IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 25, Issue 2, Ser. II (Mar. – Apr. 2023), PP 39-48
www.iosrjournals.org

Application of Situational Awareness in Healthcare Delivery: A Catalyst and Panacea in ensuring Efficient Healthcare System

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Abstract
Technological developments in healthcare have saved countless patients, it could save more lives. It is continuously improving our quality of life. Technology in the medical field has had a massive impact on nearly all activities and practices of healthcare professionals - Electronic Health Records is replacing our old paper and file method. First, the evolution of technology is beneficial to humans for several reasons. At the medical level, technology can help treat more sick people and consequently save many lives and combat very harmful viruses and bacteria infections. The invention of the computer was a very important point. Improving quality of life is one of the main benefits of integrating new innovations into medicine. Medical technologies like minimally-invasive surgeries, better monitoring systems, and more comfortable scanning equipment are allowing health professionals and patients to spend less time in recovery and more time enjoying a healthy life. As healthcare organizations face unprecedented challenges to improve quality, reduce harm, improve access, increase efficiency, eliminate waste, and lower costs, innovation is becoming a major focus once again. The healthcare industry is on the brink of massive change. In this research work, to predict diseases among children, an expert system applies a set of rules (A list of rules or rule base, which is a specific type of knowledge base) to make deductions or choices from a cluster of symptoms that was built into a database. The similarity between cases in the case base is very important in this work. The methodology for this study revolves around six phases which are data and knowledge acquisition, data and knowledge analysis, construction of rule based reasoning and case based reasoning structure, development of the healthcare reasoning model, and lastly, the validation of the model. Most AI research in the past adopt either CBR first or RBR first, but in this study, an interwoven approach was implemented. Data acquisition was achieved by reviewing medical documents and interviewing domain experts; inclusive was a thorough epidemiologic and environmental expert knowledge that can increase our knowledge of any given disease and prevent future outbreaks. The comparison results between the model and human expert reveal its efficacy/potency.

Keywords: *Diagnosis, Healthcare, Surveillance, Situational, Awareness, Electro-mechanical, Automation, Complexity, Incontrovertible, Mitigation, Reasoner.*

Date of Submission: 01-04-2023 Date of Acceptance: 13-04-2023

I. Introduction

During severe medical operations, like possibly during emergency, personnel mental workload is high and situation awareness is likely to be low when facing unexpected situations which may lead to human errors and thus the task could be imperfectly delivered. It has been observed that in human-system studies more focus are on technical elements rather than on human factors, because of the reliability of present day hardware. For this reason, more and more human factor researchers are focusing on finding an effective way to reduce the mental workload and improve the situation awareness of operators. It is believed that if mental workload is highly reduced, more time will be deployed towards achieving effective service delivery; eventually reduce error (human error), add more trust to customers and save more lives.

For us to prove to have taken good care of human error, we must show that information gathering, planning, decision–making, demonstration that the facility is fit for its intended purpose, and ensuring that the risks associated with its operation are sufficiently low are all taken care of (Melchers 2001).

As Safety-critical environment as the healthcare sector seems to be, knowing that its hardware failure and poor or late decision-making by operators could result in loss of life, significant property damage, or environmental pollution, care must be taken in assembling what it takes to work in the environment.

In medicine, errors of diagnosis is a human error that is common; though with very devastating effect, it is a worrisome issue to the entire healthcare system. Eradicating it through human efforts is very difficult despite the number of years of experience of the physician; the only way of curbing it is through analytic.

Making good and reliable diagnosis may have to depend on so many factors that include effective communications among team members, their knowledge and length of experience (knowhow) familiarity with working tools, fitness of tools, and even laid down rules and procedures. When a team member observes a situation and fails to speak out may pose danger to the overall effectiveness of their delivery. Let take for example where a patient from an accident was rushed to a clinic and the only personnel available is one that does not understand the tools, the handling of a badly injured patient is either to wait or may end up being worsened. In this scenario, both waiting and taking action may not help at all. Alternatively, meeting a team where some members out of fear will not contribute to the overall aim will also jeopardize the outcome as well.

Medical personnel are not expected to totally predict the future course of patients' illnesses but are required to take the case to a reasonable care level, such that the use of situational awareness was fully complied with from when the patient was brought in till the eventuality occurred- whether good or otherwise to the contrary. To be exempt from blames and litigations, healthcare personnel should have been alert to the condition of their patients, being ahead of the situation and expecting problems and or using advance analytic thinking aid – this is where technology comes handy, its implementation is inevitable.

In healthcare situation awareness means among so many purposes management of emergency and to collect and transmit disease surveillance data, but situational awareness is termed highly effective when the information is before the right person who is ready to analyze and make good use of it.

It is expected that clinicians, nurses and technologists in the healthcare setting should be made to undergo simulation test so as to ascertain their levels of knowledge and understanding of their job before real engagement with patients. This test will help to determine if the personnel is trained enough or should be referred for more internship training. This simulation may go a long way to tell the state of equipment and it will also form part of testing of equipment put in use in the foregoing setting. The after effect may lead to system redesign or outright changes – when series of simulations show that trainers are not getting it right as a result of not their fault but that of equipment, where will the change be, of cause the equipment.

II. Review of Literature

Correct diagnosis is very important in medical practice but its error is common, dangerous to the sick ones and costly to everybody (Thomas et al, 1990; Thomas et al, 2000), both care givers and receivers; and research has shown that such errors are still not taken care of (Graber M, 2005; Schiff et al, 2005; Kuhn G J., 2002) maybe because of subtlety of the errors. Such an error can be prevented through use of system (Gandhi T K, 2005) and cognitive (Redelmeier D A, 2005) approach via situational awareness.

Errors of diagnosis attributed to systems include breakdown in equipment. This can be corrected by re-designing of systems already in existence to facilitate physicians' clinical decision making processes and to provide a fail-safe work environment. This will lead to a reliable organizational structure that can minimize diagnostic errors (Schiff et al, 2005; Kuhn G J., 2002; Gandhi T K, 2005).

Cognitive Psychology is another important approach, which is the process that helps the physicians to reason, formulate judgments, and make diagnostic decisions (Redelmeier D A. 2005**;** Croskerry P. 2002; Croskerry P. (2003).

According to Nazir, Colombo, and Manca, (2012), the idea of situational awareness was identified during World War I where it was acknowledged as an important flair for crews in military aircraft by Oswald Boelke. He was the first to realize the importance of gaining an outstanding and informative awareness of the enemy before the enemy gained a similar alertness, and devised methods for accomplishing this, but the idea did not receive much attention in the technical and academic literature until the late 1980's when the works of Endsley started showing up in technical/academic journals. In short, it is worthy to note that Mica Endsley was a pioneer researcher in the area of Situational Awareness, focusing majorly in the aviation sub domain.

The idea of Situational Awareness did not gain much attention in the academia not until the late 1980's. Today, it is a sought out idea, both in industry and academia. Most of the research in situational awareness is not only in Aviation again, but in the areas of medicine, marine, aerospace, emergency response, military command, offshore and nuclear plant and control operations, etc.

The very first place where attention in the field was placed was on pilots and air traffic controllers, as well as the cockpit having good situational awareness of the airline, whether flying or landing (Hinrich, 2008; Cak, 2011). This must have arisen from the importance that government, corporate and individuals place on the safety of air transportation. An American company, the Douglas Aircraft Company was quoted to have used SA. They used it during human factors engineering when developing vertical and horizontal SA displays for aircraft, which was to replace the multiple electro-mechanical instruments. In a bid to enhance and increase efficiency in piloting leading to improved access to critical flight parameters and improve situation awareness, information from several instruments are pulled together into an integrated situation display. Application of SA has to a great extent immensely reduced air transport mishap the world over (Dekker, 2016).

The US air force was said to have applied SA in the Korea and Vietnam wars, this was before its application by human factors scientists in the 1990's. They used it in air combats against enemy fighters, as they were able to figure out the enemy's move ahead of time - a fraction of a second before he could observe and anticipate it himself (Nardon, 2007).

It has been demonstrated that the degree of automation in flight control, which started surfacing from early 1980 was one major reason for increased interest in research and studies in situational awareness. Because of the fact that automation brings to bear the complexity of operations, increased realization that system design is no longer best optimized for human operation and, under some conditions it is beyond human capability. At this point bringing in artificial control 'power' becomes inevitable (Sheridan and Raja Parasuraman, 2006; Koeppen, 2012).

In the aviation industry, the re-designed cockpit was one real problem pilots were facing in the industry. The new one with few CRT that replaced the older traditional cockpit made up of multitude of dials have distanced the pilot from the SA of the aircraft. With the new cockpit, the pilot is required to access a set of CRT displays in a sequential order. The older system has a greater workload but better SA than the modern one that uses displays (Singer, 2002).

What is Situational Awareness?

Situational Awareness, as defined by Davis (2016), is all about being fully engaged and aware of one's environment and any current or potential dangers to health and safety in that moment or later in case of an event, either to oneself or others. Situational Assessment is an organized process to collect, examine, blend and disseminate data in order to inform planning decisions (Meserve and Bergeron 2015; WHO, 2019). Situational assessment is also the process of achieving, acquiring or maintaining situational awareness (Endsley as cited by Endsley Mica, 2015). The assessment is not just about collecting facts and describing the epidemiology of the people but should produce a detailed and total report about the future health issues and their solutions, considering the current situation as compared to the yearning and needs of the populace (WHO, 2019).It can also be defined as an assessment of the current health situation that is fundamental to designing and updating national policies, strategies and plans in the health sector. Information from a situational assessment can be used to inform the development of program goals, objectives, target audiences, and activities (Dheepa, 2016). It is supposed to be done as a key initial step in the development stage and subsequently at least once during the health policy and planning cycle, and updated every few years, because an updated, in-depth procedural analysis that includes stakeholders' viewpoints is an invaluable resource for the whole healthcare delivery sector (WHO, 2010).

It is aimed at assessing the current state of the healthcare situation with all its attributes and challenges; as well as the provision of evidence-informed basis for responding to the needs and expectations of the entire population in terms of their health care. It is also used as a means of seeking ways of formulating strategic directions for the healthcare sector (WHO, 2019).

It is an important exercise because it is a crucial step in the planning phase and gives a recognizable voice and a solid platform to all health sector stakeholders, including the population. It will lead to increase in accountability and transparency. It will also be a good support and will as well strengthen monitoring and evaluation, and will contribute to concretizing roles and responsibilities. It will lead to the establishment of consensus on the status of healthcare in any country (Dheepa, 2016).

Use of SA in Tackling and Mitigating Health Issues

While we may not say that either of CBR or RBR will sufficiently handle a problem at a time, we decided to come up with a hybrid system of combining the two (see figure 1), it tries to combine CBR and RBR methodologies as depicted in figure 1 below. The reason was as a result of the failure of either of CBR or RBR used separately to yield desired results (Prentzas and Hutzilygerous, 2009). Therefore, while the CBR will be the custodian of how the cases are searched from the case base, the RBR will support in refining search result (Lee, 2002; Robin, Burke 2003).

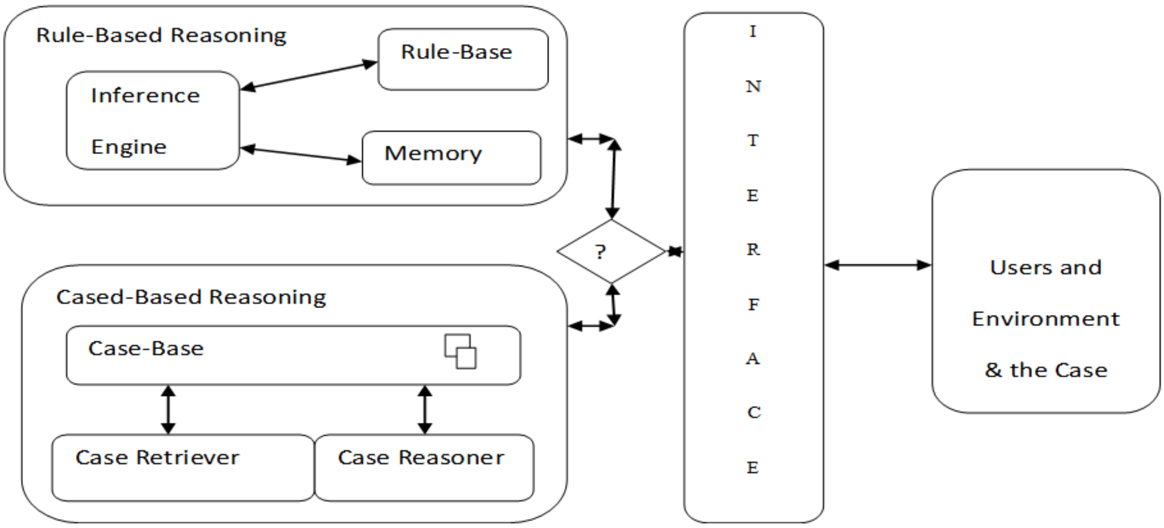

Figure 1: Hybrid System combining CBR and RBR: Efficient Disease Prediction and Control Model, EDPC (Adapted from Mariana Maceiras Cabrera and Ernesto Ocampo Edye, 2010)

Several studies have shown the short comings of either the case-based reasoning (Becerra-Fernandez, et al, 2004) or rule-based reasoning (Becerra-Fernandez, et al 2004; Prentza and Hatzilygeroudis, 2009; Begum, Ahmed & Funk, 2009; Endsley, 2001) not returning quality search results from the case base (knowledgebase). It is obvious that when such is the case, the whole aim of assistance to the clinician, nurse or midwife in a very tight corner is defeated. The physician finds out that he/she is almost overwhelmed; same is the patient and all those that care for them. In most of the time, the best-match retrieved case will not match the target case perfectly, and in this project for that reason case-based reasoning systems will usually be combined with rule-based reasoning for adapting or tailoring the specifics of the retrieved case to that of the target case (Avdeenko and Makarova (2017), Jim Prentza and Ioannis Hatzilygeroudis, (). The RBR is to serve CBR as an added advantage and for the refinement of the search result from the case base (Robin Burke 2003).

The wisdom of learning from failure is incontrovertible, yet a few organizations do well. The problem is not lack of commitment to learning, but over dependence of Managers on learning failures the wrong way (Edmondson, 2011).

In addition to corrective control measures, it is possible to use preventive measures. Rather than wait for the error to occur, it is good to look out for its signs and then stop it using available solutions (Korkali, Veneman, Tivnan, Bagrow, and Hines, 2017). For example, the solution could be applied once the system is under stress, maybe some of the elements are overloaded, and to avert some serious problems before it unfolds. Figure 2 clearly indicate when a system is under stress and what could be the end result. A predictive control strategy could be applied to save every hazard before they occur **(**Rezaei, 2016; DMI, 2019)**.** One of the preventive measures was to train all staff adequately, and force them to be situational aware in the workplace (Stubbings et al., 2012; Edozien, 2015).

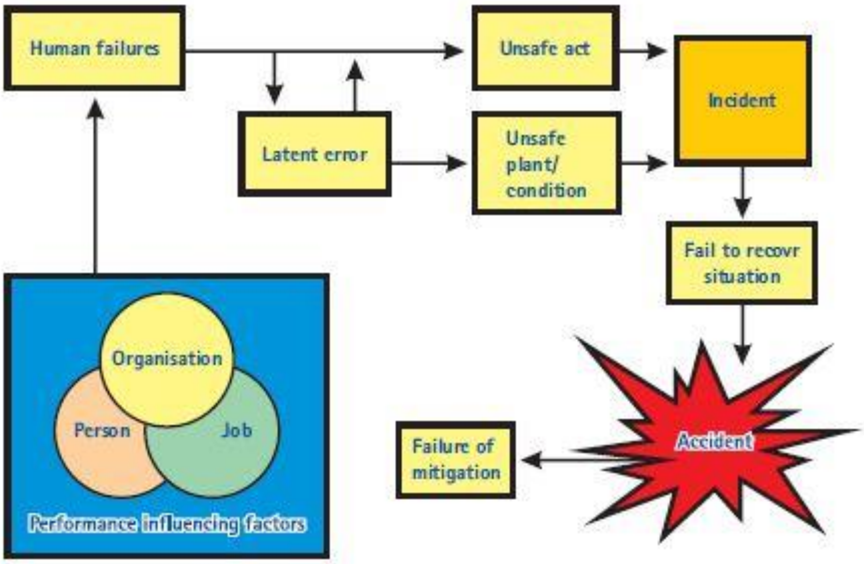

Figure 2: A system under stress and the causes of the stress (Source: http://www.hrdp-idrm.in/) (Accessed 23 September, 2019).

Situations that are approaching disaster are mitigated by calling upon more experienced personnel to handle, as shown in figure 3. Such situations are eliminated if proper monitoring were being done by nurses in case of healthcare; temperature of patients were taken at regular intervals, if not disaster is doomed already (Alano, 2006; McCallum and Higgins**,** 2012).

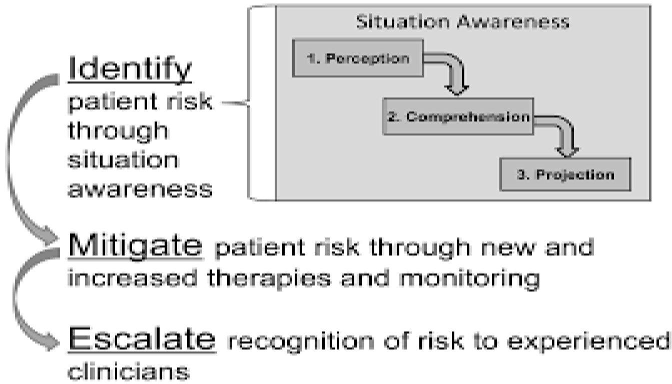

Figure 3:Flowchart illustration of corrective measures to human failure (Source: https://www.qualitysafety.bmj.com)(Accessed 23 September, 2019).

You can also mitigate situational awareness failures by having staff briefing at regular intervals (USAID, 2010; Miller and Bullermer, 2013). This will be helpful in pruning down likely errors from inception, as indicated in figure 4. This is possible by planning from inception of a job on ways of avoiding errors. Jobs that are highly likely to pose hazards ought to receive tool box meeting prior to starting time. Such briefing should highlight precautionary measures and gray areas ironed out (Phillips, 2014).

Figure 4: Pre-job briefing (Source:https://www.ask-ehs.com/) (Accessed 23 September, 2019).

Operating theatres and emergency units should be given regular and routine inspections on regular basis to make sure that all apparatus that are necessary in the system are in good working condition; such inspection should be carried out on all equipment whether such equipment is likely planned to be used presently, in the near future, or not planned at all.

The same regular routine check applies to every part of the healthcare system. All equipment should be at best working capacity (DMI, 2019). Special attention should be given to the emergency unit; if possible all equipment should have their spares, or best have alternatives (WHO, 2011; AEA and WHO, 2005).

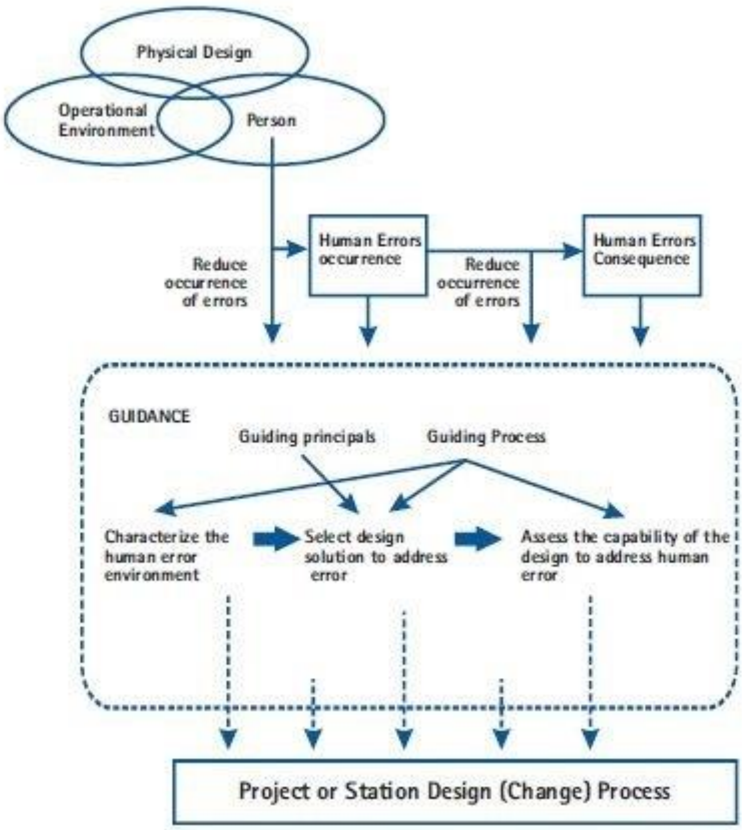

Figure 5: Project Planning Stages and inculcation of human factors (Source: www.ilocis.org/) (Accessed 22 September, 2019).

The idea that two near misses is equal to one mishap, as practiced globally in the oil and gas sector, should be taken seriously. Minor incidents should be handled appropriately; these approaches can be used to avoid the losses associated with more serious mishaps. Having tracked down failures in smaller units, the idea can be used to handle situations in more complex areas. This can help to curb / minimize cost that could have been attributed to more serious mishaps (Johnson, 2003). It has always been a good practice to note that a health care system that mitigates patients' risk will be safer and will cost less (Brady, Wheeler, Muething, Kotagal, 2014).

Another source of failure is as a result of human error that crops in the line of operation through stochastic equipment failures, deliberate violations of regulations and bad working practices in places where rules and regulations are not forcefully applied (Hansen, 2006). Systems should be designed in such a way that good conceptual model is a watchword, with good interface (DMI, 2019), having process and automation behaviour as predictable as possible just, as in figure 5.

III. Discussion

Situational awareness provides users with a more appropriate amount of information at the appropriate time, as well at a good response time. This research has suggested that since users are going to use this system on an everyday basis, they should be part of early design and implementation; this will reduce delay and cost as well as lead to an efficient end-product. Most systems that avoided users from planning to end-product end up being unstable.

It is important that all team members should have full situational awareness of their theatre, because it forces all users to have knowledge about the whole process. As mentioned earlier, it is important that the operators/users have knowledge about everything - it is not sufficient that one only knows a lot about one part of the process and a little about the rest.

It is important to have a thorough testing of the system before it is handed over to the final users. This will remove bugs and other unnecessary delays that may prop up in the future. After the testing process, and if a decision to go with the new solution is taken, all the users have to go through a training programme to get the best outcome as possible, more especially in complex places like chemical or nuclear plants.

CBR

Case-based reasoning is a prototype in which facts are represented as a set of individual cases, or a case library, that is used to process / classify, or more generally, reason about or solve complex problems. A case is defined as a set of features, and all cases in the library have the same structure. Case-based Reasoning (CBR) solves new problems by retrieving previously solved problems and reusing the corresponding solutions (Burke, MacCarthy, Petrovic, and Qu, 2000).

The idea is to have user context encapsulated inside cases to facilitate comparison of contexts, generating recommendations based on case similarities, and learning of user behaviour.

A case is defined as a set of features, and all cases in the library have the same structure. In figure 11 when a new problem, referred to as a target case, is presented to the system, it is compared with all the cases in the library, and the case that matches most closely according to a similarity metric defined over a subset of the case features called *index features* is used to solve (or reason further about, respond to) the new problem.

RBR

According to (Angeli, 2010; Vorgelegt, 2001) rule-based systems are facilities that can store and manipulate knowledge so as to yield useful information. They are widely used in AI research and applications. Normally, the term rule-based system is applied to systems involving human-crafted or curetted rule sets (ibid).

1 RBR comprise of rules or the rule base, it is a type of knowledge base – more like a database.

2 It also has an Inference Engine or Semantic Reasoner, this infers information or takes action based on the interaction between the input and the rule base. The interpreter goes through a match-resolve-act process as follows:

Match: The matching is achieved by merely comparing the left-hand side of all productions with what is inside the working memory. The matching will result in a conflict set of instantiations of satisfied productions. The new set is an ordered list that satisfies the left side of the production.

- Conflict-Resolution: What happens here is that one of the productions is executed. The interpreter will go into a halt scenario if no productions are fulfilled. Act: Lastly here the execution of the selected production takes place. The contents of the working memory may have to alter here. At the end of this phase, execution returns to the first phase (Cowan, 2016; Desposito and Postle, 2015; Mernissi, 2017).

Rules are defined in the form:

IF $condition$ THEN $conclusion$ AND $action$ (Alvarez, 2016)

In the above conditional statement, the condition is the disjunctive form of literals; conclusion is a list of literals, while action is a list of actions. The rules could be seen as a network comprising of nodes (propositions) and arcs (rules).Three types of propositions can be noted according to their position in the set of rules. First, questions are propositions only occurring in conditions, goals are propositions only occurring in conclusions, and thirdly intermediate propositions can occur both in conditions and conclusions.

IV. Conclusion

We have seen that CBR introduces problem solving and learning as two sides of the same coin: problem solving uses the results of past knowledge episodes while problem solving provides the backbone of the understanding from which knowledge increases.

Having high situation awareness and understanding of what is going on in a situation is important when working in complex places like theatre rooms, as in times of resuscitation. Decisions taken at such times are done frequently - in such a stressful and challenging environment.

As the operators work in teams, it is important that the operators have some of the same understanding and a common mental model of situations. If in all our daily routine, be it in office, home, on the way or while relaxing, we consider the term, 'what if', then most of the casualties we encounter may be a thing of the past. Why do I say so? 'What if' will help one to employ all avenues that will remove human errors in our activities.

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