

**Intelligent Software**  
**How it can be used to improve safety and training methods**

**Raymond Gillett**  
**Warsash Maritime Centre**

**&**

**Professor Tom Addis**  
**University of Portsmouth**

## **Intelligent Software**

### **How it can be used to improve safety and training methods**

For a ship to be run in a safe, efficient and cost effective manner requires a balanced combination of the right equipment and control systems for the tasks it is expected to perform together with sufficient numbers of personnel who are skilled in the relevant areas. In recent years this balance is becoming increasingly more difficult to achieve not because of problems with the equipment, which is constantly being improved, but because of a lack of availability of personnel with the required skills.

The latest research indicates that the industry will need to recruit and train in excess of 50000 people during the next 10 years to meet the demand. In the UK alone the figure is put at 1200 per year and yet the current recruitment rate of around 450 in 1999 indicate that these targets will be unlikely to be achieved. At the same time, a number of large operators have recently decided to replace personnel from developed nations with many years of experience with crews from the developing countries with limited experience. This is because of the lower operating costs that can be expected and because of the difficulties they are having in recruiting and retaining personnel from traditional sources.

Changes in work practices on board are also having an effect on the skills of personnel. Evidence is emerging that through the introduction of quality management systems and the International Safety Management (ISM) Code, personnel are actually becoming less skilled in the tasks they are expected to perform. This is primarily due to the nature of how quality systems are implemented through the use of set procedures. Consequently, because of the fear of recriminations, personnel will tend to adhere to the procedures with very little thought to other possible methods. In addition, because of this new culture, evidence also shows that new personnel are not learning the required underpinning knowledge.

These problems could be addressed by ensuring that personnel receive suitable training. However, such a policy is currently awkward to implement because:

- If a company is experiencing difficulties in recruiting personnel then there will not be the excess of staff to allow those requiring extra training to attend the necessary courses.
- Because of competition in the market place and the training costs involved companies will tend to concentrate on ensuring their personnel obtain the mandatory training with very little available for the extra training that may be needed. What training is given will tend to rely upon the traditional methods that are becoming less and less viable.
- There are limited training resources, such as the required hardware and skilled instructors available, who can successfully provide the extra training ashore.

Some of these problems can be overcome, to some extent, by using more sophisticated control systems. However, a majority of these systems are still based on logic control circuits that check conditions of single items that are then used to provide some form of non-specific indication to the operator such as alarms. Some of the more advanced systems are combining the results of a test on a condition with an element of controlling items such as valves. This approach goes some way to relieve the operator from the need to consider such a decision. However, they are still only looking at individual items and are not taking into account the possible consequence of any controlling action that is invoked. The latest systems also include some guidance to the operator by providing lists of possible causes if a warning light is displayed. However, in all these cases, the operator is still required to use his skill to be able to assess the correct action to take in the context of the total operation.

Even where personnel are available who do have the skills then because of a general lack of able manpower to assist, their ability to continuously monitor situations and undertake the multiple tasks that are required, is impaired significantly. This is often coupled with fatigue which can further compound the situation. This in itself may lead to the non-recognition of developing problems or at least restrict their capacity to identify and implement actions that may optimise operations. In the worst case somebody without the necessary skills may:

- not have sufficient knowledge to be able to even identify if a problem is developing or has occurred.
- not understand the consequences of the problem or his actions
- not be able to identify a problem or propose a correct solution

This case is more than just risky; it is a hazard to the ships, the personnel and the environment.

It is obvious that there will be a continuing lack of personnel with the necessary skills for some time into the future. One way to deal with the problem is for companies to limit their activities to the capability of the skills that are available. Not only is this just a short-term solution but also it does not provide a basis upon which to successfully grow a business, and in the long term the industry will not be able to provide the service demanded of it. That being the case other means of addressing the problem have to be found if the industry is to be able to continue to operate safely and efficiently.

To succeed, any approach has to be able to maintain the balance between the capabilities of the control systems installed and the skills available in the personnel.

One approach would be to look at new methods of providing training to the personnel to overcome some of the problems already highlighted. Most of the costs associated with traditional training methods relate to travel, accommodation and the provision of cover whilst the training is taking place. One way this could be reduced is to expand the provision of on-board training. On the job training will not normally work due to the limited skills and time available. Consequently this either has to be done by providing travelling tutors that are very difficult to justify for small audiences on each vessel, or use the expanding computer capabilities to deliver the training via a form of Computer Based Training. However, to address the multitude of skills beyond the basic, which is where the problem lies, will require a new approach to how computers can be used. The training software packages that are commercially available currently cannot cope with these more sophisticated needs.

The other approach is to build the control systems so that they are able to provide a lot more assistance to the operator. However, the limitations on what is currently available also apply here as well.

Warsash Maritime Centre have addressed both problems by developing new computer systems incorporating Intelligent Software that can be used both to provide a new approach in training provision and also to considerably enhance the capabilities of control systems.

The use of intelligent software within training systems will:

- Enable the development of systems that incorporate the knowledge and expertise of instructors reducing the need for the student to have access to supervisors or tutors to undertake the training.
- Enable the development of complex portable systems which will allow the training to be undertaken when and where convenient and be made available to a much larger audience

Similarly, its use within on board control systems will:

- Allow the expertise of highly skilled operators to be encapsulated within the system allowing it to provide intelligent guidance to the operator in the event of a sequence of conditions occurring and possibly initiate pre-emptive action.
- Provide a consistent and coherent monitoring system that will not be subject to reductions in attention or changing personnel and is adaptive to the context of an operation at any given time.

## Intelligent Software

Since the original construction of the first computer there has been a branch of computer science which has concentrated on programming computers to behave in a similar way to people by emulating thought processes and behavioural skills. The object of this development is to enable computers to undertake more of the tasks that usually have to be done by people as well as providing a formal framework in which to explore models of the human state. The term Artificial Intelligence was coined in 1956 by John McCarthy at the Massachusetts Institute of Technology and has been used since as a general description for many techniques that have tried to create intelligence within a machine. Some of these techniques include though are not limited to:

- **game playing:** programming computers to play games such as chess and checkers that usually involve trying to always achieve a unique goal against an opponent. Much of the ideas evolved from the mathematics of game theory derived from gambling and decision making (von Neumann 1928). Models of problem solving proposed by Simon and Newel in the late 50s influenced later techniques.
- **expert systems:** programming computers to make decisions in real-life situations (for example, some expert systems help doctors diagnose diseases based on symptoms). These encapsulate a defined set of knowledge with predictable outcomes. Most expert systems have been previously developed for a single application, such as those that can diagnose human illnesses, make financial forecasts, and schedule routes for delivery vehicles. Some systems are designed to take the place of human experts, while others are designed to aid them.
- **natural language:** programming computers to understand natural human languages. This has had some success in automatic dictation requiring the adoption of certain skills by the human user. It has only had partial success in automatic translation mainly because of the problems of the continuous evolution of natural language and its strong dependence on context; this defeats fluent translation.
- **neural networks:** systems that simulate intelligence by attempting to reproduce the types of physical connections that occur in animal brains. These systems learn as they progress and consequently the results can be difficult to predict,
- **fuzzy logic:** attempts to capture some of the fluidity of human concepts in a formal representation. In limited cases it has been successful but cannot capture the full range of context dependent adjustments.
- **robotics:** programming computers to see and hear and react to other sensory stimuli. The notion here is that by trying to solve the same engineering problem that nature faces then this should produce some valuable insights. The most advanced elements of AI that have been stimulated by this approach is in visual interpretation and the dynamics of jointed limbs.

In the early periods of development these techniques were implemented through a combination of hardware and software. Today almost all implementations are achieved by the use of software.

Currently, there are no computers available that can exhibit full artificial intelligence (that is, are able to simulate true human behaviour) and this is likely to remain the situation for many years into the future. At first sight the reason seems primarily due to the limitation on computing power that is currently and predicted to be available, even in the largest supercomputers. However, the large advances that have been made in the processing capabilities of modern computers in the last few years means that it is now a realistic proposition to provide a useful level of formal intelligence within a system by using standard computer technology. We can thus implement a variation of one or a combination of the techniques already described. However, it should not be forgotten that there are still other more subtle and not clearly understood reasons why such an approach cannot totally reproduce human thought (see Herbert L. Dreyfus 1992 What Computers Still Can't Do).

### **System suitable for use with Liquid Cargo Handling Operations**

In the early 1980s, expert systems were believed to represent the future of artificial intelligence and of computers in general. However as time progressed a number of problems began to become apparent most notably related to the two problems of obtaining sufficient data and the subsequent processing required. Consequently such systems have, until recently, fallen out of favour. However, by taking a new approach to how an expert system is structured we have been able to address these and other issues; issues that have limited the use of this approach. The resulting systems can now be used very effectively in a real time environment.

At the Warsash Maritime Centre we have so far concentrated on developing systems that are suitable for use with the monitoring and control of Liquid Cargo Handling Operations and to this end we have set up Warsash Intelligent Systems Enterprise (WISE).

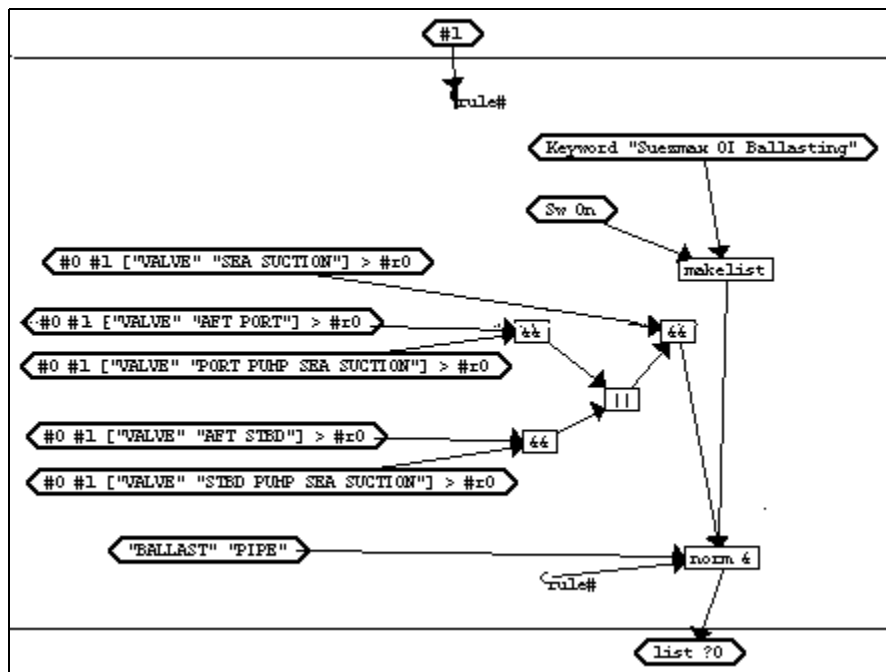
In this context we have decided to use the general technique of Expert Systems. The reason for this is that there is a large resource of expertise readily available with respect to how particular cargo operations should be conducted, equipment operated, areas monitored and the action taken in the event of problems developing. Consequently in this application the intelligent system does not need to learn new ideas or outcomes, where a Neural Net may be more suitable, but only has to be capable of implementing the defined level of expertise or knowledge in the correct way.

Knowledge can be defined as a set of known conditions and the ability to be able to link those conditions so that a future result can be determined or 'inferred'. Within an 'expert system' the known conditions or knowledge is defined within a set of rules which, when linked together, mimic the thought processes of the subject expert in determining if a set situation exists or not. Contained within each rule are specific conditions defining the items to be monitored and the values to which the actual should be compared. When placed in operation, the system compares the current values obtained from the system to be controlled with the defined values within the rules. If certain rules become true (hold) in a particular sequence or point in time then the system can link these results together by using an inference engine. At specified and regular intervals the inference engine runs through all the rules and checks all the various combinations so as to determine if particular situations exist. When a significant situation occurs the system will put out a short message or control command.

Within the WISE Systems the typical problems experienced by others when implementing Expert Systems have been overcome in the following ways:

- Knowledge capture process  
 Traditionally the knowledge of an expert is captured by another person (termed a Knowledge Engineer) who has the ability to be able to define the knowledge in a way the computer can understand. Unfortunately, the way the person capturing the knowledge perceives the information given may be different from what the subject expert meant. Consequently it is usual for the subject expert to be required to be continuously involved in system development. This ties up two skilled experts. In addition the final system requires extensive testing to ensure the correct results are obtained with the consequence of extended development time and cost.

By using a new and unique programming environment we have developed a system that allows an expert to input his knowledge directly using rules expressed as diagrams. This enables him to see the results immediately avoiding any misconceptions. This results in a significant reduction in the required development and testing phases.



Example of how a rule appears to the expert within the new programming environment

The rule is actually checking:

The ballast sea suction valve is open

AND

The ballast aft port valve AND port pump sea suction valves are open OR the ballast aft stbd valve AND stbd pump sea suction valves are open.

- Processing capability  
 Apart from the actual performance of the machine hosting the system the processing capability of expert systems is a function of the number of rules and their structure. By re-designing the structure of the rules so that they are optimised prior to processing considerable performance increases have been achieved to the extent that such a system can be used satisfactorily in a real time environment. Current systems are able to check in excess of 1300 rules, which in turn references in excess of 5000 parameters, within a time period of less than 2 secs.

- Portability  
Being developed for specific applications means that even if another application may be similar traditional methods have meant that a complete new set of rules has to be defined with an obvious impact on cost.

This has been overcome by using a special 'Rule Generator' which enables the automatic creation of multiple rule sets for different applications from one master set of rules. An example of such an application may be the development of expert systems for two different oil tankers from one defined master rule set. This can be achieved, because although the structure of the tankers may be different (ie number of tanks, valves, pipelines etc) the items that an expert monitors in trying to conduct operations are generically the same.

### **How this type of Intelligent System can be used**

It is obvious that the use of Intelligent Software (IS) of the nature described here can only be used on systems where the data to be checked is readily accessible, which usually means that it is already in a digital form. Consequently, such systems cannot easily be used on old style hardware based control / training systems. However, most modern control / training systems are based on the use of digital signals even if the final display to the operator is presented in an analogue form. Because of this reason we have taken the approach of developing the intelligent system as a separate module, which by using a suitable interface, can be linked to any appropriate control system. As well as providing the advantage that the IS module can be used with systems already installed as well as new installations. It also means that the IS module can be continuously updated and expanded as required without affecting the main control system.

A typical IS module contains:

- A rule set which defines all the parameters to be checked together with the appropriate conditions. It is also possible for a system to contain various multiple rule sets that can be used for different applications at different times, for instance:
  - Operation monitoring
  - Training mode
  - Operation efficiency evaluation
 Each rule set will have its own particular rules which can then be linked to appropriate feedback mechanisms
- The inference engine for determining the various outcomes
- The feedback system that is used to provide information on the outcomes to the system operator in an appropriate form.

The following is an example of how such a system can be used in a training environment.

WISE Cargo is a training system that has been developed to allow students to undertake training in all aspects of Liquid Cargo Handling at any suitable location or time. It is based on a Liquid Cargo Simulator that allows the simulation of all the process flow and control processes applicable to the type of ship or terminal, and the cargo being handled. This allows operators to be trained in all aspects of handling bulk liquid gas, oil or chemical cargoes. For example, using the ship models the operations that can be simulated include all of those undertaken within the usual dry-dock to dry-dock period including:

- Primary Inerting
- Gassing Up & Cooldown (if appropriate)
- Loading

Discharging  
Loaded & Ballast voyage  
Cargo conditioning  
Gas freeing

All the models incorporate the fluid and thermodynamics relating to the various cargoes and systems by using complex chemical and physical modelling techniques. This allows multiple cargoes or mixtures together with variations in vapour content to be simulated with great accuracy and the results displayed to the operator. This, together with the model simulation being run in real time, enables training to be provided with maximum realism with the student in control of all aspects of the operations in a similar way to being in a real control room.

Attached to the main simulator is the Intelligent Software module. As previously described this module contains all the rules for the conditions to be monitored primarily relating to the different levels that are appropriate within the areas of:

- Training
- Safety
- Operational efficiency

To enable the correct feedback to be given to the operator at the appropriate times the IS module has to evaluate what operations are actually being conducted at the time. As an example, on certain ship types it may not be appropriate to shut in a valve on the discharge side of a cargo pump (e.g. manifold or isolating valve) when it is running at full speed in the middle of a discharge operation. However, if the same valve is shut in when the vessel is not discharging the action may be entirely appropriate. Consequently the system needs to be capable of determining the overall context of an operation in which the individual action is taking place so that the correct feedback is provided at the right time.

In this particular case, the module has to first determine if the vessel is discharging. This it does in the same way as an expert operator by checking if:

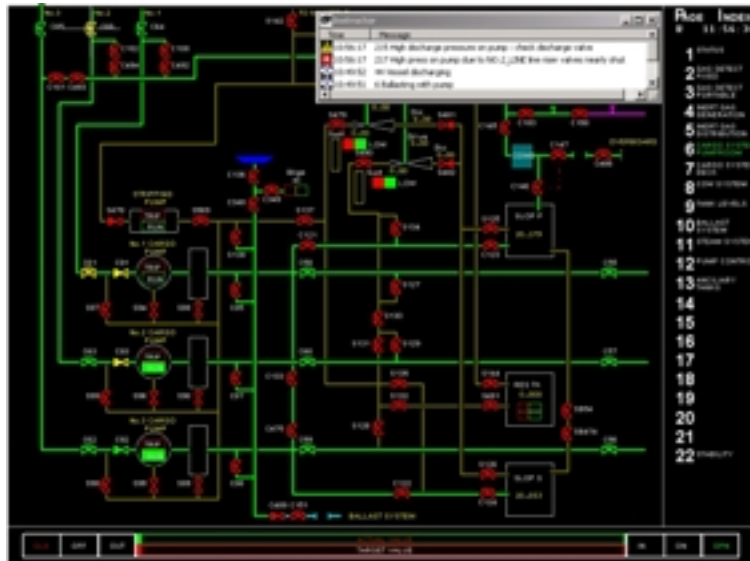
- a. A tank level is decreasing
- b. That the tank is open through to a cargo pump which is running.
- c. The line from the cargo pump to the appropriate manifold is open
- d. There is an outflow of liquid at the manifold.

If all the above conditions hold it is reasonable to assume that the vessel is discharging from that particular tank using that particular cargo pump. Now that this situation has been determined and if the system then detects that a valve has been shut in, it can output the appropriate feedback. If however, any one of the above conditions does not hold, then it is reasonable to assume the vessel is not discharging; the system can then react accordingly.

It can be seen that by linking conditions to be checked in this way the system is capable of determining very complex situations which can then be used to provide very detailed guidance or checks.

Within the training system, the initial feedback to the operator is provided by the display of short operator messages in the form of warnings, errors or just basic information. If the operator needs more detailed information or guidance the operator by clicking on the appropriate short operator message given out by the system can request this. This will then display the requested and detailed information. The presentation of the information uses current browser technology thus the messages can be linked directly to any appropriate information that can be displayed within a browser window. Consequently the information needed may be guidance on how a specific piece of machinery should be operated or the

appropriate section of a standard or company checklist, or even additional training material such as another CBT programme. All this material can be customised to suit particular installations or specialised requirements.



Main system display with short operator messages

Time	Message
10:56:17	215 High discharge pressure on pump - check discharge valve
10:56:17	217 High press on pump due to NO.2_LINE line riser valves nearly shut
10:49:52	44 Vessel discharging
10:49:51	6 Ballasting with pump

Example of short operator messages



Example of main display showing additional information about the Dilution method of inerting tanks accessed via the short operator message.

Because the system is based on PC hardware, the introduction of the IS module in this way has enabled a system to be developed that provides training at any convenient time or location, including on board ship. Previously such training would have to be undertaken in small groups in specific shore based locations where the hardware and skilled instructors would be available. Consequently, the use of such systems has provided ship / installation managers with a new way of ensuring that as many people as possible receive the required training without the additional costs.

In the control system context, by incorporating the knowledge of many experts through the use of Intelligent Software, the total required knowledge needed for the safe and efficient operation of the ship or installation can be maintained. This can be done even if ship / installation managers have to use personnel who do not have all the necessary skills. In addition such systems can provide continuous and consistent monitoring relieving some of the pressure from the operator allowing them to concentrate on other tasks. Experience derived from the logs of real situations on board an operational vessel can be used to update the knowledge of all the ships in the fleet. This knowledge when added to the existing Expert System s knowledge base will automate the process of continuous improvement in safety and efficiency.

Intelligent Software can also provide another benefit that can be used both in the training and control system applications. Because the rule sets can be easily adjusted to suit specific applications, rules can be specifically created to aid the process of evaluating the best methods of undertaking operations. This is done by getting the system to highlight specific conditions that could be approached in a different way or to provide detailed information which can then be used for comparison purposes. Such a system is already being used to assist in the process of evaluating the suitability of particular LPG cargoes for various vessels and to provide assistance in resolving problems that the vessels may be encountering.

## **Conclusion**

We have shown that intelligent systems have now developed to a point where they can be used to provide significant benefits to the operation of vessels and shore plant. Although within the paper the example of their use on Liquid Cargo Control Systems has been used, it is apparent that there are many other marine related applications where the use of such technology would provide similar benefits, for example, within integrated bridge systems and plant control systems.

However, there are two issues that will need to be taken into consideration as this type of system is introduced:

1. **Reliance on system**

There will always be the danger that as more intelligence is built into the control system that the system operators will come to rely almost totally on the information provided as opposed to using their own judgement whilst using the IS as a guidance to situation assessment and subsequent action.

When such systems are installed companies will therefore need to think carefully about how the operators are trained to use the systems to best advantage and what level of emphasis that is placed on the information provided by the system. A comparison would be the introduction of GPS and electronic charts on the bridge. They are seen as a useful aid, but the navigator must be trained to use the information as part of his decision making process rather than rely on the information totally.

2. Long term reduction in standards

The introduction of such systems on a large scale could provide some companies with the excuse of trying to reduce the regulatory standards for system operators so that they can gain a competitive advantage. Whilst in the long term it is possible that Intelligent Software may reach a point where it could undertake many operations<sup>i</sup> a lot of exhaustive testing will be required before such systems could be used with total confidence. Responsibilities will therefore be placed on the respective regulatory authorities to ensure that the standards are maintained at a sufficient level.

At the same time it will be important to ensure system operators continue to receive the sufficient training to enable them to deal with developing situations. Whilst it is much more useful to be able to receive immediate information from the IS system about a tank accidentally back filling during a discharge operation than waiting for the high level alarm to be activated when it is almost too late, the operator must still be trained in the importance of monitoring levels in tanks. The overall purpose of the Intelligent System will be to act as secondary system to catch the mistakes that humans are prone to make.

With the continuing rapid development in computer technology it is only a matter of time before the use of Intelligent Software becomes widespread. It is already being used extensively in the motor and communications industries. The systems that are now available for the shipping industry can already be used to overcome some of the problems that it is currently facing and in addition provide significant benefits. Those companies who introduce these systems at an early stage are likely to gain significant advantage over their competitors. However, as with all advances, for the benefits to be achieved to their full potential, such systems will need to be introduced with care and forethought.

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<sup>i</sup> We are already in the early stages of developing a predictive intelligent system that could be used as a basis for a fully automated control system which is able to take account of the changes that take place as the operation progresses without operator input.