An Overview of Smartrooms and Collaborative Work Environments. From Research Issues to User Acceptance in the Oil and Gas Industry

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ABSTRACT

Collaborative Work Environments (CWE) are technologically instrumented environments especially designed to support a collaborative (co-located or remote) activity. Colloquially referred to as "smartrooms" from their research debut, such environments are the joint product of multi-disciplinary expertises, as they draw from the fields of human factors, human computer interaction (HCI), pervasive computing, and various other fields. In this paper, we provide an overview of the literature on smartrooms in research and their application as collaborative work environments in the oil and gas industry. While the research literature provides with a broad view of the various topics and issues of smartroom design, the industrial literature focuses more on the organisational and human issues of setting up CWEs, providing valuable feedback on user acceptance and return on investment.

Les environnements de travail collaboratif sont des environnement de travail technologiquement enrichis, conçus pour faciliter une activité collaborative (que cette collaboration soit colocalisée ou distante). Ces "smartrooms" sont le produit d'expertises pluridisciplinaires, puisant dans les domaines du facteur humain, de l'interaction homme machine, et de l'informatique ubiquitaire. Dans cet article, nous présentons une vue d'ensemble de la littérature sur les smartrooms et leur mise en place dans l'industrie pétrolière. Si la littérature académique met avant tout l'accent sur les aspects techniques et humains de conception, la littérature industrielle nous présente quant à elle les enjeux organisationnels et économiques de ces environnements, et dévoile un retour d'expérience sur leur acceptation par les utilisateurs.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile devices**; *Collaborative interaction*; • **Applied computing → Command and control**;

KEYWORDS

Collaborative Work Environments, Smartrooms, Oil and Gas

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1 INTRODUCTION

Upstream activities in the oil and gas industry face very specific challenges. First, they involve many complex and specific technologies, processes and constraints, which in turn require as many complex and specific expertises. Constant exchange between the various experts gathered for a single activity is required for it to be successfully performed. Second, well sites are scattered around the globe, in hard to reach locations, and present harsh and even dangerous working conditions (offshore platforms are the best examples of such environments). As such, it is only natural to seek to restrict the number of people on site, in order to limit both safety issues and the cost of operating the site.

These two specific characteristics of *exploration and production* (EP) justify the need for new ways of working, and require changes in the working environments, from a specialized and isolated traditional workflow to a multi-discipline collaborative workflow. However, expertise is rare and costly; and factorizing the benefits of a multi-disciplinary and collaborative expert team among several assets seems the best solution. As such, a need for real-time remote collaboration emerges in order to meet the needs of sites all around the globe as fast as possible.

Smartrooms are technologically instrumented environments especially designed to support a collaborative (co-located or remote) activity, and as such provide an adequate solution to the challenges cited above. The term "smartroom" is rather loosely defined in the common language, and we may read about smart phones, smart appliances, smart homes, to smart buildings and even smart cities [7]. This notion of smart systems and environments stems from the field of pervasive (or "ubiquitous") computing, as it elicits the notion of communicating and processing objects embedded in our everyday world. But as users, the enthusiasm for smart systems is much more rooted in the way they seamlessly blend into our environment and lives: "*A sentient computing system doesn't need to be intelligent or capable of forming new concepts about the world - it only needs to act as though its perceptions duplicate the user's*" [1]. To achieve an illusion of human reasoning and sentience, a system needs - to a certain degree - to be aware of *context*. Although there is generally

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a strong emphasis on user location, context may involve much more information and describe the environment, situation state, surroundings, tasks, etc. [28].

We choose the definition of "smart" as *"able to assist a human activity through the seamless use of pervasive computing"*. This definition suits our needs for this article as it covers the three main disciplines that got involved in smartroom research: Human Factors, Human Computer Interaction (HCI), and Pervasive Computing.

The work presented in this paper was accomplished as a synthesis of literature for an industrial research project, with the objective to explore the potential of CWEs in the oil and gas industry. Our work consisted of two parts: first, an academic state of the art on CWEs; second, a synthesis of the industrial literature on the current implementation and use of CWEs in greater accounts of the oil and gas industry. We cover this dual work in this paper, presenting first the research works on the subject and then how the oil and gas industry implemented them in its operations. Research first focused on tackling technological and human issues in the design of smartrooms. These issues are covered in the sections II and III of this paper. In section IV, we present how companies later launched Collaborative Work Environment (CWE) programmes and provided feedback more focused on the organisational and user acceptance issues, as well as the return on investment (ROI) they obtained through such programmes.

2 CORE CONCEPTS OF SMART ROOMS

2.1 Definition of "smart" rooms

At the very core, there are two tenets in the philosophy of smartrooms. First, a smartroom is designed for, and should support a given set of activities. Such activities may include presentations, training, data analysis, problem-solving, design... etc. Collaboration is often an essential component of such activities, whether remote or co-located. Smartrooms should provide ways to improve and facilitate such collaboration. Second, the technology should not hinder the activities. For many of the authors covered in this document, ease of use was one of the primary considerations when designing their respective smartrooms [15][20][17]). The "smartness" of a room may as much come from careful design involving human factors and ergonomics as from complex technological systems. Usability is often much preferable to extended functionality, in order to ensure wide acceptance and use instead of the emergence of a few knowledgeable "wizards" [17].

Smartrooms are an inherently pluridisciplinary topic. From our review of the literature, we drew three major fields of issues: pervasive computing issues, human machine interaction issues, and human factors issues. These disciplines may not be explicitely referred to in the various papers cited in this article; but authors often consider smartrooms from these three points of view. A *pervasive computing* point of view will focus on the ability of the room to sense and reason over contextual information in order to provide behaviours that would feel adequate to its users. A *human-computer interaction* point of view will focus on the place of the user among this "sea of technology", and how to best integrate said technologies regarding the users' activities. Finally, a *human factors* point of view will focus on the human sides of smartrooms (activities, use, etc) in order to identify the issues that technology should address: in other words, to determine which issues HCI and pervasive computing should answer in order to make the room "smart" according to its users.

In this paper, we chose to structure the various issues and works in smartroom design by successively focusing on each of these three disciplines.

2.2 Smartrooms from a human factors point of view

The first way of approaching the topic of smartrooms is to adopt a human factors point of view. The primary goal of a smartroom is to support a specific human activity. As such, human factors and usability play an important role in its design and use. A key tenet of the smartroom philosophy is to allow the users to use it and work in this special environment as naturally as possible [15] [20] [17]. Smartrooms are also built to ensure collaboration. Co-located collaboration for a specific activity (e.g. problem-solving or data analysis) may require specific functional tools, such as shared visualisation spaces (e.g., a projector, or a screen wall) and shared interaction space (e.g. a simple white board). Physical arrangement and dedicated equipment is a once again a key factor: for example an horizontal multi-touch surface better favours collaboration than a vertical one [26]. Remote collaboration brings a whole set of specific issues, even if one makes abstraction of technical problems. Video-conferencing, for example, is far from a perfect solution [25][30][23]. Finally, a smartroom is instrumented and able to gather data on its user; as such, it can monitor activities that may be sensitive or even confidential. The issues of privacy (for the users) and security (of the data produced during the activities) are delicate to handle, as they are fundamentally issues of personal values, interests, and power [16].

Remote collaboration is usually achieved through off-the-shelf means, such as chat, conference calls, or video-conferencing. While a gradation in collaborative potential is clear among those three channels, there is still much room for improvement. Video-conferencing indeed features characteristics that hinders communication and as such collaboration:

- Presence disparity: a participant's perception of the presence of others is markedly different depending on whether a collaborator is co-located or remote.
- Physical arrangement incoherences: in the context of video-conferencing in a smartroom (typically hosting multiple displays for various content), the various heterogeneous displays introduce issues on how to orient work artefacts [30].
- Dual world perception: the main problem of video-conferencing is that it induces within a user a dual perception of the world around him and the world around the remote participant. This notion of "separated egocenters" [25] allows us to understand the actions of a remote participant: for example, upon seeing the remote participant manipulating a remote control, we can infer that he is controlling his video-conferencing system (that we cannot see). But at the same time, it breaks any illusion of locality between the two participants.

The Halo and BISi (*Blended Interaction Space*) rooms [23] are an exception to the general focus on technological issues. These rooms aim at blending the remote spaces by using the spatiality of human interaction: through careful physical design of the remote rooms, the rooms' designers manage to greatly attenuate the "dual egocenter issue": the fact that in a classic video-conferencing system, each user has to manage their own space and surroundings but also imagine and manage the other participant's surrounding space [25]. The Halo room features only careful physical arrangement, whereas the BISi room is a "blended interaction space for small group data intensive collaboration". The BISi rooms feature large screens arranged as a wall, a multitouch screen used as a table, and office furniture. Here again extreme care was taken on the physical arrangement of the remote rooms to maximize the sense of co-location.

2.3 Smartrooms from an HCI point of view

A second interesting vision is to adopt a Human Computer Interaction point of view. One can indeed consider a smartroom as an interactive environment that will help users seamlessly interact with an underlying system or with each other. A smartroom is dedicated to support an activity and/or the completion of a task (in the broad sense of the term). Common equipment and services found in smart meeting rooms include shared and individual visual spaces (eg large displays - TVs, projectors, or screen walls) [15] [29] for heterogeneous content distribution [25][38], and collaborative interaction. Among the first works on smartrooms is "The Office of the Future" imagined by Raskar et al. in 1998 [25]. The authors' vision is to use real-time computer-vision techniques to dynamically extract geometry and reflectance of the many surfaces in an office "including walls, furniture, objects and people, and then to either project images on the surfaces, render images of the surfaces, or interpret changes in the surfaces". This seminal vision was adopted by the LightSpace project from Microsoft Research [38] in 2010. Using off-the-shelf depth cameras and projectors, the LightSpace smartroom is able to capture the geometry of the room and create "virtual display and interaction surfaces". Physical arrangement of interaction devices (output devices, shuch as displays or speakers, or input devices, such as touch surfaces or keyboards) should also be carefully planned, as it may condition the way users will interact, work, and collaborate [23].

Remote collaboration is enabled through webcams, microphones, video-conferencing equipment or smart whiteboards [20]. This environment allows for a rich ground for human-system interaction; such interactions must be carefully designed to be as seamless as possible. Natural User Interactions (NUIs) are naturally fitted to the concept of smart rooms, as they share this philosophy of blending the interactions with a system in our natural behaviour. Moreover, they can greatly benefit from a pervasive instrumentation of the room, as they naturally benefit from or even require multimodal input [9]. Depending on the task at hand, different modalities or combinations thereof can be used to achieve a better feeling of naturalness from the user. Tangible interaction techniques augments the real physical world by coupling digital information to everyday physical objects and environments. One interesting example is Sandor et al.'s magic wand [27], which allows a smart room user to successively designate an input (e.g., a keyboard, a touchscreen), an output (e.g., one of the displays in the room) and an operation (e.g., link the keyboard to control the computer behind the display) to actively and dynamically redefine the interactions in a smart room.

Finally, a smartroom should be able to provide an array of services to its intended users. Korzun et al. [22] regroup the various services that may be available in a room in seven families: lecture services, meeting services, conference services, world information services (contextual information), sensor services (contextual information), activity and tracking services (contextual information) and discussion services. Although contextual information services do impact HCI considerations of smartrooms, they are better addressed through the scope of pervasive (or ubiquitous) computing.

2.4 Smartrooms form a pervasive computing point of view

A last approach is to adopt a pervasive computing point of view, and see smartrooms as an assembly of heterogenous sensors that allow the room to be "contextually aware": a smartroom should be able to sense the context and infer a desired behaviour from it. Contextual information can come from extremely heterogeneous sources: independent, self-sufficient communicative sensors (as in [20]) software probes, or more complex monitoring systems that provide sensing information on various levels of abstraction (e.g., emotion recognition) [8]. Such heterogeneity involves both a dedicated physical and software architecture to ensure integration. Semantic reasoning over the gathered data is then needed to manage the various services. User-tracking is usually the first piece of contextual information to be obtained. Various technologies can be used for user tracking. The notion of *Active Badges* that allow for user location in an environment go as far as the early 90's [35]. Ward et al. refined the concept to be able to locate people around specific devices [36]. The same principle was used for the Bat system [1], which allows locating its owner in a specific office in a building.

Context interpretation is also a major issue. The appeal of more "context-able" systems drove research to work on semantic reasoning. Early tools for smartrooms include ATLAS (Architecture and Tools for Linguistic Analysis Systems) from the NIST (National Institute of Standards and Technology) SmartSpace [29]. ATLAS addresses the issues of annotation of data streams (meta-data) with semantic descriptions. Standardization of meta-data allows indexing and transcription, with the goal of allowing higher-level inferences about the tasks and the users. It is hence possible to create new ontologies for a specific application. Various ontologies were specifically created for smart environments. Chen et al. defined the CoBrA-ONT and SOUPA (Standard Ontology for Ubiquitous and Pervasive Application) [5] for the EasyMeeting room [6].

2.5 Conclusion on the academic research on smartrooms

Ultimately, the goal of a smartroom is to provide a seamless technological support to the activities conducted inside. Smartroom design is hence an inherently pluridisciplinary process. Human Factors, Human Computer Interaction and Pervasive Computing are the fields most represented in the academic literature, but many other disciplines (like system engineering or design) may play an important role. Academic literature, however, only brings answers on how to design and implement such smartrooms. In the following section, we present a synthesis of the industrial literature, which focuses more on how to successfully integrate and use smartrooms and collaborative work environments, and what they can bring to the industry.

3 SMARTROOMS/CWES IN THE OIL AND GAS INDUSTRY

Over the past years, the oil and gas industry has witnessed continued and significant advances in smart oilfield technologies. These transformational changes have substantially improved operational awareness, generated advanced predictive analytics, and materially improved maintenance of infrastructure and decision making [12].

The "digital oilfield" value chain involve various components scattered across a group's structure and involving various fields of expertise (e.g., data collection and aggregation, data visualization, analytics, and decision support) [21]. Such expertise may be scarce and costly to deploy where it is needed. This is particularly true for harsher environments, such as offshore platforms, which involve safety issues, high costs for people on board, etc. These exploration and production challenges require changes in the working environment, from a specialized and isolated traditional workflow to a multidiscipline collaborative workflow [4]. Collaborative Work Environments (CWEs) are specifically created to integrate people, processes, and technology for improved cross-functional and virtual collaboration, learning and high quality decision-making [14]. As such, they are foremost a technological solution to the operational problem of distributed, but interdependent work processes [3].

3.1 Existing Programmes in the Industry

Most EP companies now feature programs involving CWEs: *Smart fields* for Shell, *i-fields* for Chevron, *Digital Oilfields* for Schlumberger... However, details on such programs can be difficult to find.

British Petroleum (BP) launched in 2003 the *Advanced Collaborative Environments* (ACE) program, as part of it "Fields of the future" program. BP had built five CWEs in 2005: the Valhall Onshore Operation Centre (Stavanger), The Andrew drilling Onshore Operation Centre (Aberdeen), The Ula Integrated Operations environment to support production operations from the Ula field in Norway (Stavanger), the Na Kika Onshore Operations Support Centre for the Na Kika field in the deep water Gulf of Mexico, and the Azeri Operations Support Centre for the Central and West Azeri platforms in the Caspian Sea. Those various rooms feature video-conferencing systems, large displays for data analysis, and physical arrangements for supporting collaborative work.

The Al Khafji Joint Operations (KJO) is a joint operation between Saudi Aramco Gulf Operating Company and Kuwait Gulf oil Company. It began as a collaborative environment infrastructure project in 2007 to address the problems of ageing infrastructures and legacy applications to enhance operational processes and facilitate collaboration between geophysicits, geologists, reservoir engineers and drilling operations [4]. KJO followed a three-phase plan to minimize disruption, facilitate transition and accommodate business priorities. The first phase was to set up an open infrastructure by migrating from legacy softwares to an open commodity platform; the second phase was to enable web applications, including a virtual collaborative workspace for remote collaboration; and the third phase saw the constructions of collaborative team rooms. Such rooms feature interactive smartboards, large displays for 3D visualization, and video-conferencing systems. On the other side, well sites are equipped with rig floor cameras, real time data aggregation systems, and video-conferencing systems. Bedaiwi et al. provide in [4] a detailed table of technology components and their characteristics in a typical architecture.

Halliburton identified three main challenges in establishing an integrated collaborative environment: technology backbone, governance, and integration and collaboration. Fayzullin et al. [13] present the detail of organisational implementation and early results for a center in Dubai. The CWE teams defined key roles (Center manager, Drilling engineer, operations geologist) and workflows are categorized according to criticality (green flag: suggestion, yellow flag: moderate intervention, red flag: instruction). However, few technical data is provided.

Petroleum Development Oman (PDO) presented in [34] another kind of remote collaboration. The*Smart Mobile worker* is a system that is worn by a field operator. It features a camera and a microphone/headset on the security helmet, along with various sensors (e.g., gas monitor, GPS/RTLS receiver, temperature) and a mobile device. The field operator is linked with experts located in a dedicated room for direct advice and support.

Petronas and Schlumberger presented in [2] an example of a tri-node collaborative work environment, for the Samarang field (Malaysia). The three environments are geographically located at Samarang offshore, sabah operations (onshore in Kota Kinabalu) and headquarters (in Kuala Lumpur). Responsabilities are split among the three locations. Headquarters provide advice and support; the onshore team performs surveillance, proposes and implements solutions or actions; the offshore team executes the decisions.

Other kind of initiatives are also worth of notice. Maersk Training began to use CWEs for the training and certification of well control employees [10]. Chevron formed a partnership with the University of South California to create CiSoft (Center for Interactive Smart Oilfield Technologies) and better manage and implement smart technologies in the fields of Integrated Asset management, Well productivity management, Robotics and Artificial Intelligence, Embedded and Networked Systems, Reservoir Management, Data Management tools, and Immersive Visualization. Future works involve the creation of an operational educational program to explore new technologies for digital oilfields [12].

3.2 Setting up a Collaborative Work Environment

Rather than depicting their technological implementations, literature on smartrooms in the oil and gas industry focuses on the process of successively setting up and ensuring a sustained use of CWEs in a group.

BP's Advanced Collaborative Environments rely on the "five petal model": people, process, technology, organisation, and physical environment [11]. At their core, CWEs are designed to enhance the collaboration between people. Due to their inter-disciplinary complexity, they involve people from various fields and levels of expertise. As such, it is primordial that the people involved in the CWE program *understand* the need for a CWE, *appreciate* its benefits, and *are involved* in the development of the CWE since the early stages. In order to optimize the use of a CWE, adequate work *processes* must be set up in order to best fit the collaborative goals of the smartroom, for example by defining a remote meeting schedule, the roles and responsibilities of each party, etc. *Technology* is an enabler of such goals. Proper technological design will help collaborative and remote work through ease of use; bad technological choices may limit the acceptance from the intended users, and as such limit the smartroom's usage. *Organisation* is key in acceptance and long term sustainability of the CWE: engagement of the management and support services, proper training, integration of the smartroom's activities in the organisational fabric can prove determining for long term use. Finally, the *physical environment* must be designed around the processes conducted in the room, and fulfill ergonomic requirements.

Bedaiwi et al. (KJO & Schlumberger) highlight a similar set of requirements [4]. Final users were involved early in the development process. Multi-disciplinary interviews to isolate key factors to support collaborative practices, with the final key requirements being scalability, openness (avoid proprietary technology), standardization, web enabling, security, and usability and ergonomics.

3.2.1 Change Management. A CWE program may be seen more as a "transformation" issue rather than a change issue, as it triggers long-term adaptations [32]. "Change" can be categorized into three types. *Process changes* involve change on the work processes one has to follow to accomplish a given task, e.g., a change in the way suppliers' payments are handled. *Technology change* happens when new equipment is used to perform a given task (i.e., a new telephone system). Finally, *capability change* introduces new possibilities, tasks, and goals in one's work. CWE programs are irrefutably a capability change. The environment itself provides a new "connectivity capability" in enabling 24/7 visual, audio and data capability with a whole host of groups, individuals and teams. However, using the new capability is a choice, as someone who feels there are no distinct advantage in it might simply avoid it and rely on more traditional and familiar methods of communicating [37].

The failure to recognize CWEs as a "capability change" rather than a technological one is the reason why many companies have installed expensive systems to connect remote groups together only to find the systems are rarely used, and collaborative environments simply revert to "rooms" where people sit surrounded by redundant technology and a disregarded capability. Factors of acceptance or avoidance may be varied: perceived usefulness of the new system (or lack thereof), computer experience of the intended users, degree of top management support... etc. However there are a few specificities for the oil and gas industry: for example, employees have experience in working over distances, compared to other industries [37].

Involving the people at every stage of the program is a key point highlighted by most literature on the subject [4][14][33][37][3]. As Bayerl et al. (BP) highlight it, an ideal process would involve the stakeholders at the early stages (interlinking organisational and individual adoption through shared proposition making), critical stages (implementation and decision making) and final stage (facilitating or undermining long term commitment) of the CWE program. Nudge techniques can be used for better acceptance [18]. The overall process of involvement should not happen too fast, and adapted involvement practices and tools should be used at each phase of the program. For example, the use of always-on cameras typically would require more in-depth acceptance efforts.

3.2.2 Ergonomics and Human Factors. Given the importance of acceptance by the various stakeholders of a CWE program to ensure its success, it is no surprise that human factors are a key design issue. Various publications present human factor evaluations and ergonomics issues in CWEs (e.g., [3] [37] [24]). Typical issues include the fact that connecting geographically remote groups together means connecting two or more cultures together, which might risk a cultural clash. Moreover, offshore and onshore culture and use of the CWE differ greatly and studies should be conducted on both environments [3]. Ergonomists will ensure the enforcement of rules that may appear basic or common sense (accessibility, data readability, etc.) but all too often overlooked [24]. Special care should also be taken on complex systems, such as alarm management, or sensitive issues, such as always-on video integration. Inspiration can be taken from control rooms and for example the norm ISO-11064 on ergonomic design for control centres [19].

3.3 Benefits of CWEs in the Oil and Gas Industry

Performances of CWEs can be quantitatively estimated. The Valhall Onshore drilling Operations Centre (OOC) is one of BP CWEs [11] which performs remote diagnostics, reservoir geosteering and stimulation jobs for several Norway fields. It is connected by fiber optic cable to the platform and is designed for full interaction with all operations, including real-time data access to rig systems, Close-Circuit Television (CCTV) coverage and communication with other centres. BP highlights the fact that the OOC generated a value far in excess of the $3 millions invested, as it generates between $5 and $6 million per year through better wells delivery (data from 2006) and a 20% reduction in drill team staff offshore. In 2008, BP estimated the benefits of CWE as 3 to 25% higher operating efficiency, 5 to 15% drilling costs reduction, and 1 to 4% reduction in downtime [3].

The extent of its CWE programme allowed Shell to achieve significant gains. Shell estimated that its CWE contribute to production gains of 1 to 5%, availability gains of 1 to 5%, and create value in the order of 5-10 million US$ per asset yearly [31]. Typical benefits include tangible benefits, such as increased production, reduced deferments, increased availability, reduced travel operational expenditures, saved man-hours, reduced number of people on board, and reduced HSSE (Health, Safety, Security and Environment) exposure from travel; as well as intangible benefits, such as improved team unity, increased motivation, improved understanding of the asset and expertise, reduced barriers to communication, and increased trust.

4 CONCLUSION

We provided a review of the literature on smartrooms in academic research, as well as their application as Collaborative Work Environments (CWEs) in the oil and gas industry. CWEs are a global trend in this field, embraced by many major actors, such as Shell or

BP. Their values, performances, and benefits are consequential, and can be measured through various key indicators, such as increased production through better well management, staff efficiency, cost reduction through an economy of people on board (POB) offshore platforms, etc. This leads the estimated ROI for each CWE to be achieved in less than a year. Other, less measurable benefits include improved team unity, increased motivation, improved understanding of the asset and expertise, reduced barriers to communication, and increased trust. With all these benefits, CWEs are certainly a very promising lead to follow. Setting up a CWE program, however, represents a deep transformation of the work processes, and the transition should be properly managed in order to ensure user acceptance and involvement.

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REFERENCES

[1] M. Addlesee, R. Curwen, S. Hodges, J. Newman, P. Steggles, A. Ward, and A. Hopper. 2001. Implementing a sentient computing system. *Computer* 34, 8 (Aug. 2001), 50–56. https://doi.org/10.1109/2.940013

[2] Dzulkarnain Azaman, Hendry Majinum-Helmi, Shahrizal Shahari, Colinus Lajim Sayung, Hassan Wan Mamat DatoâĂŹ Wan, Lee Hin Wong, Muzahidin Muhamed Salim, M Kasim M Som, and Shripad Biniwale. 2015. Samarang Integrated Operations (IO) - Tri-Node Collaborative Working Environment (CWE) Integrating People, Technology and Process. Society of Petroleum Engineers. https://doi.org/10.2118/173579-MS

[3] Petra Bayerl, Kristina Lauche, Petra Badke-Schaub, and Steven James Sawaryn. 2008. Successful Implementation of Collaborative Environments: Human Factors and Implications. Society of Petroleum Engineers. https://doi.org/10.2118/112104-MS

[4] Mohammed Ibrahim Bedaiwi and Mohammad Arief Dharmawan. 2010. Collaborative Environment Infrastructure in Al-Khafji Joint Operations, A Case Study. Society of Petroleum Engineers. https://doi.org/10.2118/127928-MS

[5] H. Chen, T. Finin, and A. Joshi. 2004. Semantic Web in the context broker architecture. IEEE, 277–286. https://doi.org/10.1109/PERCOM.2004.1276865

[6] Harry Chen, Filip Perich, Dipanjan Chakraborty, Tim Finin, and Anupam Joshi. 2004. Intelligent Agents Meet Semantic Web in a Smart Meeting Room. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 2 (AAMAS '04)*. IEEE Computer Society, Washington, DC, USA, 854–861. https://doi.org/10.1109/AAMAS.2004.152

[7] H. Chourabi, T. Nam, S. Walker, J. R. Gil-Garcia, S. Mellouli, K. Nahon, T. A. Pardo, and H. J. Scholl. 2012. Understanding Smart Cities: An Integrative Framework. In *System Science (HICSS), 2012 45th Hawaii International Conference on.* 2289–2297. https://doi.org/10.1109/HICSS.2012.615

[8] Alexis Clay. 2009. *The emotion branch, a software architecture model for emotion recognition in interactive software: application to dance and augmented reality.* Ph.D. Dissertation. UniversitÃľ Sciences et Technologies-Bordeaux I.

[9] Alexis Clay, Marion Wolff, and RÃľgis Mollard. 2014. User-designed movement interactions. *Journal EuropÃľen des SystÃĺmes AutomatisÃľs (JESA)* 4-5-6 (2014), 453–472.

[10] Nelly De Nicolais, Rossana Vadala, John Abate, Jan Olsen, and Jamie McHattie. 2016. Enhanced Well Control Implementing Human Factors. Society of Petroleum Engineers. https://doi.org/10.2118/181035-MS

[11] Tony Edwards, Mike Saunders, and Kerry Moore-Cernoch. 2006. Advanced Collaborative Environments In BP. Society of Petroleum Engineers. https://doi.org/10.2118/100113-MS

[12] Iraj Ershaghi, Donald Paul, Mike Hauser, Jim Crompton, and Vega Sankur. 2016. CiSoft and Smart Oilfield Technologies. Society of Petroleum Engineers. https://doi.org/10.2118/181068-MS

[13] Timur Fayzullin, Peter Kowalchuk, Tom Goebel, and A. Tok Shopeju. 2013. Using Real-Time Operations Interventions in a Drilling and Subsurface Collaborative Environment. Society of Petroleum Engineers. https://doi.org/10.2118/166695-MS

[14] Knut Fosse and Dominic Taylor. 2006. Collaborative Decision Making in Operation Centre Environments. Society of Petroleum Engineers. https://doi.org/10.2118/100704-MS

[15] A. Fox, B. Johanson, P. Hanrahan, and T. Winograd. 2000. Integrating information appliances into an interactive workspace. *IEEE Computer Graphics and Applications* 20, 3 (May 2000), 54–65. https://doi.org/10.1109/38.844373

[16] Robert Gellman. 1997. Does privacy law work? In *Technology and Privacy*, Philip E. Agre and Marc Rotenberg (Eds.). MIT Press, Cambridge, MA, USA, 193–218. http://dl.acm.org/citation.cfm?id=275283.275291

[17] Gene Golovchinsky, Pernilla Qvarfordt, Bill van Melle, Scott Carter, and Tony Dunnigan. 2009. DICE: designing conference rooms for usability. ACM Press, 1015. https://doi.org/10.1145/1518701.1518856

[18] M. Healey, K. Parker, and L. Saldin. 2016. Using Nudge Techniques to Influence Behaviour in an Engineering Office. Society of Petroleum Engineers. https://doi.org/10.2118/181050-MS

[19] ISO. 2013. *Ergonomic design of control centres.* ISO ISO 2012 11064. International Organization for Standardization, Geneva, Switzerland.

[20] B. Johanson, A. Fox, and T. Winograd. 2002. The Interactive Workspaces project: experiences with ubiquitous computing rooms. *IEEE Pervasive Computing* 1, 2 (April 2002), 67–74. https://doi.org/10.1109/MPRV.2002.1012339

[21] S. Jose, T. Sookdeo, I. Says, Y. Carreno, and R. Ferrero. 2016. The Smart Digital Platform for Effective Well Control Management. Society of Petroleum Engineers. https://doi.org/10.2118/181041-MS

[22] Dmitry Korzun, Ivan Galov, and Sergey Balandin. 2013. Development of smart room services on top of Smart-M3. IEEE, 37–44. https://doi.org/10.1109/FRUCT.2013.6737943

[23] Kenton O'hara, Jesper Kjeldskov, and Jeni Paay. 2011. Blended interaction spaces for distributed team collaboration. *ACM Transactions on Computer-Human Interaction* 18, 1 (April 2011), 1–28. https://doi.org/10.1145/1959022.1959025

[24] Ruurd Pikaar, Niels de Groot, Erik Mulder, and Bas Remijn. 2016. Human Factors in Control Room Design & Effective Operator Participation. Society of Petroleum Engineers. https://doi.org/10.2118/181007-MS

[25] Ramesh Raskar, Greg Welch, Matt Cutts, Adam Lake, Lev Stesin, and Henry Fuchs. 1998. The office of the future: a unified approach to image-based modeling and spatially immersive displays. ACM Press, 179–188. https://doi.org/10.1145/280814.280861

[26] Yvonne Rogers and SiÃćn Lindley. 2004. Collaborating around vertical and horizontal large interactive displays: which way is best? *Interacting with Computers* 16, 6 (2004), 1133–1152.

[27] C. Sandor, A. Olwal, B. Bell, and S. Feiner. 2005. Immersive mixed-reality configuration of hybrid user interfaces. IEEE, 110–113. https://doi.org/10.1109/ISMAR.2005.37

[28] Albrecht Schmidt. 2000. Implicit human computer interaction through context. *Personal Technologies* 4, 2-3 (June 2000), 191–199. https://doi.org/10.1007/BF01324126

[29] V. Stanford, J. Garofolo, O. Galibert, M. Michel, and C. Laprun. 2003. The NIST Smart Space and Meeting Room projects: signals, acquisition annotation, and metrics, Vol. 4. IEEE, IV–736–9. https://doi.org/10.1109/ICASSP.2003.1202748

[30] Anthony Tang, Michael Boyle, and Saul Greenberg. 2004. Display and Presence Disparity in Mixed Presence Groupware. In *Proceedings of the Fifth Conference on Australasian User Interface - Volume 28 (AUIC '04)*. Australian Computer Society, Inc., Darlinghurst, Australia, Australia, 73–82.

[31] Frans G. van den Berg, Giles A.R. McCallum, Matt Graves, and Elizabeth Heath. 2014. Collaborative Work Environments Deployed At Global Scale. Society of Petroleum Engineers. https://doi.org/10.2118/167871-MS

[32] Frans G van den Berg, Giles A.R. McCallum, Matt Graves, Elizabeth Heath, and Allen Evans. 2013. Collaborative Work Environments in Shell - Global Scale, Learning and Evolution. Society of Petroleum Engineers. https://doi.org/10.2118/167455-MS

[33] Frans G. van den Berg, G. A. R. McCallum, and Stewart Wallace. 2015. Collaborative Working in Shell - Value Achieved, More to Follow. Society of Petroleum Engineers. https://doi.org/10.2118/176787-MS

[34] Jaap Erik Van Dijk. 2013. Smart Mobile Worker- Bringing our Facilities closer! Society of Petroleum Engineers. https://doi.org/10.2118/167426-MS

[35] R. Want and A. Hopper. 1992. Active badges and personal interactive computing objects. *IEEE Transactions on Consumer Electronics* 38, 1 (Feb. 1992), 10–20. https://doi.org/10.1109/30.125076

[36] A. Ward, A. Jones, and A. Hopper. 1997. A new location technique for the active office. *IEEE Personal Communications* 4, 5 (Oct. 1997), 42–47. https://doi.org/10.1109/98.626982

[37] Paul Williams. 2008. Collaborative Working - People Issues In Perspective. Society of Petroleum Engineers. https://doi.org/10.2118/111605-MS

[38] Andrew D. Wilson and Hrvoje Benko. 2010. Combining multiple depth cameras and projectors for interactions on, above and between surfaces. ACM Press, 273. https://doi.org/10.1145/1866029.1866073