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RESEARCH ARTICLE

STUDY ON ENVIRONMENTAL DEGRADATION OF UNDERGROUND MINES BY AUTONOMOUS EXPLORATION USING ARTIFICIAL INTELLIGENCE

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ABSTRACT

Artificial Mines are the place from where we are extracting the ore and through the ore we get our goods which pose significant threats to society, yet a large fraction of them lack accurate maps (Tanmoy Maity, 2001). This article discusses the software architecture of an autonomous robotic system (A application of Artificial Intelligence) designed to explore abandoned mines (Environment Degradation). We know that, now a day we are fully dependent on machine whether it a small task or a larger one. We neither ignore the importance of machine nor the mine product such as fuel, ore or our day to day requirement goods (Dissanayake, 2003). So to identify the safest mine and exploration of abandoned mine, we have built a robot capable of autonomously exploring abandoned mines (Baker, 2003). A new set of software tools is presented, enabling Robots to acquire maps of unprecedented size and accuracy. On May 30, 2003, our robot "Groundhog" successfully explored and mapped a main corridor of the abandoned mine near Courtney, PA (Apostolopoulos *et al*., 2001). The article also discusses some of the challenges that arise in the subterranean environments, and some the difficulties of building truly autonomous robots.

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INTRODUCTION

If we look to our previous data, in few recent years, the quest to find and explore new, unexplored terrain has led to the deployment of more and more sophisticated robotic systems, designed to traverse increasingly remote locations. Some of the mines area are very typical to identify. In general, in some of the mines a human can't easily enter and predict the situation. But the Robotic systems have successfully explored volcanoes (Bares and Wettergreen, 1999), searched meteorites in Antarctica (Apostolopoulos *et al*., 2001; Bar-Shalom and Li, 1998), traversed deserts (Bapna *et al*., 1998), explored and mapped the sea bed [1,2], even explored other planets (Baker, 2003; Belwood and Waugh, 1991). In the mines area the accidents are obvious because of roof fall, explosion and water moisture. A recent near-fatal accident in Somerset, PA, speaks to this end: When miners in their routine work accidentally breached a nearby abandoned mine, fifty million gallons of water poured upon them, cutting off nine miners and almost burying them alive. The cause of this accident was officially determined to be a lack of accurate mine maps.

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If we look to our miner details we have so much well equipped machines which can easily predict the situation in the mine, but those are usually just idealized 2-D drawings. Little can be inferred from such sketches with regards to critical measures, such as the volume and the structural soundness of an abandoned mine. Accurate models of such abandoned mines would be of great relevance to a number of problems that directly affect the people who live or work near them. Abandoned mines are the hidden mines in the area which are usually not accessible to people (Burgard *et al*., 2000). So the question arises why ?. Can we able to identify such mines. The another most important reason is

- Lack of structural soundness is one reason;
- The harshness of the environment (e.g., low oxygen levels, flooding) and the danger of explosion of methane,

This makes mine a superb target domain for autonomous robots. However, mapping a mine with a robotic vehicle is a challenge (Cox, 1993). The must be rugged enough to survive the harsh environmental conditions inside the mine. For example The 1,500 pound vehicle, nicknamed "Groundhog" and shown in Figure 1; which is used to identify such abundant mines in a very smart manner and is fully equipped with latest AI technique.

Construction of Groundhog

Groundhog is essentially built out of the front halves of two ATVs, endowing it with identical steering mechanisms on either end. While the exact configuration of the robot varied from experiment to experiment, in its final configuration Groundhog was essentially symmetrical, enabling it to retract without having to turn around (Bosse *et al*., 2003).

Figure 1. Testing the system inside the Bruceton Research Mine, a well-maintained mine accessible to research teams

Groundhog's development began in the Fall of 2002. Approximately a dozen test runs were carried out in a well-maintained inactive coal mine accessible to people: the Bruceton Research Mine located near Pittsburgh, PA (Besl and McKay, 1992; Burgard *et al*., 2000).

Figure 2. On October 27, 2002, Groundhog was deployed into the Florence mine near Pittsburgh, PA

Figure 2 depicts the vehicle after descending approximately 30 meters into the mine, here operating on a tether and under remote control. On May 30, 2003, after a long series of test runs carried out in the Bruceton Research Mine, Groundhog finally entered an inaccessible abandoned mine in fully autonomous mode. The mine is known as the Mathies mine and is located in the same geographic area as the other mines. The core of this surface-accessible mine consists of two 1.5-kilometer long corridors which branch into numerous side corridors, and which are accessible at both ends.

Figure 3. Groundhog enters the Mathies mine near Courtney, PA

Figure 3 depicts both ends of the mine. A map of the mine, provided to us by the Mine Safety and Health Administration and the mine owner [3, 4]. The data acquired on these runs has provided us with models of unprecedented detail and accuracy, of subterranean spaces that may forever remain off limits for people.

Simultaneous Localization and Mapping

Localization and Mapping is also known as navigation process, in which we are trying to identify the position, as well as the status about the mines. Groundhog has a navigation system which is comprised of a software package that solves the SLAM problem by acquiring 2-D maps. The SLAM problem is maily defined as "which is short for simultaneous localization and mapping (Dissanayake *et al*., 2000) arises when a vehicle attempts to build a map while simultaneously localizing itself relative to this map". On the surface, at the lowest level of processing, Groundhog's mapping system utilizes a real-time scan matching technique for registering consecutive scans [4, 5, 6]. Scans are acquired using laser range finder pointed forward. It usually utilizes GPS to acquire absolute position information. Underground, we do not have the luxury of GPS localization.

Data Association

Once a scan data is obtained, then the next issue arises how to associate the different data in to a single form so that we can take some necessary steps to go for the safest mining [7]. Finding the "correct" consistency constraints is an instance of a more general problem known as the *data association problem* (Bar-Shalom and Li, 1998; Cox, 1993). The data association problem comes about when a robot has to decide whether two measurements, taken at different points in time, correspond to the same object [8]. It is a biggest problems arises in the most of the case at association.The scan matcher already addresses the data association problems when aligning scans. However, here the spatial error between consecutive scans is typically small, and simple heuristics such as nearest neighbor work well (Besl and McKay, 1992). When closing loops, however, the error may be large, and nearest neighbor may be misleading [8, 9]. Example of our data association technique:

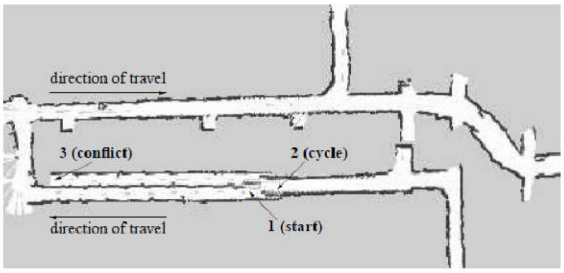

Figure 4(a)

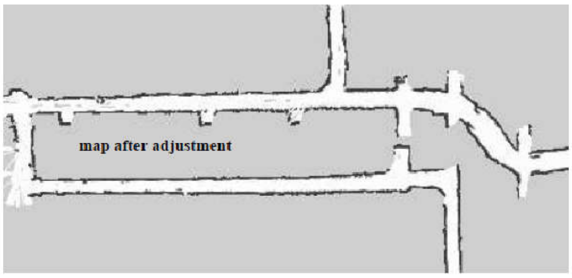

Figure 4(b)

When closing a large loop, the robot first erroneously assumes the existence of a second, parallel hallway. However, this model leads to a gross inconsistency as the robot encounters a corridor at a right angle. At this point, our approach recursively searches for improved data association decisions, arriving at the map shown on the bottom. The figure showed above indicate Such a situation Figure 4(a), where a localization error induces a data association error which, in turn, leads to a broken map. Miss mapping even a single loop can have a devastating effect on the overall map, and as a result the vehicle may get lost in the mine and never return which is as showed in the Figure 4 (b).

Configuration Space Models

It is the another important step of navigation decisions, where the robot maps its sensor data into a configuration space representation (Baker *et al*., 2003; Bapna *et al*., 1998), in which planning amounts to finding a trajectory for a point object. In indoor mobile robotics, it is common to navigate using 2-D maps (Baker *et al*., 2003; Apostolopoulos *et al*., 2001), a strategy that has been reported to work even for active underground mines (Baker *et al*., 2003; as showed in figure 5(a),5(b) Bares and Wettergreen, 1999). In abandoned mines, however, the robot needs richer information than the 2-D information used for acquiring large-scale maps [10,11].

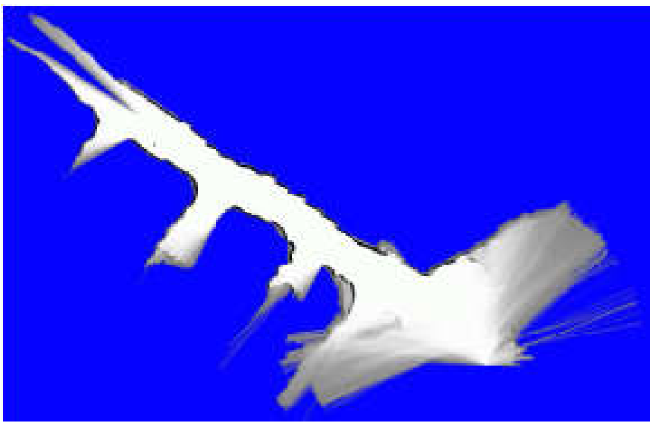

Figure- 5(a)

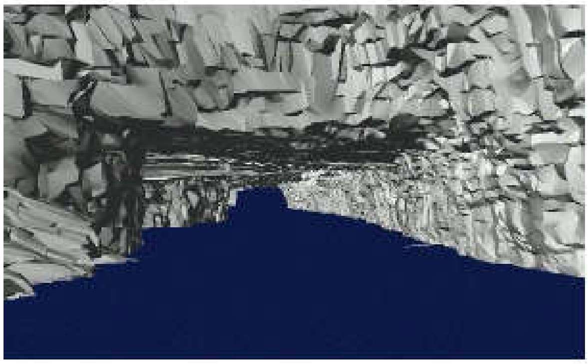

Figure- 5(b) View of a local 3-D map of the ceiling.

This is because holes and debris on the ground may easily create insurmountable obstacles. Other obstacles may reduce the free space above the ground, such as low-hanging wires and partially collapsed roof structures. These challenges tend not to pose problems in active mines, which are typically kept free of debris. They are, however, paramount in abandoned mines [12, 13]. For exploring abandoned mines it is therefore imperative that the vehicle analyzes the full 3-D structure of what lies ahead.

Shortcomings and Future Challenges

As we know that the mining process is very essential for us and for the nation too. We are fully dependent on the mine product now a day. So to go for the mining process in a safer way we need to identify each and every scenario about the mine before the mining [14]. Here we have described the software architecture of a deployed system for robotic mine mapping. Here we have taken the case of Groundhog system which suggests a number of opportunities for further research [15]. The abandoned mines are also a important fact now a day, so that one can autonomously map entire mines, not just fractions thereof [15]. Difficulties in this task arise from the fact that side corridors were frequently closed before miners abandoned them, to stop the flow of gases from inactive into the active parts of a mine. Such closures pose insurmountable obstacles to our present system, but might be surmountable given appropriate means of environment modification.

Limitation

The following are the limitations found in the case of abandoned mines navigation through the help of robots, such as

- The small radii of conventional boreholes make it difficult to lower a vehicle large enough to negotiate the rough ground terrain.
- A second limitation of the present system is its inability to negotiate water and heavy mud.

Benefits

We can easily able to communicate with a robot while inside a mine would have great operational benefits, both with regards to trouble shooting and for assisting the robot in its exploration decisions.

Conclusion

Since, presently there are only low-bandwidth technologies for communicating directly through solid matter are present. So we need to have highly smart intelligent robots which can able to troubleshoot the problems of the mines.

No doubt, Despite these limitations, Groundhog's success in exploring and mapping abandoned mines opens a world of opportunities for subterranean robotic exploration. But we need to have a more intelligent and smaller robot which can easily undergo through the major area surface of the Planet to mapped with great detail, so that the mining can be made more and more safer.

About The Author (Biography)

Prof. Amar Nath Singh is a reader in Computer Science & Engineering department at Gandhi Engineering College, Bhubaneswar, Odisha. He received his Master in Technology (M.Tech) Degree in 2007 from BPUT, Rourkela, Odisha. He is presently pursuing his PhD work in the field of Artificial Intelligence and its application over underground mines area. His research area includes Wireless Sensor Network, Artificial Intelligence, Fuzzy Logic, Algorithms, and Web Logic, etc.

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