Situation awareness in context-aware case-based decision support

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Abstract—**Humans naturally reuse recalled knowledge to solve problems and this includes understanding the information that identify or characterize these problems (context), and the situation. Context-aware case-based reasoning (CBR) applications uses the context of users to provide solutions to problems. The combination of a context-aware CBR with general domain knowledge has been shown to improve similarity assessment, solving domain specific problems and problems of uncertain knowledge. Whilst these CBR approaches in context awareness address problems of incomplete data and domain specific problems, future problems that are situation-dependent cannot be anticipated due to lack of the facility to predict the state of the environment. This paper builds on prior work to present an approach that combines situation awareness, context awareness, case-based reasoning, and general domain knowledge in a decision support system. In combining these concepts the architecture of this system provides the capability to handle uncertain knowledge and predict the state of the environment in order to solve specific domain problems. The paper evaluates the concepts through a trial implementation in the flow assurance control domain to predict the formation of hydrate in sub-sea oil and gas pipelines. The results show a clear improvement in both similarity assessment and problem solving prediction.**

Keywords: **Situation awareness; Context awareness; Domain modelling; Case-based reasoning; Decision support; Action research; Agile user-centred design.**

I. INTRODUCTION

The primary aim of decision support systems (DSS) is to support humans in the performance of tasks that involve decision making and the choice of appropriate actions[26] in order to overcome human limitations such as low vigilance or impaired cognitive capacities[19]. In safety critical scenarios, like air traffic control in the aviation industry, anaesthesiology in heath care, terrain monitoring in military command and control, and subsea pipeline safety in the oil and gas industry, maintaining situation awareness of the environment is essential for effective decision-making.

Situation awareness (SA) is a cognitive process in decision-making and is defined as ”the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future”[6]. The Endsley situation awareness model has three layers comprising perception, comprehension, and projection. The perception layer recognises all the necessary information about the environment. The comprehension layer interprets the perceived information in order to understand the current state of the environment. The projection layer uses knowledge of the current state of the environment to predict its future state.

In the SA widely researched domain of air traffic control, the use of predictive displays which enhance situation awareness of air traffic controllers has made a significant improvement in air traffic control performance[7] the same way it improved the performance of anaesthetists in operating theatres[19].

In the domain of military command and control, Feng et al[8] investigated situation awareness with context awareness (CA). A context aware system uses the context to provide relevant information and services to the user[21]. Individual human operators in Feng et al's work were provided customized views and decision support through domain agents that employed user contexts to extract information from the situation awareness model. The approach provided an insight into a mechanism of combining the two concepts by providing solutions to domain-specific and situation-dependent problems. Situation-dependent problems are domain problems influenced by the state of the environment. However, the decision module of Feng's work had some limitations due to the system's production rule ability to handle situations of uncertainty and incomplete data. This limitation is corrected in some other context-aware approaches either by substituting rule-based domain model with case-based reasoning[14] or by combining domain model with case-based reasoning[29]. Whilst these CBR approaches in context awareness address problems of incomplete data and domain specific problems, future problems that are situation-dependent cannot be anticipated due to lack of the facility to predict the state of the environment.

The work presented in this paper combines the concept of situation awareness, context awareness, case-based reasoning, and general domain knowledge in decision support. The case-based reasoning component of the system is the part that seeks to accomplish a certain task. The situation awareness component uses the context of the user to provide relevant information about the environment to be used in the reasoning process. The general domain knowledge provides explanations to the outcome of the reasoning process. The approach, apart from its usefulness in solving problems of incomplete data and domain specific problems, will also be useful in anticipating situation-dependent problems. To the best of our knowledge, no previous work has integrated these four concepts together in problem solving. This paper focuses on the architecture of the approach. The approach is evaluated for the prediction of hydrate formation in subsea gas pipelines, a scenario in Flow Assurance control in the oil and gas industry.

The remainder of the paper is as follows. The following section provides an overview of the background knowledge for the approach. We then present our methodology and the system architecture and show how it can be applied in a problem domain (hydrate formation). The system architecture and related methodology are evaluated from that application. Finally, the paper is summarized and concluded.

II. Background

Situation awareness (SA) involves a variety of cognitive processes employed by operators in a complex and dynamic environment to understand the current state of the environment in order to anticipate its future state. This concept was first recognised in solving problems for crews in military aircraft during the World War 1[20]. In the mid-1970s the US military ergonomists started investigating the factors affecting aircrew, and from then onwards, SA became an established concept[31]. The concept was later adopted by the human factors researchers for studies of complex environments[6].

A similar concept to situation awareness is the notion of context awareness. Dey[4] defines context as ”any information that can be used to characterize the situation of an entity”. A system is said to be context aware if it uses context to provide relevant information and services to the user[21]. Context awareness was introduced by Schilit[28] to develop an application that adapts to the location of use, nearby people and objects, and the change of those objects over time. With technology advancement and the rapid growth of mobile computing in recent times, context awareness has attracted greater research attention[8].

Sometimes, the term context awareness and situation awareness are used interchangeably as if the two concepts mean the same thing. For example, Kofod-Petersen et al[12] and [13] represented all the parameters for the problem description, both static and dynamic, as context at the perception (first) layer in their three layered architecture comparable to the Endsley SA model. With this single architecture, context awareness (CA) and situation awareness (SA) were discussed synonymously.

To avoid the seeming confusion over the use of these two concepts, it is important that we stick strictly to the generally accepted definition[6] of situation awareness, which emphasises the elements in the environment. Context awareness allows systems to dynamically adapt to changes in a user's task domain, by updating relevant information and service provision, whereas situation awareness focuses on information on the state of the environment in which these tasks are carried out[8]. Feng et al work in the domain of military command and control provided a clearer distinction between these two concepts in a system that used context-aware domain knowledge to provide customized decision support to users through agents which extract information from the situation awareness model to the users in accordance with user's contexts. However, the scope of the decision support of Feng's approach was not extended to situations of uncertainties and partial knowledge due to its purely rule-based nature.

Machine learning techniques have been shown to be useful for dealing with uncertain knowledge[32]. For instance, case-based reasoning is effective where the general domain knowledge is difficult to extract and instead requires reasoning based on local knowledge or where it is difficult to formulate rules describing the situations[9]. CBR also helps in situations of incomplete domain data[22]. Case-based reasoning (CBR) is one of the most effective paradigms of knowledge-based systems[14]. CBR draws from experiences of past cases in order to solve new problems. CBR is consistent with human natural problem solving methods of using a previous solution that was successful for a problem in the past to solve a similar new problem[27]. The user queries the database when trying to solve a new problem. The system searches for similar past solutions by matching and comparing the current problem to old problems. Previous solutions are retrieved based on a correspondence of the new problem to some past problems. The system retrieves a set of similar cases and then evaluates the similarity between each case and the query. The most similar case(s) retrieved are presented to the user as possible scenarios for the current problem. If the solution retrieved is applicable to the problem, the user reuses the solution, and if it cannot be reused, the solution is adapted manually or automatically. When the validity of the solution has been determined, the user retains it with the new problem as a new case in the database for future use. At this point, the case is considered to have been learnt[10].

Contexts are not cases per se but are transformed into cases or can be used to identify cases. Zimmermann [33] used contexts just like cases in a case-based reasoning system in a mobile scenario. The user context was enclosed in cases to facilitate comparison of contexts, and provide solutions based on context-similarities.

Case-based reasoning methodology presents a foundation for a new technology of building intelligent computer applications [27] but is much more useful when combined with domain models [13]. A domain model is an object model of the subsystem (problem domain). Domain analysis in addition to functional and non-functional analysis is needed to specify a system [18]. The idea behind domain modelling is that users in describing what is of interest to them during requirements capture, are not interested in, and possibly are completely unaware of the rules that apply to the situation. The way to capture these rules is by dialog with domain experts.

Khajotia et al[11] used a domain (corrosion) model with CBR to build a model for corrosion rate prediction, a flow assurance problem in oil and gas operation. The domain model in this approach was used at the CBR 'revise' stage and so it makes no contribution to the determination of the solutions but was rather used for the automated adaptation of the solutions generated. In a situation where the CBR system is manually adapted, the domain model, as presented in Khajotia's approach, will have no role to play. Shokouhi et al[29] used a domain model with CBR in a manner that the two concepts contribute to the generation of the solutions. The Shokouhi's knowledge intensive case-based reasoning (KiCBR) system was developed to find solutions to problems associated with hole cleaning, a drilling problem in the oil and gas industry, based on either the CBR or the general domain knowledge model alone, or both of them combined. The domain model in Shokouhi et al's approach is used at the CBR 'reuse' stage. The domain model provides alternative solutions and explanations through its explanation facility. Result indicated that the KiCBR approach obtained a higher similarity and accuracy than either the CBR system or domain model alone. The explanation facility of the domain model which allows the user to see what factors contribute to the problem is an improvement to a similar work by Babka et al[2] who also used a domain model at the 'reuse' stage as an alternative to finding solutions to the problem. Babka et al's work developed to predict soil settlements of reclamation areas has a domain model that cooperates with CBR in recommending to the user the most suitable solution as well as suggesting its own solution where no suitable past solution can be found from the CBR library for a current situation.

Although case-based reasoning when combined with domain knowledge has been seen to provide good solutions to problems, some problems are situation dependent i.e. the problems are partly or fully influenced by the environment. Cases of such problems contains features of the domain, and the environment, and to solve these problems the goal-directed perspective of situation awareness which requires attention on specific environmental information that will affect task performance need to be explored to improve its similarity assessment. A systematic and iterative method of monitoring the impact of situation awareness model on the combination of domain knowledge and CBR is also essential.

III. Methodology

We integrated the methodologies of action research (AR), user-centred design (UCD), and the agile development (AD) to form a comprehensive research-design cycle (Fig 1). The usefulness of action research methods is that, it links theory and practice, thinking and doing, reflects on the process and the product, achieving practical as well as research objectives[3]. It addresses two challenges, "action" and "research"[1]. In other words, action research addresses social issues in a practical fashion and also makes a contribution to developing and testing theory. This is made possible through cycles of action and reflection with the outcomes of each cycle checked against set plans and goals (Fig 1). The integration of these different methods results in a research-design process comprising three segments; scenarios, agile user-centred design,

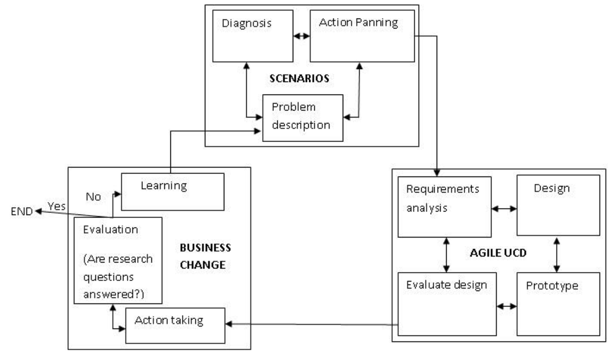

Fig. 1. Action research-design model

and business change. The starting segment of the research-design process is the domain modelling using scenarios. Even though scenarios are generated at the first segment, they evolved throughout the project lifecycle. Scenarios in our project comprised of problem description, diagnosis, and action planning. The second segment is a user-centred design by agile development method. Agile UCD is an iterative and evolutionary development comprising of requirement analysis, design, prototype, and design evaluation.

When the design process was completed, the result was taken to the research action-taking level in the business change segment, where in collaboration with practitioners, an intervention strategy was adopted to see if the design solved organisational problems. After action-taking, there was collaboration with practitioners to evaluate the outcome of the implementation, assessing the effect of the theoretical concept on practical problem solving.

We evaluated the first round of our research-design process to see if our specified objectives has been met. Our first design was short of expectation which resulted to an adjustment in our thinking that specified a new direction (learning) which again went through scenarios to agile development and then back to the business change segment. The iterative research and design cycles continued until our research questions were answered.

IV. System Architecture

This research project presents a Situation-aware case-based decision support system (SACBDSS) designed as three-model architecture; situation awareness model, general domain knowledge model, and the case model (Fig 2). Integrating these models provides the system the capability of solving domain specific problems, problems involving uncertain knowledge, and anticipating situation-dependent problems. The general domain knowledge model and the case model together formed the knowledge-intensive case-based reasoning (KiCBR).

A. Situation awareness model

The situation modelling is based on one parameter; environment. The system assesses the situation with the information about the environment. The assessment includes

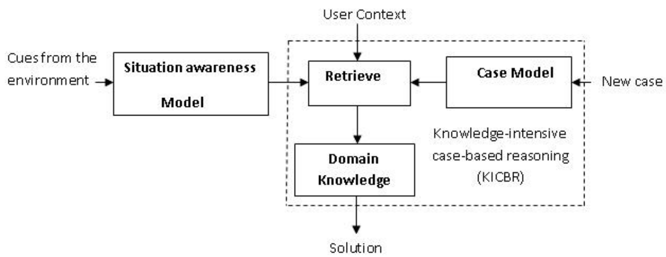

Fig. 2. Situation-aware case-based decision support system (SACBDSS)

understanding the information, comparing it with an individual user context. Context modelling in this approach is based on six attributes; goal, plan, identity, location, distance, and time. The goals define the recommendations generated by the CBR system. Plan is the action plan to achieve the goal. Identity defines the entity type under consideration. Location is the geograpical position of the entity. Distance is the position of the entity relative to a point, and time is the time to execute a plan. The model is the Endsley's 3-level situation awareness model. The model receives sensory data about the environment, interprets the data with respect to an individual user context, and then anticipate the future state of the environment.

LEVEL 1: PERCEPTION:

The recognition of the status and the dynamics of relevant elements in the environment is the first stage in determining situation awareness.The elements are the entities. Entities are objects in the environment which have attributes. The entity class in this work is the general description of an object in the environment with relevant attributes. The data structure that encapsulates all the relevant information of the physical occurrence in the environment are the events. Events in this work are contexts. An event injection causes the situation model to reassess the relevant entities attributes and their relation with each other which eventually will result in a new situation awareness. This layer recognises information from the environment and from the user and then structures the information into a coherent shape.

LEVEL 2: COMPREHENSION:

At the second (comprehension) stage, the significance of the information from the first level is determined, and integrated to form a holistic picture of the environment. This involves understanding and reconciling the user context with cues from the environment to know the current state of the environment.

LEVEL 3: PROJECTION:

To foresee the future state of the environment, there must be an understanding of the current situation. The system keeps a finite history of the time space information on the state of the environment of the entities. To predict the future situation at a point in time, statistical inference is performed over these historical data. For example, the projection function in our SA implementation is the subsea temperature. Our system kept a finite history on solar radiation, waves, and the resulting ocean depth temperatures, and statistical inference was performed on these historical data to predict the future temperature.

SA CLASSIFICATION:

Information is presented to users only if it is of relevance and significance to the users in order to reduce their cognitive load. Therefore, situation awareness model presents for solution retrieval only scenarios that are relevant and significant with respect to user's context and situation. Depending on how the SA may affect the goal attainment status of the user, SA is used for retrieval of relevant solutions in one of the three ways: Situation that have no effect on goals are presented as NORMAL, situation that may have an effect is presented as WARNING, and an extremely bad situation is presented as DANGER. A DANGER in one context may be a WARNING or a NORMAL in another context or vice versa.

The situation awareness model classify the situation by a classification rule that assigns an appropriate message level to each recognised situation.

B. Case model

The case model is the library containing past cases and their solutions. As a situation-aware case-based reasoning (SACBR), cases in the case model have both context and situation features. A user profile in the case base is a set of cases capturing previous interactions rather than a single composite case. In other words, a case is a set of time-extended cases with a start and an end point in time. A past case has a finite history of the time space information on the situation in a particular context. Predicting the problem solving method or the future of a new case is based on the assumption that every case obtains a history and a future and two cases with a similar history have a similar future[33]. The prediction of the problem solving method is preceded by the prediction of the situation of the environment, one of the attributes for the case's problem description.

The case's problem description is a seven dimensional vector of complex attributes from context, and situation (Fig 3). With user context the system retrieve from the situation awareness model information that are of relevance to the individual user. With the same context and the customized situation awareness, the system also retrieve from the CBR library scenarios that have happened in the past, in similar contexts, and for similar situations. The retrieval process for cases using the CBR tool (jcolibri) consist of pre-query processing and query-processing. The pre-query processing create an index containing statistical information for all the cases in the case base, before queries are made. The query-processing uses information contained in the index to determine the case(s) most similar to the query, using the "Nearest Neighbour" algorithm. The CBR retrieve facility also carries out pre-processing of the context and situation information,

Problem description	Attributes	Case structure
Context	Goal	The main goal or team goal
	Identity	Entity type
	Plan	Action plan to achieve goal
	Location	Position of the entity
	Distance	Position relative to a point
	Time	Time to execute plan
Situation awareness	Environment	Current situation e.g. WARNING
		Time extended future situations e.g. NORMAL-DANGER-WARNING

Fig. 3. Context and situation case representation

to decide whether the new input is significantly different from the current situation, in order to limit the number of executions of the case-based reasoning cycles[12]. A piece of information about the environment has different meanings and usages to different users depending on their individual context. Users shared context attributes except for plans and times. In the similarity assessment, the system put certain weight on the attributes. If the plan and time changes, the case-based reasoning system is able to detect the similarity value exceeding a certain threshold value, and this will trigger an event that will initiate the case-based reasoning cycle generating new action recommendations.

C. *Domain knowledge*

Scenario-based analysis is used in developing a problem domain model[25]. Scenarios are represented under three subheadings; problem description, diagnosis, and action planning. Problem description is the problem domain task description in sentences. More than one scenario is used for tasks description in order to produce a generalized domain model. Each of the scenarios updated our understanding of the problem domain as against a single scenario that will give partial information[24]. In diagnosis, the sentences are simplified to a network of propositions. The propositions are analysed to generate objects, responsibilities, interaction models, methods, and class structure. With systematic question-asking method involving some why, how, and what questions, the propositions are further analysed to generate new propositions. And lastly, in action planning, the new set of objects, interactions; methods etc from the new proposition are used to elaborate the scenario, making it more appropriate for functional requirements (use case) analysis.

The domain knowledge model is used at the CBR "Reuse" stage to provide explanations to retrieved solutions, and also to provide an alternative solution where no suitable past solution can be found from the case model.

V. Situation-aware case-based decision support for hydrate

A. *Hydrate formation*

Natural gas hydrates are solid crystalline compounds that are formed by the chemical combination of natural gas (methane, ethane, propane, butane, isobutene, isopentane, carbon dioxide, hydrogen sulphide, nitrogen etc) and water under high pressure and at temperature considerably above the freezing point of water. Hydrates are formed under high pressure and low temperature conditions inherent to the seafloor. Gas hydrates are subset of a compound known as clathrate. A clathrate compound is one in which a molecule of one substance is enclosed in a structure built up from molecule of another substance. Gas hydrate crystals look like ice or snow in appearance but do not have ice's solid structure as they are much less dense, and exhibit properties that are generally associated with chemical compounds. It is as a result of an hydrogen bond that water is able to form hydrate. The hydrogen bond brings water molecules to align in regular orientations. The presence of natural gas molecules causes the aligned water molecules to stabilize, and a solid mixture precipitates.

Natural gas coming from underground formations in the oil and gas operations normally arrives at the wellhead saturated with water. Wellhead temperatures are normally colder than that of the reservoir, which usually contain water, so that water condenses from the gas at the wellhead and enters the flow lines from the well. If the pressure at the wellhead is high, the gas may remain saturated in the flow lines or become saturated due to further cooling of the gas as it flows through the lines. The above situation results in hydrates formation in oil and gas flow lines causing flow assurance problems. The problem causes flow lines to block making the oil and gas operators to lose millions of dollars. To maintain steady flow in fields, oil and gas operators carry out flow assurance analysis which includes the prediction of hydrate formation.

B. *Hydrate situation awareness modelling*

To effectively predict the formation of hydrate, knowledge of the sea floor (the environment) is necessary in addition to knowledge of the pipelines (the domain). The environment of sub-sea gas pipelines is the ocean water. The solar radiation that hits the surface layer of the ocean water is absorbed and mixed by waves and turbulence but decreases as it sinks downward. The temperature decreases very rapidly and continue to fall slowly with increasing dept, making the deep ocean temperature to be between 0-3 degrees celcius (32-37.5 degrees Fahrenheit) depending on the location and time. This situation increases the density and decreases the temperature of the seafloor until it freezes. Situation awareness of ocean depth is one of the features of the cases in our CBR library. Situation awareness consists of three stages; perception, comprehension, and projection.
PERCEPTION: The key elements or entities for perception from the environment are solar radiation, and waves. The

system senses the incident solar radiation, wind speed, and wind direction. Wave is determined by wind speed and wind direction. The context of users; phase type, composition, pressure, geographical location, distance below sea level, and time are also recognised.

COMPREHENSION: Key parameters of the elements, such as the solar intensity, wave height, wave speed, and wave length, are identified in order to understand the current state of the ocean depth. Water waves stores or dissipate energy and the wave height contains the wave's energy. A wave's energy is proportional to the square of its height (potential) e.g a 4m high wave has 4x4=16 times more energy than a 1m high wave. The wave length determines how deep the heat can sink. With the thymodynamics equation of motion for vertical mixing, the extent at which the radiation has mixed up at an identified depth was determined.

A particular temperature means different things to different users. The system provides situation awareness based on the meaning of the temperature with respect to an individual user context which comprised of identity, plan, location, distance, goal, and time. In this work, identity is single phase binary gas, distance is the depth, location is the north sea, the goal is to predict the formation of hydrate, the plans are the different compositions of the gas, time is the hour and day to execute the plans. Users share identity, distance, location, and goal but have different plans and times. The tasks of all the users involves single phase binary gas pipelines, all at the same location, with the same goal of predicting the formation of hydrate. Achieving this goal is mostly dependent on the knowledge of the pressure and the temperature of the gas, and precise conditions in terms of pressure and temperature depend on the composition of the gas[30]. Therefore, the plans attribute which is the composition is not the same for all users. The time of carrying out the plans are also not the same.

PROJECTION: To predict the ocean floor temperature and its meanings at any particular point in time, statistical inference is performed on the database of the ocean water in a particular context to estimate the temperature and its implication in the near future. A problem is identified by reconciling the estimated ocean temperature with the hydrate formation temperature of the gases in the pipelines.

C. Hydrate case base modelling

A case in the CBR library represents a hydrate forming condition at a specific gas composition. A condition has attributes such as location, identity, distance, composition, time, and situation. To make a case, all the the relevant environmental and contextual data are analysed and a problematic condition is captured as a case.

The retrieved preventive and remediation measures are reused by the engineers. Where these solutions do not provide all the answers to a hydrate formation threat, the solutions are adaptated. Flow assurance engineers are allowed to feel in control by allowing them to analyse the formation threats and manually adapt the solutions. The successful preventive and repair activities are stored for the future use.

D. Hydrate domain modelling

The plan attribute comprises of the volume and the pressure but without the temperature of the gas. An appropriate temperature corresponding to the volume and pressure is retrieved by the CBR. To use domain knowledge to provide explanations to the retrieved case, our system used published data[15] of pressure and volume of ten different pipelines P1-P10 to calculate the hydrate formation temperature. The pipelines has fixed volumes of gases with varying pressures. Published data was used because access to oil and gas industry experts for data and knowledge acquisition are limited.

The system used the combined gas model to find the hydrate formation temperature of the gas and the results of these calculations were almost the same with retrieved gas temperatures.

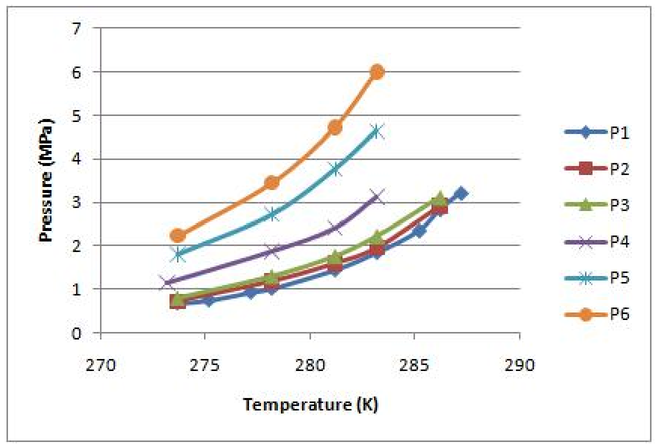

Fig. 4. Phase envelope

Fig. 4. presents the hydrate formation temperatures at different pressures for P1-P6.

VI. Evaluations and Results

The case base contains sixty seven cases of hydrate forming conditions. Using the linear Nearest Neigbour similarity framework, the case matching for the Knowledge-intensive case-based reasoning (KICBR) alone, and the situation-aware knowledge-intensive case-base reasoning (SAKICBR) will be presented. The 10-fold cross-validation technique is used to evaluate the methods. In the first three test datasets, seven cases are taken out of the case base and matched against sixty one train cases, and in the remaining seven test datasets, six cases are taken out and matched against sixty one train cases. The KICBR method had a mean accuracy of 0.6 in all the ten different evaluations with number of matches ranging between 404 to 453. The accuracy of the SAKICBR method for the same number of evaluations was 0.7 with number of matches ranging between 490 to 512. The mean accuracy and the best matches are summarized in table 1 and table 2 respectively.

In the matching results of test cases, the two methods retrieved the same best match for only a few test cases. In most of the retrievals as shown in table 3, the best match for the

TABLE I
MEAN ACCURACY

Evaluations	1	2	3	4	5	6	7	8	9	10
KICBR	0.64	0.65	0.64	0.62	0.60	0.60	0.66	0.64	0.67	0.61
SAKICBR	0.76	0.76	0.75	0.76	0.75	0.75	0.74	0.73	0.73	0.74

TABLE II
NUMBER OF MATCHES

Evaluations	1	2	3	4	5	6	7	8	9	10
KICBR	430	436	432	422	404	406	447	429	453	411
SAKICBR	512	510	503	510	504	504	500	493	490	501

unsolved cases are different. For example, having case 22 and case 40 as test cases, the retrieved cases as best matches for the two methods were case 30 and case 51 respectively. But in case 3, case 10, and case 62 as test cases, the KICBR retrieved case 45, case 40, and case 22 respectively as best matches. For the same test cases, the SAKICBR retrieved case 49, case 1, and case 18 respectively as best matches. Without the automated adaptation function this system requires additional human reasoning, increased participation of the engineers in evaluating the solutions and deciding if it can be reused. The engineers analysed the retrieved cases to decide on the solutions that are more relevant.

For instance, evaluating case 45 retrieved by the KICBR and case 49 retrieved by the SAKICBR as best matches for the test case 3 revealed that the risk of possible blowout in "‘direct heating "‘ recommended by the KICBR is high. The preventive measure recommended by the SAKICBR through case 49 is "antiagglomerant additive and/or presence of natural surfactants". This measure allows hydrate crystals to form but size of the particles is limited and transported within the hydrocarbon phase as a suspension. According to experts, the measure requires minimal cost for seperation at the processing plant, which is preferable compared to the danger prone direct heating method.

For the test case 62, engineers evaluated the solution of case 22 retrieved by the KICBR and the solution of case 18 retrieved by the SAKICBR. The solution of case 22 is "amonia injection" and that of case 18 is "‘depressurization"’. By expert analysis, the cost of chemical injection is huge and it is always considered as the last option. Careful analyses of the solutions by the experts revealed that the condition of case 62 is still within the scope that "‘depressurization", a cost effective measure, can control.

TABLE III
SIMILARITY ASSESSMENT

Test case	case 3	case 22	case 10	case 40	case 62
Best case by KICBR	case 45	case 30	case 40	case 51	case 22
Best case by SAKICBR	case 49	case 30	case 1	case 51	case 18

The effect of integrating situation awareness to case-based reasoning, particularly knowledge-intensive case-based reasoning was observed by changing not only the similarity but also the retrieved cases. The results shows a good and significant improvement in both similarity assessment and problem solving prediction.

VII. CRITICAL ANALYSIS OF THE APPROACH

Carrying out domain analysis with practitioners using scenarios provided us the understanding of the domain activities, the social settings, resources, and goals of users[17]. The evolutionary and question-asking process of scenarios filled our knowledge gap about the domain[23] and acted as a communication mechanism between the users and the user-centred design process. Methods such as interviews, surveys, and field studies are well suited for scenarios. Any or a combination of these methods, provide good understanding of who users are, why they need the system, and in what context they are going to use the system[16]. We carried out a combination of interviews with field studies in our domain analysis. The application of these methods is by a collaborative work between researchers and practitioners but we discovered that access to domain practitioners can be difficult for an effective collaborative work. In situations where researchers cannot exploit all the required methods due to non availability of the practitioners or where information are being withheld by practitioners, the domain analysis may provide inaccurate or incomplete information for requirements tasks. For example, we planned to build the domain model with the Cheng Guo hydrate model. We carried out a study of the model with practitioners up to a point where it was difficult for the two groups to meet. The stoping point was actually where the key parameters for building the model were to be analysed. As an alternative to enable us complete the project, we used the simple general gas model. Some specific hydrate attributes could not be analysed with the general gas model which resulted to some assumptions. In the next iteration, we shall start discussion with experts by defining key parameters of the chosen hydrate model.

Designing for situation awareness is a user-centred design process[5]. By focusing on user-centred design, we developed understanding of the user, understanding of why we are developing the system and who will be using the system. As the UCD process ensures an understanding of the users, the agile development model ensures that we can work iteratively, enable faster development of a functional prototype, which are more easily communicated and tested, thus giving us better input for the next iteration. The two methods complement each other. The agile iterative development is more appropriate for the user-centred design process, as evaluation in agile development is done many times during the project to give room for a change in direction if necessary. Where there is need for a change, the constant evaluations enable us to redesign at an early stage, saving time and resources. This approach requires engagement from everyone involved in this project; ourselves, and the practitioners. This highly collaborative way of working ensures that any problems that would have arisen are noticed at an early stage. This iterative process is strenuous but it yields the desire results. However, we hope to end or reduce the number of iterations in the next round of our research-design cycle by being more detailed in our interviews, field works, and analysis, in order to capture all the essential domain information for the completion of the project.

This agile development approach uses elaborated scenario from domain analysis as the basis for requirements analysis. The object-oriented method using the Unified Modelling Language (UML) was used to explore and model the requirements and the functional specifications of user-system interactions to achieve a user-centred design. Like scenarios, interviews, surveys, and field studies are also used for requirements analysis. Without effective collaboration of practitioners with researchers, users requirements will also not be properly captured thereby making the analysis inaccurate. Action research method provided us the platform to collaborate with practitioners to effectively capture users requirements. We shall adopt the same detailed approach in the users' requirements capture in the next iteration for us to draw the end of the project life cycle closer. Combining action research with agile user-centred design enable two things to be achieved simultaneously, thus providing the opportunity for collaborative process of progressive problem solving between us and practitioners to solve organisational problems.

VIII. Conclusion

We have shown in this work that knowledge-intensive case-based reasoning (KICBR) can be made more promising in problem solving by integrating it to situation awareness. Using knowledge of the state of the environment together with the user context to provide solution in situation dependent case-based decision support improves similarity assessment and problem solving prediction than using the user context alone.

We have also presented a method of integrating an iterative research process with an iterative design process to form a comprehensive research-design process. The usefulness of the method has been discussed. In the next stage of our work, we shall reflect on the lessons learnt from this implementation for example, the general gas model which is handicaped in providing all the required explanations. We aim to build the next explanation facility with a more robust domain model.

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