

Investigations of Ubicomp in the Oil and Gas Industry

Clint Heyer

ABB Strategic R&D for Oil, Gas and Petrochemicals

Oslo, Norway

clint.heyer@no.abb.com

ABSTRACT

In this paper we describe a use context for ubicomp technology seldom investigated: the industrial setting, and in particular, the oil and gas industry. We suggest that the field offers interesting challenges to the ubicomp field and briefly outline some design opportunities. In particular, we identify the need to ease flowing of activity across boundaries of space, physical/digital and varied systems. We also describe our grounded approach, starting with qualitative field studies and leading through to the design and implementation of novel prototypes. The contribution of this paper is a concrete description of this alternative use context and a sketching of potential ubicomp solutions to meet industrial needs.

Author Keywords

Industrial, ubiquitous computing, oil and gas.

ACM Classification Keywords

C.3 [Computer Systems Organization]: Special-Purpose and Application-based Systems; C.4 [Performance of Systems]: design studies, measurement techniques

General Terms

Design, Human Factors.

INTRODUCTION

Reviewing the 101 papers and notes of the last three ACM UbiComp conferences yields only one paper with an industrial user-oriented application [5]. While supporting technology such as wireless sensor networks can be used in industrial contexts [4, 6], there is a marked paucity of ubicomp applications beyond domestic, office and healthcare settings. Industrial contexts can be problematic for research as sites are difficult to gain access to and safety regulations can severely limit the kinds of research activities that can take place on-site. For example, in oil and gas, it is not possible to use or introduce any kind of device that is not certified safe for use in explosive environments, essentially precluding all consumer-grade electronics.

An industrial workplace is quite different to those generally encountered in ubicomp. Physical environments are often

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dirty, weather-exposed, noisy, and in many cases, dangerous. Workers might perform their tasks with protective equipment, hindering hearing, vision and dexterity. Activity tends to be oriented to machines and materials rather than computers and information. Industrial settings pose new challenges for location tracking and activity sensing as well as the design of appropriate form factors and interaction modalities.

The oil and gas (O&G) workplace is a mixture of indoor and outdoor environments, tightly packed into multiple levels in the case of offshore rigs, or sprawled over a large area for onshore facilities. High-pressure, extremely high and low temperatures as well as explosive and toxic materials mean that for all activity, the highest concern is for health, safety and the environment (HSE). Devices which contain energy or may otherwise cause a spark cannot be used within most areas of a plant unless they are properly protected and receive certification. This severely hampers rapid or exploratory prototyping as certification is an expensive, time-consuming process that is usually conducted toward the end of a product's development.

In an effort to improve operational efficiency, the oil and gas industry has seen a push toward ‘integrated operations,’ which is essentially concerned with the more efficient use of data. Better instrumentation such as wireless sensors and communication backbones mean that data can be collected in real time. Visualisation and analysis of the data can be carried out, looking for early indications of faults and equipment wear. Better informed, a greater amount of planning and engineering activity can be conducted from a safer, onshore location rather than offshore. Workflows can be streamlined and made more cost efficient. For the Norwegian Continental Shelf alone, it has been estimated that integrated operations could add up to USD\$42 billion in value [7].

The work described in this paper was sub-project of a broader industry collaborative R&D project examining integrated operations. Running for two years, the ubicomp investigations took a holistic approach, starting with fieldwork to examine O&G workplaces and identify design opportunity, followed by implementation of supporting architecture [3] and prototypes. This paper is a broad account of these activities and serves to illustrate industrial ubicomp research in practice. In addition, it aims to demonstrate ubicomp’s opportunity and applicability to the

O&G industry as it pursues its ‘integrated operations’ vision.

FIELDWORK

Before embarking on design and prototyping, it was desired to gain an understanding of how work is actually carried out at O&G facilities and the problems faced by the shift team. To this end, a number of ethnographic field studies and interviews were conducted at O&G sites [2].

A typical shift team consists of field operators, control room operators and shift leaders. Field operators have individual skill and process specialisations, for example a mechanic who has specialised in the export compressor process area. Field operators are generally mobile, moving around the plant responding to requests from control room operators and contractors, who carry out the bulk of maintenance, upgrades and repairs. Of the shift team, field operators spend the most time in the plant and as a result have a rich awareness and knowledge of its physical embodiment, for example gaining a feel of the ‘right’ sound and vibration of a pump or smell of an outlet pipe. Control room operators (who usually rotate periodically into a field operator role), sit in the control room and manage the logical process. From their control stations, they have access to process information, such as the pressure of a pipe, and can make manipulations remotely, such as opening a valve. Control room operators frequently need to request field operators to verify readings or perform operations they are unable to do remotely. Shift leaders oversee the shift, and act as a liaison with other areas of the organisation, and are able to assist in the control room or field if a crisis occurs.

NEEDS & OPPORTUNITY

Several needs have been identified through field studies and other investigations. A full treatment of these is beyond the scope of this paper, here we highlight two which might be suitable for a ubicomp-oriented approach (further observations are reported elsewhere [2]).

The shift team flow their activity across a number of boundaries [8], largely accomplished through their own assemblage and tailoring of digital and non-digital artefacts. Boundaries exist between physical locations, systems, artefacts and so on. For example, when in the plant, an operator might jot down a pipe’s tag number (the universal plant referencing scheme) and a fault description in order to enter it into an information system later. Here, we see a transitioning between spaces as well as between physical and digital artefacts. In addition, support is often required to bridge the conceptual gap of the logical process, as it exists in engineering diagrams and process control, with the physical manifestation of the process. Control room operators report that it’s easy to forget that field operators need to travel some distance, climb stairs and so on to carry out the controller’s requests. From the control room, space appears collapsed. Likewise in the field, the logical process is less clear when standing amongst a thicket of pipes or huge storage vessels.

In the plant, operators are relatively information-poor. Many instruments have displays but it is difficult to gain an overview of status and trends for even a small number of instruments, let alone the entire plant. Moreover, a sense of the logical process can be difficult to maintain and reconcile with its large, complex, physical manifestation. As a result, field operators need to request information via radio to the control room, where operators have access to a wealth of current and historical data.

PROTOTYPES

Hazvac: enhanced fire & gas sensing and visualisation

Fire and gas detectors are installed throughout an O&G facility and linked to the process control system so that operators are immediately notified of alarms, or in the case of a large number of alarms, the process is automatically shut down. While sensors cover all areas of the plant, they are sparsely distributed due to installation costs. As a result, when an alarm occurs, control room operators are not able to clearly discern the scale of the problem, or whether the alarm is a false-positive. Moreover, field operators who are dispatched to verify and investigate alarms do not have a clear awareness of what to expect when arriving.

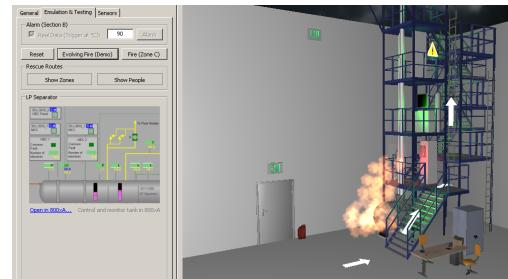


Figure 1. Visualisation of sensor data and process information.

‘Hazvac’ (Figure 1) was designed to address this shortcoming and demonstrate a practical, HSE-improving application for wireless sensor networks. It employs a large number of cheap, self-contained and self-organising Dust Networks-based wireless sensors. Thus false-positives are more easily distinguished and the scale and movement of a fire or gas leak can be monitored. Meshes can be deployed in areas that require particular attention and would supplement existing fixed sensor infrastructure which has stringent demands for availability and redundancy. As suitable fire and gas sensors were not available, we combined wireless nodes with temperature sensors to demonstrate the concept. A control room operator interface was developed to provide a volumetric, contextualised visualisation of sensor data. Personnel in affected zones are also identified (through strategically-placed RFID readers) so that emergency response can be better managed. Informants indicated that gross zone-oriented tracking was more acceptable than precise location tracking from a privacy perspective.

Ambient Awareness

A theme that emerged from the field work is the lack of high-level ‘glanceable’ information. Informants outside of

the shift team, such as engineers and managers, noted that they had all the information they could ever require available in various digital sources, but the effort required to generate a useful view of the information was too great to satisfy a quick curiosity. Two concepts were developed to explore ambient awareness in an industrial setting. The first uses a commercially-available Nabaztag rabbit (Figure 2), which has motorised ears, several colour LEDs and an in-built speaker for streaming audio. Setting colour patterns and ear positions can provide a glanceable display, for example to abstractly represent the amount of unacknowledged alarms in the system. Once set to represent a particular overview, no configuration is required and general information can be gleaned by a short glance.



Figure 2. Nabaztag rabbit installed at a process control station (left), focus and context display (right, approx. 100x30x10cm).

While the Nabaztag is useful for showing current information, we had less success in representing information with context, for example its trend over time. A custom ambient display was created to explore focus and context (Figure 2). A curtain of white satin is articulated by three servo motors, which can lift it independently at three points. Behind the sheet is a colour LED strip, that can ‘paint’ the entire display in any arbitrary colour. For example, colour can be used to show change in pipe pressure, transitioning from green to red depending on its deviation from expected values. The curtain can be used to represent pressure over the last month as a gradient, contextualising the current status with longer trends.

Perimeter+

When carrying out work in the field a visual barrier is erected around the work site to alert others of potential danger. If there is risk of exposure to gas or work is being carried out that could be a source of explosion, a sensitive shoebox-sized gas detector is required in addition to the wearable gas detector which is always in use. Detectors audibly and visually alert workers to the presence of noxious or explosive gases like methane, which is odourless and colourless. These detectors are not, however, integrated into the plant’s HSE alarm system, and therefore alerting of these potentially dangerous conditions only occurs if others can be notified over the radio. In a crisis situation, or if the worker is incapacitated, it may be some time before colleagues are notified and emergency procedures initiated.

‘Perimeter+’, our concept to address this concern (Figure 3), enhances worker safety by sensing localised HSE risks and communicating this data back to the plant alarm system so

alerts can be comprehensively managed. The existing work practice of erecting a visual barrier is leveraged, but offers additional protection to the person on site. In its current implementation, we have developed versatile LED arrays that can display a number of different behaviours, such as using arrows to guide people away from a threat, or indicating ambient sensor readings. Every tower has its own LED array, each of which has seven discrete channels of adjustable light output. Infrared sensors were used to demonstrate the concept rather than expensive fire and gas sensors. We are also investigating a higher mobility version constructed of surface-mounted electronics and conductive fibres embedded in a ribbon that can be drawn out and strung around equipment making a lightweight perimeter. An embedded RFID reader allows workers to scan their work permit, activating the barrier and notifying the control room that work has commenced. Live sensor data is also available remotely, visualised as expanding circles displayed in relation to the sensor’s spatial layout.

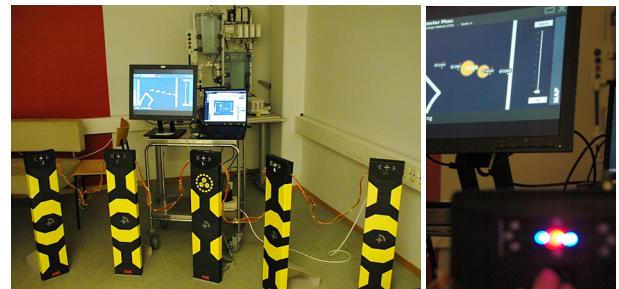


Figure 3. Perimeter+ deployed (left) and activated (right).

Flashscope

To provide additional information to field operators, we developed Flashscope, a handheld augmented reality system (Figure 4). Holding a small package of laser projector and camera (eventually taking the form factor of a flashlight), it can be directed at an object of interest. The object is recognised, live process data fetched, and an appropriate visualisation projected. The projection takes into account the spatial relationship between projector and object by tracking image features and occasional calibration with structured light.



Figure 4. Flashscope in hand (left) and projected result (right)

Flashscope effectively ‘reveals’ digital information which is fixed to the object’s surface, for example, a virtual water line can be traced out by playing the Flashscope up and down a

tank. Object recognition and tracking utilises the SURF algorithm [1] and is currently able to track objects at approximately five frames per second. By utilising projection instead of a handheld screen, information is more easily accessible to co-located colleagues, and is designed to be as simple to use as a flashlight – simply turn on, and shine at an object. Although Flashscope performs well in the laboratory setting, we are currently investigating higher-lumen projectors and the feasibility of remote image processing so Flashscope can run untethered from a computer.

Munin

Field operators usually have little control over equipment in the plant as most modern plants have a high level of automation. In order to have equipment started, stopped, or running parameters changed, field operators need to radio to the control room and ask for the change to be made. Control room operators locate the equipment in their process control system, open its interface, make the change, and report back to the field operator. This can slow work activity for both parties and unnecessary complexity is introduced due to the translation between physical and logical entities. The existing process however, does provide situational awareness benefits for the control room operator. For example, since she is executing a command to manually shut down a pump, she can expect an immediate alarm, and acknowledge it with little concern. If remote parties are manually shutting down pumps, the same alarm will be unexpected and need to be investigated. ‘Munin’ (Figure 5) is a prototype that runs on the Windows Mobile platform and is integrated into existing process control infrastructure, via industry-standard OPC¹. First the operator selects a machine to manipulate, either by scanning it with the handheld’s RFID reader or entering its tag number. A panel appears, allowing the operator to

observe its current state and parameters. Once authenticated, they are able to initiate the manual control mode, for example to increase the power of a pump. Enabling manual mode should require the acknowledgement and consent of a control room operator so that situational awareness is maintained.

CONCLUSIONS

In this paper we provided background for ubicomp

opportunities in the oil and gas sector and detailed some of our early prototypes. The prototypes were developed as a design response to needs that became apparent through on-site fieldwork and other qualitative approaches. In particular, improved safety for field operators through wireless sensor meshes, improved remote visualisation and connected, active barriers; ambient awareness of plant activity; and enhanced



Figure 5. Munin mobile process control interface

productivity with in-field, mobile process control and information. Although several of the prototypes are not highly sophisticated in a technical sense, they demonstrate the potential for ubicomp to address real-world problems in industry, in particular, by improving worker safety and efficiency. Due to safety regulations, prototypes were not field tested, however in future work we aim to evaluate their suitability and usefulness with field operators.

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¹ <http://opcfoundation.org>