Robotics

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AI-powered Decision Making in 'Robotic Solutions'

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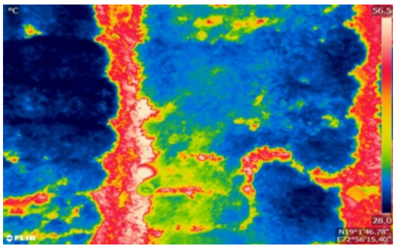

Thermal image of the plantation

ABSTRACT

Artificial Intelligence (AI) based decision making enables robotic solutions to perform intellectual tasks. In robotics, AI solves many complex problems which are otherwise difficult to solve. In this article, some of the robotic solutions developed at BARC,wherein AI powered decision making had been used, are described. AGV based material transfer system is one of the instances, where AI-powered decision-making hasbeen applied to enable autonomous operation. Drone based system, developed for land survey and research in nuclear agriculture, uses AI to build models that provide crucial information for decision making. Perception is a challenge in self-driving robots. Deep Learning based data driven AI approach has been used to build perception system with sensorpacks containingLiDAR, monocular camera and stereo camera.

KEYWORDS: *AI powered decision, Robotic solutions, Artificial Intelligence, Autonomous operation, Aerial robotics, Perception system*

Introduction

System designers use different degrees of AI in decision making such as '**decision automated**', '**decision augmented**' or '**decision supported**' approaches in the overall scheme of solution[1]. Irrespective of the approach, AI part is to attain the reasoning ability needed to take rational conclusions for decision making. AI uses deductive and inductive reasoning for problem solving and it includes methods like heuristic algorithms, probabilistic algorithms, machine learning methods and many more. Some of the algorithms conclude the result with certainty while others conclude with associated probability. Robots in real-world face challenges similar to what a human face in decision making. But the evolutionary advantage and the vast amount of prior information human has, is missing in robots. Robots rely on the knowledge passed on by the system designer or have to extract useful information from the data received through a variety of sensors they possess. AI models help to use 'the prior knowledge passed on' as well as 'to make sense out of raw data' from the sensors. With the current state of AI technology, all decision making cannot be made fully autonomous. System developers need to bring human in the loop and make compromise in autonomy for effectiveness of the solution. Based on the level and the nature of human intervention apt for the robotic solution, system developers have a range of choices of concepts. Some of these concepts are as follows[2].

- **Human in the loop** - The human actor makes the decision and the AI part provides only support in taking decision.
- **Human in the loop for exceptions** – Most of the decisions are automated and the human actor handles exceptions alone.
- **Human on the loop** – AI part makes micro-decisions and human is only assisting AI.
- **Human out of the Loop** – AI part makes every decision. Human intervenes only to set new objectives, constraints etc.

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With this background, further sections will describe some of the robotic solutions developed in-house wherein AI powered decision making had been utilized.

Autonomous Material Transfer System

Nuclear industry requires automation not only for improving the efficiency of the process but also to reduce the occupational hazards to workers. Automated guided vehicle (AGV) based Autonomous pellet boat transfer system (APBTS) developed at DRHR, BARC as shown in Fig.1 and Fig.2, aims to improve on both the fronts[5,7]. It is an AGV based system which can transfer materials in an industrial facility without the need of an operator to drive it. APBTS has adopted 'Human Out of the Loop' model in the implementation. Based on the real time data from the network of sensors located in the shop-floor, the system decides from where to pick-up and where to drop-off the material. AGV does the transportation of material from pick-up stations to drop-off stations. An effective planning solution[3,4] is required to achieve certain goals like 'efficient utilization of AGVs', 'optimal task assignment' etc.

Search algorithms are crucial to path planning which involves finding the best possible route for the AGV in terms of cost, time, energy or any other user defined parameter. Although, traditional uninformed search algorithms are useful in many cases, for mobile robot-based applications, their utility is limited. Algorithm like "Dijkstra's" are optimal; however, they are not fast enough to solve the problem and automate the overall solution in practical environment. So, for this application, a heuristic-based search algorithm which is fast to solve the problem is essential and if it is optimal, that is an added advantage. Algorithms like A*, D* fall in this category and are popular for the problem domain. Both are deterministic planning algorithms, A* is a complete and optimal, under certain conditions and D*, which is based on A*, is used for

Fig.1: AGV trial at NFC, Hyderabad.

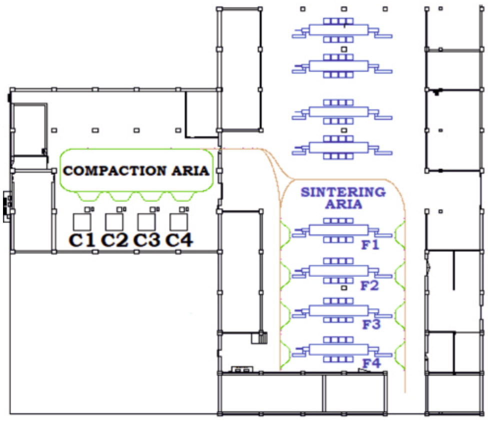

Fig.2: Layout of the plant.

dynamic planning in partially known and dynamic environment. In this line, a customized software solution[4] has been developed for planning the path for AGVs.

The whole process of material transportation on the factory floor is executed without the intervention of human. System utilizes the prior information about environment and process, which is provided by the designer or operator. This includes map of the area, know-how of the process being automated, constraints etc.

Drone based System for Land Survey & Agricultural Research

Aerial robotics, empowered with AI, is changing the face of various application domains including the geographical survey and agriculture for betterment. Drones can navigate to the places where a human can't, provide new information affordably and cover large area in short span of time. DRHR, BARC has developed drone-based solutions to conduct' photogrammetric survey' of land and 'thermal & multi-spectral imaging' for agricultural research as shown in Fig.3 to Fig.6.

With a drone and an onboard camera, it is possible to carry out land survey with the same quality of highly accurate traditional methods. This takes only a fraction of time required by traditional methods. It uses photogrammetry technique, bundle-adjustment based optimization which minimizes the reprojection error, to combine images that contain the same point on the ground from multiple vantage points to yield detailed 2D and 3D maps. Quality of the result depends on various factors like planning, image quality, weather pattern, control points, expertise of the surveyor etc. Drone captures Multispectral/Thermal/Colour images of survey site using high-resolution multispectral, thermal and visible-spectrum onboard imager. It autonomously navigates along a pre-defined path and captures images along the trajectory. Some decisions like defining way points, postprocessing of data etc. are left to the human operator.

For agriculture applications, some of the prominent areas are yield prediction, crop health, field phenotyping of plant response to drought etc. Thermal imaging is now an established technology for the study of stomatal responses and for drought phenotyping. This could be helpful for the development of drought tolerant varieties of different crops through mutation breeding. Computing vegetation index maps, by means of drone based multispectral imaging, helps to assess health of the crop. Such a system together with other solutions help to perform relative biomass analysis, drought stress assessment, agricultural production prediction, nutrition monitoring, identification of pests and diseases that are affecting the crop etc.

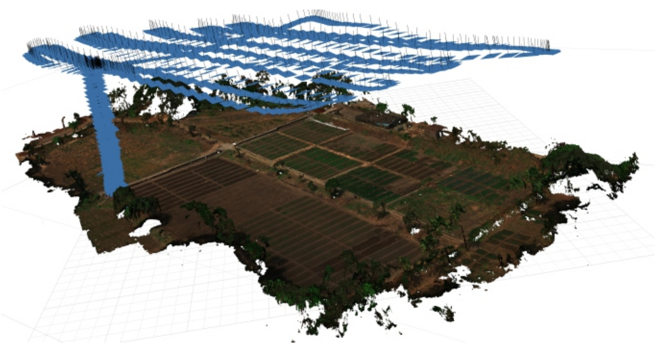

Fig.3: Digital Elevation Model of a Farm.

Fig.4: Vegetation Index map of a Farm.

Fig.5: A patch of the plantation .

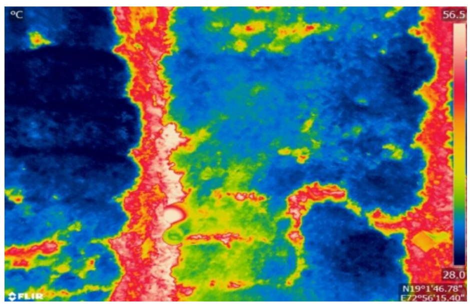

Fig.6: Thermal image of the plantation.

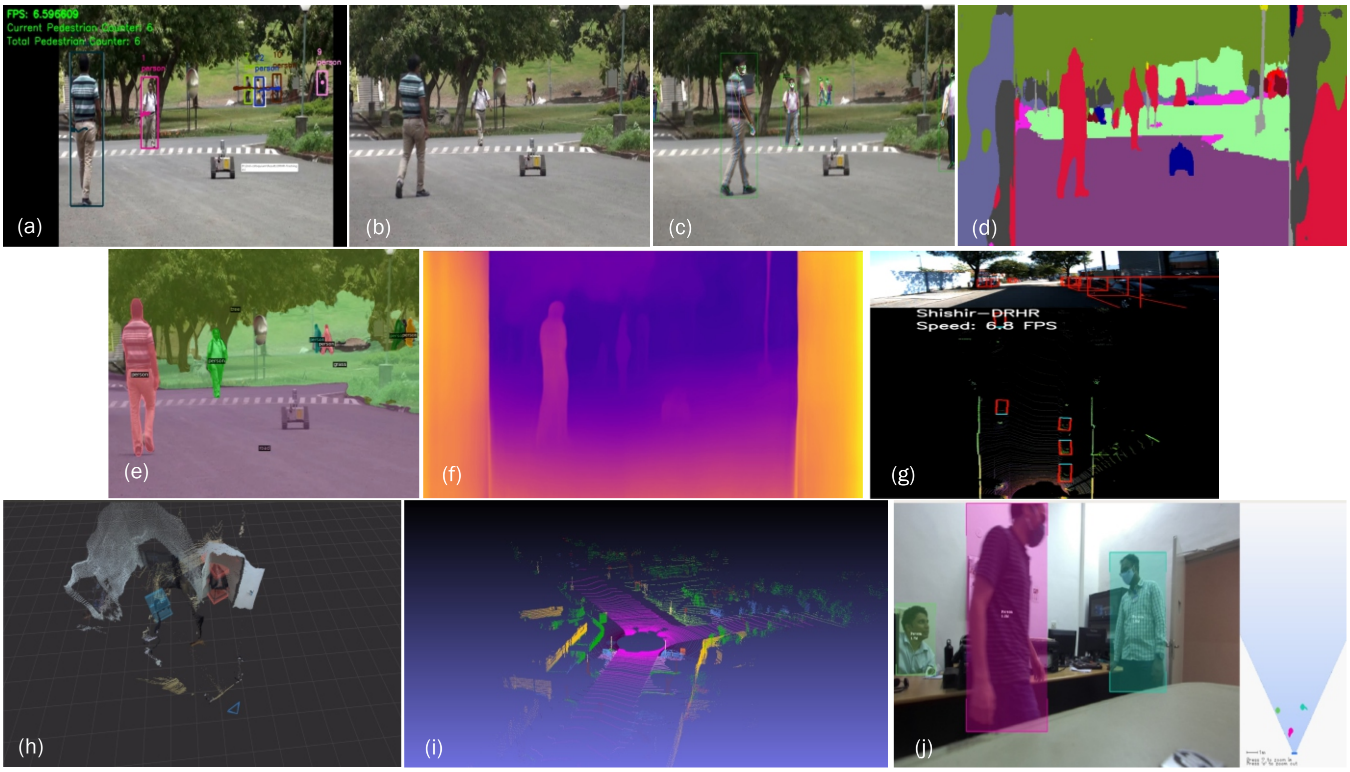

Fig.7: (a) 2D Multi Object Tracking (b) Pose estimation (c) Raw image (d) Semantic Segmentation (e) Monocular depth (f) Panoptic Segmentation (g) 3D object detection in LIDAR (h) 3D detection in stereo camera point cloud (i) LIDAR based semantic Segmentation (j) Real-time 3D tracking.

Perception system for Mobile Robots

Autonomous mobile robots navigate and make decisions without the help of any external agent. The ultimate aim of this technology is to achieve driving capability of human or better and delegate the task to AI engine. Any industry will benefit from such technology in material transportation in factories[5], security & surveillance[6],disaster management etc.

Sensing the environment is a prerequisite for navigation. Just like humans use their senses to probe the environment for safe navigation, mobile robots have sensors such as cameras, LIDAR, radar, sonar, GPS, IMU etc. DRHR, BARC has developed solutions to process data from such sensors using deep learning techniques (Fig.7). This includes detection of objects commonly found in indoor/outdoor environment. Semantic segmentation (SS), which tags each pixel of the image with a category like road, footpath, vegetation, building etc. This is useful in outdoor applications, where the robot needs to travel on road. Panoptic segmentation (PS) combines the task of semantic and instance segmentation which helps to reduce computational cost. Monocular depth estimation and optical flow identifies depth, flow vector for each pixel in an image. It helps in 3D understanding of the scene and motion. Multi object tracking (MOT) provides the temporal information and full body pose estimation is helpful for human activity recognition and tracking.

Conclusion

Future of robotics is intertwined with the progress in the field of artificial intelligence as AI is in the core of intelligent behavior of robots. Advanced robotic solutions inherently demand the development of AI based components to solve challenging real-world problems. Deep Learning (DL) based solutions have achieved a performance level in many applications which makes them a viable option to use in the practical conditions. The new paradigm for future research in robotics is end-to-end sensorimotor learning with reduced intervention from human actor.

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