# APPLICATION OF LOGIC PROGRAMMING TECHNIQUE ON MARITIME ACCIDENT ANALYSIS

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## SUMMARY

Maritime accident is a serious problem. Such problems are difficult to solve and traditionally regulations are enforced to solve these problems. The principal idea behind applying regulations is to control the human decisions/actions so that the marine systems are designed and operated within the safety limits. Despite all sorts of efforts and technological developments, significant accidents are occurring and investigations suggest that accident problems mostly trigger from human decisions/actions. Hence, the authors view accident problem as logic problem and thereby, applies logic programming technique in accident analysis and prediction. In this paper the authors discuss some elementary aspects of the development of logic predicates for reasoning based on crew actions and perceptions. Recent real world accident cases are studied in order to develop the predicates. The study suggests that logic programming technique can be utilized for maritime accident prediction and various root causes of accidents can be analysed. Recommendations on future developments have been proposed and discussed briefly.

## NOMENCLATURE

| | |
|---|---|
| RCO | Risk Control Option |
| SOOW | Senior Officer of the Watch |
| JOOW | Junior Officer of the Watch |
| AB | Able-Bodied Seaman |
| INS | Integrated Navigation System |
| MV | Motor Vessel |

## 1. INTRODUCTION

Accident is an unwanted event that results detrimental consequences on health, society, environment and economy. Since the invention of steam engine over two hundred years ago mankind has progressed astronomically in science and technology. During this time mankind also experienced major accidents whenever new technology or engineering product were brought into the society. The accident of Titanic in 1912 and the accident of Costa Concordia in 2012 can be considered in this context. Both ships are the state of the art ships equipped with the best technology known to the engineers at that time. Yet accidents occur and people lose their lives along with huge economic consequences.

In this paper, the authors attempt to present logic programming technique as a tool for analysing and understanding accident problems so that it can be controlled and prevented. The behaviour of crew is mimicked by perception and action logics in Prolog programming environment. At the beginning, an effort has been given to understand the accident problem itself and the traditional approaches to solve such problems are discoursed. Case study of several recent major accidents have been discussed as well. A new concept for accident analysis is proposed based on the discussion and the case study. The new concept is then investigated and the future challenges are identified. Finally the study draws some conclusions and recommendations for future research.

## 2. THE ACCIDENT PROBLEM

Over the years many accident theories have been proposed that attempt to explain the accident phenomena and identify ways to control it. Researchers from various fields of science and engineering (including medical doctors, electrical engineers, and others) try to contribute in this regard. However, the common question that appears to the mind of accident researchers is 'how we can stop a particular type of accident occurring in the future again?'. This query triggers the analysis of accidents in both macro and micro perspective. Thereby, various tools of accident research are developed and utilized. During the last century a number of new accident theories have been proposed like the domino theory [1], the organizational accident theory [2], System Theoretic Accident Modelling and Process (STAMP) [3] and others. These theoretical models give insight into the mechanism of accident occurrence from different perspectives.

In practice, the safety of many engineering systems (including maritime/ship transportation) is evaluated by risk analyses considering the above mentioned accident models and often appreciable results are achieved. So far significant developments have been observed in maritime risk modelling as well [4]. A fundamental aspect of risk analysis is that risk values depend on the application of risk control options (RCO) and the risk value itself is of less significance without the RCOs. By applying different RCOs, different risk values are calculated which helps making decision which RCO to apply to prevent/control accident. Nonetheless, there are some fundamental issues and limitations of risk analysis. For example, the results of risk analysis (and statistical analysis as well) provide probability or chance of occurrence of a particular type of accident over a defined period of time (e.g. the number of accidents take place per year) [4, 5]. These analyses are not able to predict how and when an accident may take place.



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In order to overcome the limitations of traditional risk analysis methods the authors recently initiated research on the applicability of logic programming technique in accident prediction and analysis [6-9]. The authors highlight that each accident can be explained logically once the accident investigation is complete. Therefore, when a logical sequence of events are known, such knowledge can be utilized in an expert system to prevent similar accident to take place again. So far the elementary concepts have been discussed in the previous papers. In this research paper the concept of action/perception of ship crew and its applicability is logic programming will be discussed. Therefore, accident case studies have been conducted in order to understand the concept more elaborately.

## 2. ACCIDENT CASE STUDY

Three accident cases have been selected for this paper. The first accident case is the accident of Costa Concordia which took place in Italy in 2012. The second accident case is the accident of MV Bright Field which occurred at the Mississippi river, New Orleans, Louisiana on 14th December 1996. The third accident case is the accident of MV Planet V which collided with a pontoon at Westerschelde, The Netherlands on 26th of May 2012. The similarity between these accidents is that all the accidents originated from and propagated by human decisions and could have been prevented if the decisions were taken otherwise.

### 2.1 ACCIDENT OF MV COSTA CONCORDIA

The accident of MS Costa Concordia took place on 13th January 2012. The ship grounded on the rocks Le Scole, near Giglio Island, Italy [10]. The ship operated by Costa Crociere – a subsidiary of Carnival Corporation – was on route from Civitavecchia to Savona, carrying over 4200 people on board. 32 lost their lives and 60 were injured in the accident. With its gross tonnage of 114.000, 13 decks, 290 meters of length, 35 meters of beam and 8 meters of draught, Costa Concordia was launched in 2006, and at the time it was the largest Italian cruise ship ever built. The accident demonstrated that catastrophe may occur even with ships that are considered masterpieces of modern technology and despite more than 100 years of regulatory and technological progress in maritime safety since the accident of the Titanic. Figure 1 shows the final path of the Costa Concordia[11].

A study by Lieto [12] identifies several operational errors during the voyage which resulted in the accident. The author utilised Reason's Organisational Accident Model [2] to identify the errors. Table 1 shows the list of errors with logical description. For the first error, the external influence of paying a tribute to the mentor and a request to change the voyage plan makes the Captain to decide to change in the voyage plan. However, the Captain decided to take informal procedure because of the regulatory limitations form the company.

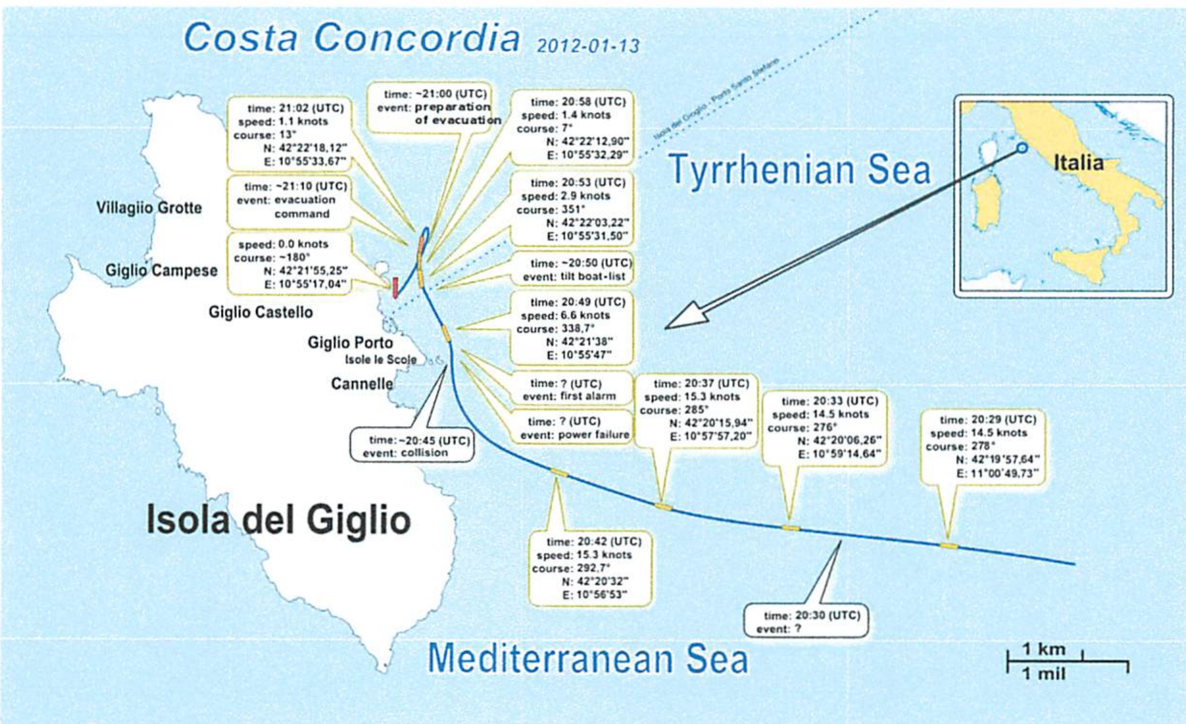


Figure 1: Timeline Representation of the Accident of Costa Concordia [11].



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Table 1: Logical Description of the Errors.

| Error | Logical Description |
|---|---|
| 1st Error | <u>Voyage Planning</u><br><br>*Captain Decision: Change in voyage plan.*<br><br><u>Because:</u><br>1. The mentor of the Captain is in the Giglio Island.<br>2. The Hotel manager also requests the Captain to sail past. |
| 2nd Error | <u>Route Planning on Paper Charts</u><br><br>*Senior Office Decision: Plan route on large scale paper charts - incomplete route planning.*<br><br><u>Because:</u><br>3. Limited time to start the voyage.<br>4. Informal procedure of Captain |
| 3rd Error | <u>Route Monitoring on Papers Charts</u><br><br>*Junior Officer Decision: Faulty route monitoring – no danger observed on the chart.*<br><br><u>Because:</u><br>5. On large scale paper charts the rocks are invisible.<br>6. On the final stage of approach to the island, the Junior Officer left route monitoring and went to assist Helmsman to translate Captain's commands. |
| 4th Error | <u>Route Monitoring on INS</u><br><br>*Senior Officer Action: Wrongly set INS chart alarm.*<br>*No challenge from Captain (Captain's Decision).*<br><br><u>Because:</u><br>7. The danger of rocks was not perceived due to planning route on the large scale charts.<br>8. Informal voyage procedure reduced the formal attitude. |
| 5th Error | <u>Bridge Team Management</u><br><br>*Senior Officer Action: No challenge on Captain's Decision*<br>*Junior Officer Action: No challenge on Captain and Senior Officer decision.*<br><br><u>Because:</u><br>9. Captain adopted informal procedure. |
| 6th Error | <u>Ship Handling</u><br><br>*Faulty execution of Captain's commands.*<br><br><u>Because:</u><br>10. Helmsman could not clearly understand Captain's Command |

Secondly, limited time for modifying the voyage plan, and captain's reliance on Senior Officer of the Watch (SOOW) resulted in a decision of planning the voyage on large scale charts. Here the Captain could have intervened SOOW to draw the voyage on small scale charts where the danger of grounding could have been spotted. But the limited time and informal procedure resulted both the Captain and the SOOW to decide to plan the voyage on large scale charts.

The third error triggered when there was no proper route monitoring. This happened in two cases along the voyage. Firstly, the Junior Officer of the Watch (JOOW) didn't have "planned larger scale charts" to fix ships position. Therefore, JOOW couldn't detect any danger. As there was no observed danger and there is informal procedure, the JOOW decided not to challenge. Secondly, in another case JOOW left route monitoring and went to assist the Helmsman, as there was language/communication barrier.

The fourth error was regarding to route monitoring on Integrated Navigation System (INS). The chart alarm was set to go on if the radar distance is 2000 meter or less from the ground. It was not set for crossing the 10 meter bathymetric line. If it was selected, the captain might have received a warning alarm and could take actions much earlier (as soon as 10 meter draft compromised).

At the final stage of the approach the Captain took over command form SOOW. But SOOW or JOOW didn't challenge in any form. Captain's intentions and expected outcomes were not clear. Because of the presence of guests and hotel manager his role as a team leader was not fulfilled. The lack of challenge from the ship crew could be the fifth error.

When the Captain took over the control from SOOW, valuable time was lost. Within that very short span of time the ship crossed safety contour from 0.5 Nautical mile to 0.28 nautical mile. During this period the captain was giving verbal orders to the Helmsman but due to language barrier the Helmsman could not execute the commanded orders accurately. Therefore, JOOW came to assist in translating the orders. At this point of voyage it was very crucial not to make any errors while executing the navigational orders. Yet, the Helmsman misunderstood some of the orders and it was too late to correct it. This was the final error. Hence a series of perceptions-actions of ship crew resulted in an accident.

## 2.2 ACCIDENT OF MV BRIGHT FIELD

The accident of MV Bright Field took place shortly after 1400 hrs on 14th December 1996 [13]. The fully loaded Liberian bulk carrier temporarily lost propulsion power as the vessel was navigating outbound in the Lower Mississippi River at New Orleans, Louisiana. The vessel struck a wharf adjacent to a populated commercial area that included a shopping mall, a condominium parking garage, and a hotel. No fatalities resulted from the accident, and no one aboard the Bright Field was injured; however, 4 serious injuries and 58 minor injuries were sustained during evacuations of shore facilities, a gaming



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vessel, and an excursion vessel located near the impact area. Total property damages to the Bright Field and to shore side facilities were estimated at about $20 million [14]. Using the information available for the final 6 minutes before the accident a time history of events with logical description can be constructed as shown in Table 2 [13].

Table 2: Time History of Events for the Final 6 Minutes.

| Comments | Time | Person | Observation/ Action/Decision | Situation |
|---|---|---|---|---|
| Without Engine Power (3 Minutes till impact) | 1406 | | Engine power drops. | Bright Field passing under a bridge. |
| | 1406+ | Master | Asks his mate to call engine room and demand an increase in power. | |
| | 1406+ | Chief Engineer | Thinks except for the low rpm everything is normal. | He possibly thinks the low rpm is from the bridge control. |
| | 1406+ | Second Mate | The second mate calls the Chief Engineer and demands increase power. But he doesn't relay the information of ship's heading and manoeuvrings situation to the Chief Engineer. | It seems the danger of collision or allision is not comprehended. Perhaps both the Master and the Second Mate thought the engine power would be back soon. |
| | 1406+ | Chief Engineer | As the Chief Engineer doesn't perceive any danger, he suggests transfer of engine control from wheelhouse to engine control room as a usual practice. | |
| | 1406+ | Master | As he doesn't know about the particular cause of the problem, The Master agrees to transfer the control to the engine room. | This decision seems right one in the sense that previously the engine showed starting problem and it was started from the engine room. |
| | | | Waste of valuable time: This transfer of control takes usually 20-30 seconds and must be completed before engine stopped. As soon as the lube oil pressure reached desired state, the engine could have been operable from the engine room. | |
| | 1407+ | Chief Engineer | The Chief Engineer could have increased engine rpm at this stage. | But the Master cannot determine his course of action. Due to language barrier he wasn't fluent with the pilot who was navigating the ship. |
| The Allision | 1411 | | Engine power came back on 1408. But the crew realized very late that allision is inevitable. The port bow of Bright Field strikes a wharf adjacent to a populated commercial area including a shopping mall, a condominium parking garage and a hotel. | |

According to the investigation report [14] it was found that the ship had problems with its engine lube oil system prior to few days of the accident. On the open sea, in good weather, temporary malfunctions in the vessel's main engine may be tolerable; however, in the close quarters of the Mississippi River, where safe manoeuvring is directly dependent upon a responsive main engine, a loss of power can, as it did in this instance, present an immediate threat to other vessels and to shore side facilities. Hence, a combination of engine failure and series of wrong perception-actions of the crew resulted the accident of MV Bright Field. A schematic diagram of the ships final path and the surrounding location is shown in Figure 2 which gives an overall idea on the accident site.

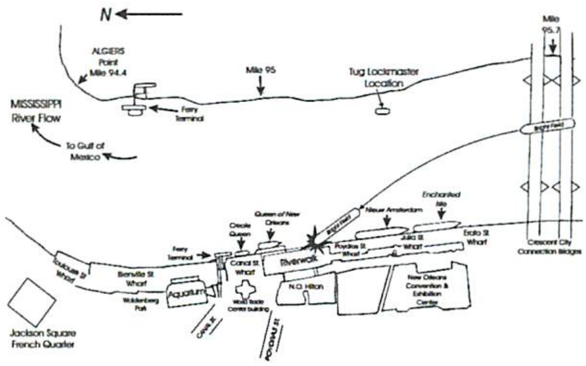


Figure 2: Allision of MV Bright Field [14].

## 2.3 ACCIDENT OF MV PLANET V

The accident of MV Planet V took place on 26th May 2012 at the Westerschelde, The Netherlands. The motor vessel lost its engine power and collided with a towed (by tug MTS vantage) pontoon while an Able-Bodied seaman (AB) lost his life trying to reduce the ship speed by dropping anchor [15]. Figure 3 shows a snapshot from the wheel house of the tug taken just moments before the collision between MV Planet V and the pontoon. Table 3 shows a list of major events in terms of crew perception and crew action that took place prior to the occurrence of the accident [15].

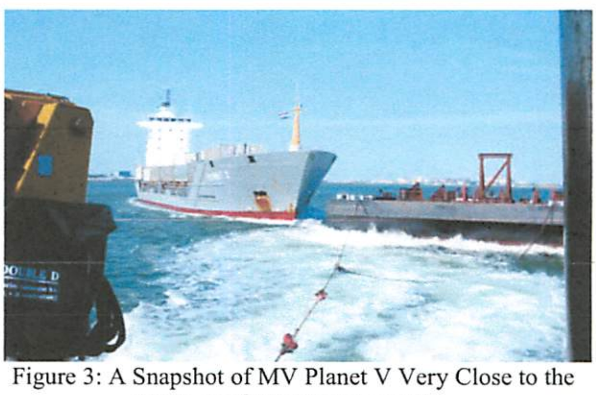

Figure 3: A Snapshot of MV Planet V Very Close to the Pontoon of MTS Vantage [15].



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Table 3: Timeline of Major Events before Collision.

| Time | Event |
|---|---|
| 16:30 | **Chief Officer Action:** carried out a routine test of the navigation systems on the bridge deck. Nothing unusual observed. |
| 40 min | Voyage preparation was made using a Voyage Plan (*Before departing for sea, the captain has to draw up a voyage preparation document, which is referred to as Voyage Plan*). |
| 17:10 | A tugboat MTS Vantage leaves for its destination with its pontoon tow. |
| 8 min | **Pilot Decision:** The Pilot of the MTS Vantage contacts the Pilot of MV Planet V by VHF to inform about the tugs intentions. |
| 17:18 | **Captain Action:** Main engine of MV Planet V is started. |
| 6 min | At this time two auxiliary engines for the auxiliary generators were running. The shaft generator was also running which was used to provide power for the bow thruster. At 17:24 the ship departs the harbor. |
| 17 min | **Captain Action:** The Captain informed the engine room crew that the bow thruster was no longer required. **Chief Engineer Action:** The Chief Engineer, therefore, shut down the auxiliary engines and used the shaft generator for necessary power. |
| 17:41 | MTS Vantage passes the Sloehaven harbour entrance with a speed of 6 knots. |
| 17:45 | MV Planet V passes the harbour entrance. The speed was 11 knots. |
| 17:48 | MV Planet V is along the starboard side of the pontoon. The speed of Planet V was knots. |
| 17:48:23 | The main engine of MV Planet V fails. Immediately the electrical systems on board failed and the ship went into total blackout. |
| 16 seconds | The ship started to turn port after the electrical failure. |
| | **Crew Perception:** The crew and the Pilot observed that the rudder angle indicator showed starboard rudder angle. |
| | **Pilot Action:** The Pilot of MV Planet V informs the Pilot of MTS Vantage about the situation and requests 'full speed ahead' for the tug to prevent collision. |
| 17:48:39 | **Captain Action:** The Captain of Planet V instructs AB to return to forecastle, and prepare the anchor. |
| 17:49:34 | **Captain Action:** The Captain orders to drop the anchor via VHF. The pilot was not consulted with about this. The intention of the Captain is to slow down the ship and accelerate its turn to the port in an attempt to pass the tug and the tow at its stern. |
| 21 seconds | The tug started increasing speed and turning to port in an attempt to increase its distance from MV Planet V. |
| | **Captain Action:** The Captain orders AB not to run out of chain any further. |
| | **AB Action:** AB tightens the anchor winch brake. Despite this the anchor chain continues to run out at high speed. |
| | **AB Action:** To apply additional force AB climbed onto the electrical motor of anchor winch. |
| 17:50:05 | MV Planet V hits the pontoon amidships on its starboard side. |
| | After collision MV Planet V moved along the pontoon while the anchor chain continued to run out. The loose bitter end of the chain flew out of the sparling pipe and fell overboard. AB standing on the electric motor was hit and fatally injured by the anchor chain. |

From the above case studies it is possible to comprehend that accidents could be prevented if appropriate decisions were made by the crew at the right time. For example, the Costa Concordia accident could have been prevented if the helmsman could have executed the command in time or the other crew members avoided the errors. The allision of MV bright field could have been prevented if the Chief Engineer knew about the danger ahead and took emergency restart of the engine. On the other hand, in the Planet V case, if the auxiliary generators were kept running then the bow thruster could have been used to avoid the collision and the AB could have saved his life by avoiding the emergency anchor manoeuvre or standing in a different spot. Therefore, the point of argument is that to prevent an accident it is important to comprehend the chain of perception-action sequence of the crew. If this chain can be understood and analysed, it might be possible to prevent future accidents of similar nature.

## 3. THE LOGIC MODEL CONCEPT

In the previous research works [6-9] the authors proposed and discussed the use of expert system in accident analysis and prediction. This paper can be considered as an extension of the previous research works. In this research the crew perception-action predicates are proposed to be incorporated in the expert system. As the case studies discussed above suggest that the crew perception and action plays a vital role in propagation of events and eventually the occurrence of an accident, Therefore, modelling the crew perception and action may yield an interesting domain for accident analysis where human interventions can be analysed along with physical/mathematical models of different systems. So far there are no known or established techniques that are able to mimic the crew behaviour during a voyage. However, the authors of this paper assume that the fundamental element of such modelling is logic. Therefore, the authors propose construction of logic predicates using the accident investigation reports and timeline study of accidents. Prolog programming language has been chosen because of its advantage in logic programming techniques.

### 3.1 DEFINITION OF LOGIC

Logic may be defined as the science of reasoning. However, this is not to suggest that logic is an empirical (i.e., experimental or observational) science like physics, biology, or psychology. Rather, logic is a non-empirical science like mathematics. Reasoning is a special mental activity called inferring, what can also be called making (or performing) inferences. A useful and simple definition of the word 'infer' – 'To infer is to draw conclusions from premises'.

Inferences are made on the basis of various sorts of things – data, facts, information, states of affairs. In order to simplify the investigation of reasoning, logic treats all of these things in terms of a single sort of thing called 'statements'. Logic correspondingly treats inferences in terms of collections of statements, which are called 'arguments'. The definition of 'argument' that is relevant to logic is given as 'an argument is a collection of statements, one of which is designated as the conclusion,



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and the remainder of which are designated as the premises'.

The reasoning process may be thought of as beginning with input (premises, data, etc.) and producing output (conclusions). In each specific case of drawing (inferring) a conclusion C from premises P1, P2, P3 ... , the details of the actual mental process is not the proper concern of logic, but of psychology or neurophysiology. The proper concern of logic is whether the inference of C on the basis of P1, P2, P3 ... is warranted (correct) or not. A simple structure of logic is given below:

```
logic(Conclusion, Premise 1, … Premise n):-

    Premise 1   = _________,
    Premise 2   = _________,
    …
    …
    Premise n   = _________,
    Conclusion = _________.
```

## 3.2 TYPES OF LOGIC

Logics can be classified in several ways. But fundamentally there are two types of logic: (1) Deductive Logic and (2) Inductive Logic. Deductive logic or deductive reasoning is the process of reasoning from one or more general statements (premises) to reach a logically certain conclusion. The truth of the premises guarantees the truth of the conclusion and vice versa. Inductive reasoning (as opposed to deductive reasoning) is reasoning in which the premises seek to supply strong evidence for (not absolute proof of) the truth of the conclusion. While the conclusion of a deductive argument is supposed to be certain, the truth of the conclusion of an inductive argument is supposed to be probable, based upon the evidence given. In other words, in inductive reason the truth of the conclusion does not necessarily guarantee the truth of all the premises.

## 3.3 PERCEPTION-ACTION OF CREW

In this paper the development of perception – action predicates are discussed. The principal idea is that all crew takes action based on his or her perceptions. The perceptions build from surrounding world parameters and actions from other crew members. In real world the perception – action sequence is much more complicated as it involves more people and dynamic environment. Figure 4 shows a schematic diagram of this concept. In this figure a 4 crew members are visualised – a Captain, a Senior Officer of The Watch (SOOW), Junior Officer of the watch (JOOW) and a Helmsman. The Captain perceives something from the actions of his co-workers. At the same time the Captain may perceive something from the surrounding environment as well. This perception may lead to an action of the Captain. In the case of Costa Concordia accident the action of the hotel manager and the presence of the Captains mentor lead the Captain to decide to change in the voyage plan. This action lead more actions of the ship crew as consequence which has been discussed in the previous sections.

However, a set of perception-action predicates are required to model a comprehensive scenario. As this paper is focused only on the concept building only a limited number of predicates are developed. Table 4 shows an example of predicates developed from the accident case studies.

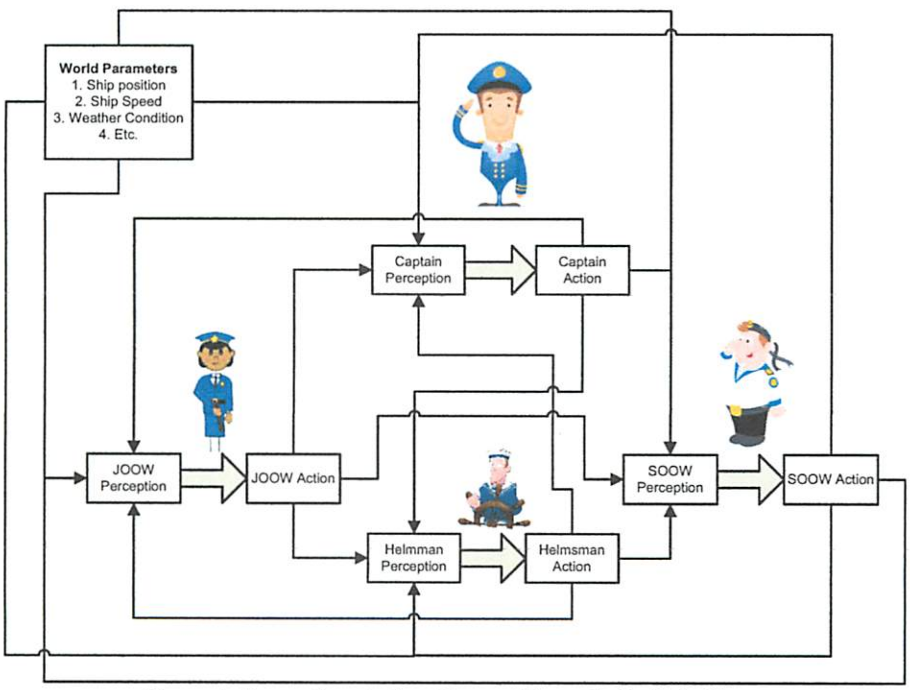


Figure 4: Perception–Action Concept Example for Ship Crew.



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Table 4: Perception-Action Predicate

| No. | Crew | Predicates |
|---|---|---|
| 1. | Captain Perception | Premise: Engine RPM Low.<br><br>Conclusion: Transfer Control To Chief Engineer |
| 2. | Captain Action | Premise: Ship sailed out of the harbour and there is enough engine power.<br><br>Conclusion: Shut down the engine for bow thruster. |
| 3. | SOOW Perception | Premise: Captain decided informal voyage.<br><br>Conclusion: No need to practice formal procedures. |
| 4. | JOOW Perception | Premise: Ship is on informal voyage and voyage plan is done on large scale charts with no dangers observed.<br><br>Conclusion: No need to check on monitor route on small scale charts. |
| 5. | Chief Engineer Action | Premise: Engine has history of starting problem.<br><br>Conclusion: During a voyage if the engine fails then request transfer of control from bridge deck to engine room. |

Utilizing the predicates developed in this study it is possible to deliver a set of outputs as shown in Figure 5. The logic program executes and attempts to reach for its goal. In this given case the goal is to find out how the ship may be grounded. The given conditions are that the ship is in the inland water and had experienced frequent engine problem. Under this circumstance the logic model is constructed using the knowledge of MV Bright Field Accident. The goal is set to find how the ship will be grounded. Using backtracking technique the logic model is able to find out the sequence of perception-actions of ship crew. This capability of logic programming gives the power of logical computations and ability of usage in accident analysis.

**Situation**: Engine power drops.
↓
**Captain Perception**: Engine fault.
↓
**Captain Action**: Ask chief engineer to increase power.
↓
**Chief Engineer Perception**: Problem in lubrication oil pressure.
↓
**Chief Engineer Action**: Request engine control to be transferred to Engine Room.
↓
**Chief Engineer Perception**: System automatic restart.
↓
**Chief Engineer Action**: Wait until full engine restart.
↓
**Situation**: Ship is in a river bend and there is limited time to take evasive action.
↓
**Captain Perception**: Common problem, engine will be restarted soon.
↓
**Chief Engineer Action**: Transfer control back to bridge deck.
↓
**Situation**: Too late to take evasive action.
↓
**Situation**: Ship is grounded.

Figure 5: Action-Perception Flow among Ship Crew.

## 4. IMPLEMENTATION CHALLENGES

Marine accidents are very complex in nature as it involve contributions of both man and machine. Modelling human crew in terms of perception-action is the new idea that has been undertaken in this paper. However, there are a significant number of challenges that needs to be addressed in order to implement the concept. This study identifies some of the important challenges such as:

- The traditional procedural programming languages (e.g. C++, Java, FORTRAN etc) requires a lot of coding to construct the predicates. Therefore, in order to combine the logic model with physical world model (e.g. ship manoeuvring model) new techniques are required.

- A comprehensive knowledge base is required to construct the predicates which is a time consuming and complex task. To build the knowledge base it is essential that a significant number of accident cases are considered and studied. This indeed requires a lot of time.

- For a particular perception there could exist many possible actions. Furthermore these actions can be taken at different time steps. This gives rise to a problem of infinite possibilities. This problem needs to be addressed and practical solutions has to be derived.

- For a particular action there could be different perceptions based on different types of personalities. This gives rise to the infinite possibilities as well.

- It is, therefore, very much important to define the problem boundaries to limit the possibilities and thereafter, attempt to solve the problem within the given space and time.



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## 5. CONCLUSIONS

This paper investigates the concept of crew perception-action method on accident analysis by logic programming technique based on accident case studies. So far the concept appears to be very much promising. The perception-action technique has the potential for in-depth analysis of maritime accidents. Such an approach may produce very precise results on how and when a particular type of accident is going to take place. This is an advantage over traditional risk based techniques.

The challenges for implementing the concept are identified and discussed briefly. It is nevertheless, highly recommended that further in-depth research is required to implement the concept.

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