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Artificial Intelligence—The Emerging Technology

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Abstract. Artificial Intelligence (AI), once considered as an obscure branch of computer science, is now having a growing number of adherents in a wide variety of fields. AI is particularly useful for combat automation in defence. The combined works of computer scientists and technologists and cognitive scientists have brought out for intelligent information processing knowledge is the key factor. In the last few years, AI has been tried out with a high degree of success in certain areas such as the Expert Systems and the Computer Vision Systems. Both these have great potential in target classification and identification, information fusion, multiradar Air Defence Network, C^2 (Command and Control) operations etc. in defence.

1. Introduction

The continuum of activities and processes in a conflict situation comprise of such actions as the gathering of information, evaluation in the military context, decision-making, communicating the decision for carrying out the action and modifying the context from the feedback received. For centuries, changes in these activities and processes were spread over long periods of time and, therefore, a military commander could learn his job from the precepts and principles laid down according to the experiences of past commanders. In the span of a life time, the parameters of weapons, fire power, range, speed and means of delivery were relatively constant thereby providing little scope for innovation and adaptation.

In the last few decades, however, the parameters and the type of weapons available have increased at an exponential rate. Consequently, the decision processes associated with the application of today's array of weapons have become quite demanding. A second factor unique to future conflict situations is the pressure to operate with shortened decision-making timeliness due to high mobility of the forces and the need for the battlefield planners to be truly adept at rapidly recognising, reacting to and committing resources. A third factor is the vast amount of information that will be available for making decisions. New, highly sophisticated and more numerous sensors and systems have capability to collect, process and present large amounts of information based on imaging, ELINT and other processes. The military commanders are expected to assimilate and distil the vast accumulation of disparate data into a pattern amenable for presentation to take critical decisions. With large scale introduction of electronics in modern warfare, it is now possible to consider the fusion of information provided by the sensors that may be incomplete, uncertain or even incorrect, and to attempt to mechanise the dynamics of the conflict. The process of such integration and automation in war is still in its infancy but the goal of competent automated decision-making is extremely attractive as this has the potential to generate decisions/commands, many orders of magnitude more quickly and reliably than by humans under stress conditions.

The accomplishment of such a task is expected to be achieved through Artificial Intelligence (AI), a technology which has been designated by the US Government as one of the major pay-off technologies in the coming decades. The funding for activities in this field will be of the order of 1.5 billion US Dollars for the next three years in that country alone. Two recent studies have forecasted that in the next two to five years the worldwide computer industry will produce a wave of AI products with wide scope for application in both civilian and military contexts. In the latter area, it is expected to augment the power of existing computer, mechanical and weapon systems and eventually replace humans in most problem-solving aspects. Already a number of applications in military areas have been initiated in the United States. For example, KNOB, TARTR and SPOT are three programmes which will aid decision-making in weapon-to-target, tactical air target selection and carrier aircraft launch situations. Another well-known programme connected with a target classification scheme uses AI to classify naval ships from radar images and is currently under evaluation. AI is also finding application in C^2 (Command and Control) situations including distributed problem solving, crisis warning and management, automated planning and situation assessment.

2. What is AI ?

Artificial Intelligence, which was once considered as an obscure fringe of computer science, has emerged from academic research into a discipline that is being applied to practical problem-solving by a growing number of adherents in a wide variety of fields. It was born as a science in 1956 at Dartmouth College in USA where computer engineers and scientists from prestigious academic institutions and industries gathered to discuss ways of simulating thought with computers. The dominating belief at that time was that a few laws of reasoning coupled with powerful computers would result in intelligent or thinking machines. As work in the field of AI continued for a decade, research in AI took off along two distinct lines namely intelligent machines and cognitive science motivated by a common methodology and working hypothesis. The methodology was to make use of programming as a means to perform experiments through which new ideas were evolved about the nature of intelligence. The working hypothesis was that the result would be a theory of intelligent information processing which could be carried out either by the biological tissues in the human brain or by the IC chips in the computer.

A glance at the vast amount of literature on AI yields several definitions for Artificial Intelligence. One of the simplest, defines it as that branch of science or technology which is mainly concerned with devising computer programmes to make computers smarter. Another version states AI as any activity performed by a non-human entity that is usually considered to require intelligence when performed by human beings. It is immediately evident that the motivation for taking up work in AI arises from our age-old desire to create machines that will equal if not excel human capabilities by way of reasoning, problem solving, sensory analysis and manipulation. A parallel motivation has been the urge to study the nature of intelligence and codification of knowledge. While the cognitive scientist has been involved in the scientific aspect of constructing an information processing theory of intelligence, the computer scientist and technologist explored the computational approaches to intelligent behaviour. In the latter case, the emphasis is towards manipulation of knowledge through reasoning by a computer. The concept in this case is that knowledge is central to intelligence.

The kind of knowledge that is required for intelligent behaviour has been the subject of intense discussion amongst AI researchers and cognitive psychologists. For example, Wiederhold presents nine categories of knowledge in decreasing levels of abstraction. According to Bernstein, knowledge consists of descriptions, relationships and procedures. Frederick Hayes-Roth, on the other hand, considers knowledge as made up of three basic constituents, namely, facts, beliefs and heuristics; the last being defined as that knowledge consisting largely of rules of thumb and educated guesses. From the point of AI understanding, the categorisation due to Barr and Feigenbaum is more relevant. According to them, four types of knowledge need only be presented. These are: (a) Objects and classes or categories and description of objects, (b) Actions, events, time course of sequence of events and their cause and effect relationship, (c) Knowledge about how to do things or performance of skills, and (d) Meta-knowledge or knowledge about what humans know i.e. the extent and origin of knowledge of a particular subject, the reliability of that information and relative importance. It also includes our strengths, weaknesses, confusability and levels of expertise in different areas.

The knowledge so categorised has to be used in the AI machine for performing cognitive tasks. This calls for acquiring more knowledge, retrieving relevant facts from the knowledge base and reasoning about these facts in search of a solution. Acquisition of fresh knowledge per se would not result in improvement of the solution to a given problem unless this newly acquired knowledge is assimilated and accommodated in an integrative and interactive fashion with the existing knowledge base. After that, the process has to determine what portion of this knowledge is relevant to a given situation. This entails the explicit linking between the several data structures in the knowledge base. Finally, the AI programme has to carry out reasoning which means it must be able to deduce and verify a multitude of new facts beyond what has been explicitly put into it.

This process of knowledge representation and encoding in machine readable form and making use of it for problem-solving process by computers has been successfully achieved in the last decade only in very specialised fields of human endeavour. The major part of the work in the field of AI is presently concentrated in two major application areas and these are Knowledge Based Expert Systems and Computer Vision with application to robotics.

3. Expert Systems

The biggest technology success in AI has been the development of Knowledge Based Systems or Expert Systems as they are more familiarly known. Expert systems are AI computer programmes designed to represent and apply factual knowledge pertaining to specific fields of expertise for arriving at solutions to problems. Expert systems are generally modelled on human experts and a typical system will therefore consist of a Knowledge Base, an Inference engine and a work space. The Knowledge base may use facts, rules of thumb, models and other general knowledge factors of a specified domain while the Inference engine carries out a sequence of operations that manipulate and combine the data structures based on logic and heuristic reasoning. The work space is an area in the computer memory set aside for storing the problem descriptions constructed by the computer programme from the data input by the user or inferred from the knowledge base. Expert systems differ substantially from conventional computer programmes because their tasks in general have no algorithmic solution and quite often have to operate on incomplete or uncertain information.

For a particular task or area of knowledge to qualify for building an expert system, it should satisfy the prerequisites of availability of 'public' and 'private' knowledge. Public knowledge includes information available openly, such as published definitions, facts and theories in the form of articles and text books. Private knowledge, on the other hand, is the knowledge residing in experts. It consists largely of heuristic knowledge or rules of thumb based on the experience and judgement of the experts. This knowledge has to be culled into a form that is amenable for machine computation. This is now called Knowledge Engineering. Finally, for ready acceptance by human beings, the criterion of efficiency by which the solutions to the problems are arrived at is very crucial. The distinguishing feature of an Expert System is the degree of closeness it can achieve in imbibing the ability of experts to recognise large-scale or macro-patterns and arrive quickly at reasonable hypothesis.

It is necessary to recall at this stage the fact the traditional computer programmes where numbers and mathematical operations are carried out are very special cases of symbols and symbol manipulations. In Expert Systems, on the other hand, symbols represent virtually any type of object, person, process, concept or class of objects. Newell and Simon define symbols "as physical patterns that can occur as a component of symbol structure which is composed of a number of symbols related in some physical way as being next to each other". Symbols can thus be considered as strings of characters and symbol structure as a type of data structure.

3.1. *Knowledge Reprseentation*

As knowledge is the fundamental constituent of any Expert System, the representation of the knowledge base for manipulation by the machine is an important aspect which has been researched upon in depth. The most important current approaches are Predicate Logic, Semantic Network, Frames and Production Rules.

Predicate logic is a widely used formal language of symbol structures used in computres for knowledge representation mainly because it most often aids in our intuitive understanding of the domain. It is precise and demands a clean syntax, clear semantics and, above all, the notions of truth and inference. The usefulness of this type of logic was first mooted during the 1960s mainly as a result of research into mechanised theorem proving. Initial efforts were towards the use of the resolution procedure developed by Robinson for automatic theorem proving and one such system, QA 3, was successful in solving simple problems in a number of domains such as chemistry, robot movement, puzzles and automatic programming. Unfortunately, the resolution method is unable to handle complex problems because of the method of deduction which becomes impossibly slow as the number of facts known about a domain increase. Several domain-independent heuristics were then tried out to constrain the search but they have proved to be too weak. However, there is no doubt that the formal precision and interpretability of logic supplies expressiveness that the other schemes lack.

The concepts of semantic networks have been borrowed from the field of psychology where these have been used as psychological models of human memory. This is an approach for representing abstract relationships amongst objects in the knowledge domain of interest, e.g. membership in a class. Such a relationship is best represented graphically by a network of nodes and links, with the former representing objects and the latter representing relationship among objects. The links are 'IS-A' links describing the existence of a generalisation between a sub-class and its super-class. For example 'Cow IS-A Quadruped' is a typical example of a sub-class (Cow) related to a super-class (quadruped) through an 'IS-A' link. In this case, it can be seen that the easiest way of inferring the information would be from the top levels of the hierarchy downward along the links. In this way, it is possible to share information among many nodes thus facilitating economics of large-scale representations. This type of approach is reminiscent of human thinking but the multiplicity of links as we go down in hierarchical level can lead to situations of being lost in the mesh unless a strong guiding principle such as the beam-search is used.

Frames are prototypes that represent objects by certain standard properties and relations to other objects. Frames were conceived by Minsky to break knowledge into highly modular chunks. A framework system is thus essentially a semantic network in which objects are represented by frames with inheritance relations defined. They can also contain default values which define the systems expectation for variable attributes. For example, a 'Crow' frame might list 'white' as the default value for the colour attribute, as albino crows do exist in nature. Frames organise knowledge in such a way that recall and inference are made easier. It has been found that frames are particularly useful to represent knowledge of certain stereotypical concepts or events.

Production systems were first proposed by Newell as models of human reasoning. They represent knowledge as pattern-action, if-then, antecedent-consequent and situation-procedure pairs and this has proved to be an easier method for encoding rule based knowledge in many applications such as speech understanding, medical diagnosis, mineral exploration etc. One obvious quality of production systems is modularity i. e. they provide a high granularity of information (facts and rules). They have the advantage that information can be easily added or updated and changes due to actions can also be easily kept track of. Further, they make it easier for representing heuristic knowledge, particularly domain specific information. Davis and King consider production systems to be most appropriate where (a) the knowledge is diffuse, consisting of many facts as opposed to concise unified knowledge, (b) the processes can be represented as a set of independent actions, and (c) the knowledge can be easily separated from the manner in which it is to be used. It is, however, to be noted that production rules suffer from inefficiency of programme execution and the formalism makes it hard to follow the flow of control in problem-solving.

There is another issue of knowledge representation that is of interest to expert system designers. This refers to the use of fuzzy logic to represent information that lacks precision. Fuzzy logic uses graded or qualified statements rather than those which are strictly true or false. The elasticity in the fuzzy logic avoids the conventional rigidity in computer programming and thereby simplifies the task of translating human reasoning which is inherently elastic. By providing a single inferential system for dealing with the fuzziness and incompleteness of information, fuzzy logic provides a systematic basis for the computation of certainty factors in the form of fuzzy numbers. These can be equated to linguistic qualifiers such as 'likely', 'unlikely', 'almost certain' etc. Zadeh considers fuzzy logic as an asset for expert system computer programmes.

As each of the schemes discussed above has relative advantages and demerits, the present trend in expert system design is to combine representations with each scheme being considered for the best representation of a particular portion of the knowledge. An expert system may, therefore, use production rules to define procedures for discovering attributes of objects, semantic network to define the relationship among the objects referred, and frames to describe the objects' typical attributes.

3.2. *Inference Engine*

The next aspect of the expert system that has to be considered is the reasoning mechanism employed to infer new facts from what has already been stored. This involves dynamically creating new symbol structures from old ones. Since an unguided application of inference procedure leads to combinatorial explosions in most real life situations, there is a necessity for working out a control strategy.

In so far as the search process is concerned, the simplest formulation is the state-space approach. In this, the mechanism of inference uses states and operators. The state can be considered as similar to a snap shot of the problem at any given stage of the solution and the change from one state to another being affected by the operator. A straight forward approach is blind search where we select some ordinary scheme for the search and apply it till the solution is found. The search proceeds by successively generating and examining the branches emanating from the nodes (states), starting with the root node (initial or goal state) and proceeding along generated branches to new nodes. In the breadth-first strategy, the states of the search tree are examined level by level starting from the root node. No nodes at a deeper level are examined until all nodes at a previous level have been explored. The depth-first approach is based on the fact that new states are generated from the state currently under examination. In this search mode, the direction of the search is always from root node to successor node until there is a necessity to back track. To prevent consideration of paths that are too long, a depth bound is normally specified.

Since the root node can be either the initial state or the goal state, there are two ways by which the desired solution can be realised. In the forward (data-driven) inferencing mode, the system attempts to reason forward from the initial state to a solution. In the backward (goal-driven) inferencing mode, the system works backward from a hypothetical solution to find evidence supporting the solution. This requires very often the formulation and testing of intermediate hypothesis (states).

Since blind search methods do not make use of any knowledge about the domain for guiding search, in most situations the practical limits on the time and the memory space available reduce their effectiveness. Heuristic search methods using domain specific information to guide search have now been evolved to mimic the process of inferencing most often employed by human experts in search of a satisfactory solution. One straight forward method is to apply an evaluation function to each generated state and then pursue those paths that have the least expected cost. The A* algorithm suggested by Nilsson is one such formalism which is guaranteed to find a solution path of minimal cost if any solution path exists.

While this approach has been well received for game type problems, in real life situations the evaluation function is elusive and sometimes a strategic retreat may be called for. Hence to be useful, evaluation functions must characterise the solution space adequately which in turn means the availability of a substantial amount of knowledge.

Hierarchical methods have been put forward by many workers in the field of expert systems as an efficient problem solving approach. In this approach the emphasis is to reduce the combinatorics by carrying out a search of the abstracted representation of the solution space. The search in this case is quicker because the abstracted space is smaller and single steps in this space correspond to big steps in the original search space.

The present picture of the search methods is best summarised by Schank. He states that "Searching massive amount of information requires not efficient algorithms, but knowledge representation that obviates the need for these algorithms".

3.3. *Knowledge Acquisition*

One of the least discussed aspects of the Expert System is Knowledge Acquisition which has limited the widespread use pf these in problem solving. Since the expertise is to be derived from a human expert, communication problems impede the process of transfer of expertise into a programme. The vocabulary of the expert about the domain is often inadequate for problem-solving and thus the designer has to work closely with the expert to extend and refine it from the point of view of structuring the domain specific knowledge. In view of the specialisation needed for this work, a new branch of engineering called Knowledge Engineering (KE) has come into existence. Formalised ways for training personnel in this field are available in very few academic institutions in the world today.

3.4. *Programming Tools*

A number of tools or languages exist today for building an expert system. These range from general purpose programming languages such as LISP (list processing) to knowledge representation languages such as UNITS, KRL, OWL, etc. In addition, expert system shells such as EMYCIN, KMS, ACE, ARS etc. are also available for building successful application systems.

3.5. *User Interface Aspects*

Expert systems need to interface to several different categories of users and they have to carry on meaningful dialogue to explain their own reasoning, understand a user's problems, and insist to solve them. The normal user requirement is in the form of simple data entry but varying modalities of presentation or display of information.

There is a considerable amount of difference of opinion among scientists as well as among laymen about the present state of technology and usefulness of Expert Systems. One set of opinions states that the present day expert systems are particularly useful in situations where expertise is scarce and where different parts of the expertise are distributed among many people or where the expertise is simply not available on a reliable or continuing basis. An entirely contrary opinion as expressed by Anderson states that today's expert systems are limited to diagnostic type of applications because they have not incorporated the human traits of perception, criticism and multiple levels of reasoning. From the point of application to military situations, it is safe to predict that they have significant potential and that potential systems will be realised in the next five to ten years.

4. Computer Vision

Computer Vision which denotes perception by a computer based on visual sensory input is another popular topic in the field of AI today. Even though there is diversity of view points with respect to the organising principles, and the associated technologies are yet to be fully rationalised, commercial products are already available in the world market. Computer Vision differs from Image Processing in that while the latter is concerned primarily with image-to-image operation, the objective of the former is to construct a description of the scene from which the images were obtained. The processes involved in Computer Vision are recognition of objects present in the scene and determining their properties and relationships. The images do not contain sufficient information to construct an unambiguous description of the scene due to the facts that depth information is lost and overlapping of objects in the scene frequently occurs. In addition, many different factors such as level and angle of illumination etc. complicate the recognition process. Therefore, the techniques used in Computer Vision are derived primarily from pattern recognition and artificial intelligence. Most of the work in this field has been influenced by the findings of Marr and his associates about human visual information processing. Therefore, an understanding of the computational theory of human vision would be helpful to appreciate the work carried out in Computer Vision.

4.1. *Human Vision System*

The human eye is basically a sophisticated vision sensor which gathers and assembles raw visual data about the environment. This data is in the form of a complex two-dimensional image and it is characterised first by features which arise from physical discontinuities in the scene. These features are then interpreted by the brain into useful information such as texture, colour, shape, orientation, approximate dimensions, distance and even motion. This yields a 'two and half dimensional', representation of the scene specifying the physical shapes of the visible surfaces. The human perception at this stage combines a top-down with a bottom-up approach by studying the entire scene as a whole (global approach) as well as sensing discrete components of the scene and structuring them in the brain till the entire scene is interpreted (local approach). The degree to which a global versus local analysis is processed depends on the extent to which earlier models of the scene have been stored in memory. In the case of a familiar scene such as one's own residence (say), a quick glance establishes its identity whereas in the case of an unfamiliar house, a detailed bottom-up analysis of the scene elements are required to fix it in the human mind. Scientifically, it can be stated that the human eye/brain system views the scene as a hierarchy of groups and sub-groups of image elements. It also relies heavily on the use of symbolism for interpreting images. This is made possible because of the vast number of previous visual experiences stored in memory.

4.2. *Computer Vision Systems*

The four basic elements that constitute a computer vision system are :

(a) Sensing Element — This should have the capability to receive incoming radiation from an object or scene.

(b) Image Formulation Sub-system — This should have the capability to receive the incoming radiation, process the signals for compatibility with computer processing capabilities.

(c) Image Analyser — This should analyse and measure various characteristics of the image.

(d) Image interpreter — This leads to decision about the object or scene under observation and is carried out by a computer.

Though vidicon cameras had been used in the earlier generation of machine vision systems, solid state cameras with CCD or CID (change-injected image devices) sensors with 256 × 256 elements per array are being increasingly considered at the sensory element. The output of the camera is a matrix of voltage levels proportional to the average light intensities over the area of the image. This image is captured and frozen by an image formation subsystem typically 625 times a second. If the system is binary, then the memory storage requirement works out to be 65,536 locations for analysis. If a 16 level grey scale is used, then the storage requirements go beyond one million locations. The human retina with 10^8 cells operating roughly at 100 Hz performs atleast 10 billion operations per second and this is one reason why computer vision systems have to go a long way to match the capability of the human vision.

The image analyser extracts from the stored bits of information the local features such as edges, curves, spots or corners to use as elements in building a description of the image. The earlier approaches to the iconic process were based on signal processing concepts but it was soon realised that this is not feature-specific. To obtain feature-specific responses, 'gating' requires to be applied. An alternate method that has found favour is based on modelling the image as an intensity surface. Though these approaches are quite powerful, they do not deal with the scene and, therefore, changes in surface reflectivity, surface orientation or in illumination can give rise to erroneous results. This is the hierarchical bottom-up approach and can yield good results for simple scenes made up of only a limited number of previously known objects.

In the hierarchical top-down approach, image matching by template is employed to search for a specific object or structure within the scene. The standard signal processing approach of matched filtering at the fixed level and searching for consistent combination of these matches appears to have yielded consistent results. From the point of view of reduced computational cost of the matching process, it is advantageous to find matches at low resolution and then search for high resolution. There is no systematic way of determining the initial resolution cell for matching and it has been the practice to try adhoc approaches for successful matching performance in most situations.

The image interpreter performs the job of recognising the simple objects appearing in the scene, measure properties of and relationships among these objects and represent the scene with a relational graph in which the nodes correspond to objects, labelled with property values and the arcs correspond to relationships. In this process, the AI approaches mentioned under knowledge representation and control strategies are quite relevant if the computer vision system has to possess the capability to recognise objects under a wide variety of distortions.

For three-dimensional scenes, the basic approach is to use shading, textures, shadow edges and other image features as constraints on the objects that are present in the scene. Even though each constraint may lead to many different shapes for the object, a unique shape merges on combining a number of constraints. From this it can be concluded that the object is actually present and also deduce its orientation.

The field of computer vision still faces many challenges. Existing systems can deal only with restricted types of scenes and are not fast enough. Kanade and Reddy sum up the developments in this field by stating that 'much more knowledge of the world has to be incorporated into the programme for developing generic systems. There must be a mechanism to store large-scale spatial information about an area from which relevant data can be extracted and into which the newly acquired information can be fed. Finally, there has to be a dramatic increase in the speed of vision processors. Once such high speed processors are available, highly computationally intensive methods may be attempted, leading to more versatile systems'.

5. Defence Applications

The ultimate aim of AI in defence is towards combat automation. While this final goal is still far off in time, AI has been used in some interesting applications such as target classification identification, information fusion for situation assessment and signal understanding in electronic warfare.

Target Classification and Identification

The major sensor element in military applications is the rader which is mainly used in detecting and tracking desired targets. Recent developments in radar systems have made it possible to extend their capability to imaging. The imaging radars take a number of forms depending on the application. They range from synthetic aperture radars (SAR) carried on moving platforms to stationary radars for imaging moving objects such as aircraft or orbiting objects or celestial objects. These are coherent radars which effectively use range and doppler information to produce radar images. These images are of relatively poor quality. Compared to optical images, these are noisy due to the false alarms and are subject to highly variant reflectance properties of the objects with respect to the viewing angle by the sensor. In complex objects such as ships the image analysis based on the range-doppler information is quite involved due to lack of information on the viewing angle, ambiguities in ship's orientation, varying orientation of strong scatterers such as radar or communication antennas and due to masking.

Traditional approaches such as statistical pattern recognition would call for enormous amount of data storage corresponding to storing of the range-doppler maps for all interesting views of the composite target and orientations of the strong scatterers. This type of problem is thus tailor-made for AI applications. An expert system for Radar Target Classification would have a knowledge base which would contain : (a) Pre-stored list of all the possible target classes, versions and their known tactics, (b) Contextual information-type of weather, possible routes in that sector/theater, serviceability and losses of the hostile forces, (c) Intelligence information obtained by humint and other sensors or sources of information, and (d) Parametrised templates for each target class based on range-doppler information to include minor variations.

The inputs from the imaging radars first undergo signal processing, image processing and pattern recognition to extract strong easy-to-find features, such as extreme edges and points and superstructures that stand out. This information is correlated with the contextual information such as the likelihood of particular target classes in the operational area to reduce the candidate target classes. For each of the selected target classes based on the data stored in memory, additional image features are formed and compared with the image radar data currently under examination. This process is repeated until the process of target classification is completed. This is a hierarchical search process combining data driven (bottom-up) and goal directed (top-down) strategy. The heuristic portion of the knowledge base is obtained from the human expert and this would contain the dimensions, the relative positions of strong§ scatterers such as antennas, the super-structures and the likelihood of particular classes of targets being used by the hostile forces. If more than one sensor is used, say a laser radar or an infrared sensor along with the imaging radar, then AI techniques can be used to combine the data to take advantage of the complementary nature of the sensors. The combined information of target classification from multiple sensors when subjected to an AI process leads to target identification.

5.2. *Information Fusion*

The aim in this case is to integrate information drawn from diverse sources in order to understand and determine a possible threat situation. Even though there may be a large number and type of sensors, the information available individually from them may be incomplete, uncertain and even erroneous. For example, there may be hostile systems which operate on a passive mode acquiring information through communication nets. This leads to incompleteness of our information of the situation. The hostile weapon system radars may be put on for very short time for completing their mission and it may be difficult to correlate the data collected from them and track. In this case, there is uncertainty in the determination of the parameters. There can be hostile threat systems in use which do not utilise the normal RF spectral region for their operation or may have characteristics which are wide open. In this case the information gathered may be erroneous.

The AI system operates with an architecture that emphasises active acquisition of information by seeking out high value information in a top down fashion. The present information is utilised to anticipate likely significant events that may arise in the near future. Threat operation sequences, known association of threats derived from knowledge of enemy's typical deployment patterns are processed to hypothesise possible as yet unseen threats as a module. By examining the list of possibilities, ordering the list according to system's current requirements and examining models of its sensor resources, an optimal sensor configuration can be chosen for these postulated threats. The control module determines the type of data that has to be collected from the sensor configuration for the selected threats and directs the sensors to undergo the necessary sequence of actions. The data so collected by these sensors is now required to be analysed and interpreted. This is done by comparing the latest reports from the sensors with the current situation model and updating it.

The Expert System will then consist of a total Knowledge Base representing the range of capabilities of sensors, threats, and defenses. The Dynamic Scene model is the structure which stores the current situation information. This model is a layered representation which relates sensor reports to emitters and to threat systems. The data in the Dynamic Scene model include mode information, time information and location data. While a conventional approach would have given satisfactory solution, the AI approach in this case with access to other sources of data and contextual as well as heuristic knowledge of human experts would yield results with minimum false alarms and ambiguities. Finally, the AI system gracefully degrades as the environmental conditions worsen due to severe hostile EW action or threat execution.

5.3. *Other Applications*

An interesting application of AI is the Mobile Intelligent Robots employed for traversing land environments in the reconnaisance mode. The Robot would have to be fitted with radar, infrared, TV and laser sensors in a multi-goal environment. AI techniques will be of use in fusing the multi-sensor information and adaptively allocating the limited resources.

AI can be very gainfully employed in a wide area air defence network to support a multi-radar track-while-scan system. The problems here would be mostly in the area of measurement association and measurement ambiguities. The contextual and heuristic information of human experts would from the knowledge base of an expert system. This would enhance the air defence capabilities of such a network.

6. Future Trends

Though it is risky to predict the future trends in an emerging area of technology, there are certain broad trends in AI which are likely to gather momentum in the coming years. It is evident from the enthusiasm with which Expert Systems have been accepted in their short period of existence that they will penetrate deeper and over a wide front in commercial, industrial and defence applications. Since AI technology has shown the way for mechanisation and automation of transfer of expertise; the impact on imparting of education in technical, vocational and service areas will be truly astonishing. Expert Systems, personal computers and telecommunication networks are synergestically interacting towards expert-to-expert and nation-to-nation knowledge exchanges. The developments in the field of Computer Vision will give greater fillip to robotics to operate in environments which vary with time. Intelligence Robots may also take over many functions which are performed today by humans.

Artificial Intelligence will provide the means for knowledge dissemination and to keep pace with knowledge generation so that the rate of obsolescence that is occuring today in such areas as electronics, biotechnology, medicine etc. will be reduced. The explosive growth of technology and the shortened lifetime of knowledge has exposed the weakness in the transfer mechanism through human beings. This could have stifled further technological growth and its application and set back the clock of progress. Fortunately for human civilisation, Artificial Intelligence, once considered as an obscure branch of computer science has provided the mechanism to overcome this difficulty and enable mankind to forge ahead.

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