, & Schmidt (2016)

41. Chang et al. (2015)
42. Zao et al. (2016)
43. Perlini, Salinaro, Santalucia, & Musca (2014)
44. Wei, Yan, Bie, Wang, & Sun (2014)
45. Sousa, Alves, & Rodrigues (2016)
46. Stunt, Kerkhoffs, Horeman, Van Dijk, & Tuijthof (2016)
47. Asadipour, Debattista, & Chalmers (2016)
48. Zhu, Ong, & Nee (2014)
49. Jang et al. (2014)

				50. Chia & Saakes (2014)
				51. Meleiro et al. (2014)
				52. Liu, Mei, Zhang, Lu, & Huang (2016)

The last component of the 4CID model is the part task practice which recognizes that some parts of the task are automatic and recurrent. In order to develop the automation of the skill it is required that the learner practice the task repeatedly. As such there is no transfer mechanism identified that supports this component, which may be for a simple fact that it's straight forward.

5 Conclusion

The presented reference framework for training expertise with AR and WT delivers methodologies that enable efficient and effective training of industrial skills. The reference framework combines the state-of-art transfer mechanism identified in the literature with the 4C/ID model for supporting the design and development of training applications. By classify transfer mechanisms the framework supports the instructional designers to design effective expertise training applications using AR and WT. The framework may have non-significant limitations such as, zero recorded transfer mechanism to support automation. It also helps in identifying gaps in the literature, for example, on certain transfer mechanisms there are several or no studies. It may be argued for the fact that it is a simple matter of practice; however various factors such as motivation have to be accounted. Thus, the framework is also a great starting point to explore how the boundaries of expertise development can be further pushed back.

The framework is an ongoing task and new transfer mechanisms will be documented as work progresses. However, as the framework stands now, it is sufficient to inform any training application designers with the technological and pedagogic overview he/she may need in order to design and develop an effective training platform. The framework is the conceptual support for the WEKIT project design and development. Further task involving the framework includes documentation of guidance and recommendations to hand-pick the transfer mechanism that cater the instructional designer needs. The framework needs to be evaluated in terms of what makes out an optimal set of transfer mechanisms. Therefore, we believe the framework is a significant step in merging the best of the AR and WT with Technology enhanced learning approaches.

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