Design and Implementation of Inspection and Cleaning Robot for Power Plants

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Abstract
Robotics is the fastest growing branch of technology which deals with construction, operation and control by using sensors, feedback system, artificial intelligence and computerized tools. Now, it has moved on to hazardous applications in various power plants. The advances of technologies for mobile robotics enable the application of robots to increasingly complex tasks. Along with the increased speed of embedded microcontrollers, the service robotic sector has started to grow. In power plants, there are several places such as vessels, surface, nozzle pipes which need to be inspected and cleaned regularly. To ensure the integrity of power plant, these various places must be periodically inspected using ultrasonic sensors and visual cameras. The surfaces and many parts of the plant should be cleaned as many times as required to prevent contaminations. Cleaning of power plants is a tedious task with high efforts regarding time and personnel costs. This paper investigates a robot which is guided using wireless communication by a remote location to inspect and clean various fields effectively. The robotic system is devised to reduce inspection time along with effective cleaning scheduled in places where human exposure is risky. This paper presents the design and implementation of an inspection and cleaning robot in power plants.

Keywords: Robot, microcontroller, remote control.

I. INTRODUCTION

Robots are increasingly being integrated into working tasks to replace humans. They are currently used in many fields of applications including office, military tasks, hospital operations, industrial automation, security systems, dangerous environment and agriculture. Recent technological advancement in robotics has ever increasing need and contribution in the safe and secure power plants. This increasing trend is not only associated with the revolution in robotics, automation and nuclear technology but is primarily because of the escalating concern over the human and environmental safety. Special attention has been drawn towards Safety [1]. Inspection of power plants is essential for a safe and optimal operation of the facilities. Plants get older and older and security assessments are both, necessary and regulated by law. More and more robots are used to execute inspection because of several reasons: automatic or semiautomatic tasks, faster execution, enhanced precision, zones difficult to access, fast global assessment. Cleaning of power plants is a tedious task with high efforts regarding time and personnel costs [2-3]. The advances of technologies for mobile robotics enable the application of robots to increasingly complex tasks. Robots were initially used in the automation sector to handle repetitive and simple tasks reliably, with the objective of cost reduction per product. Along with the increased speed of embedded microcontrollers, the service robotic sector has started to grow[4]. A robot is a mechanical or virtual intelligent agent that can perform tasks automatically or with guidance, typically by remote control. In practice a robot is usually an electro-mechanical machine that is guided by computer and electronic programming. Robots can be autonomous, semi-autonomous or remotely controlled [5].

In a number of robotic industrial applications, human workers are replaced by machines mostly because the latter are more efficient, precise, productive, and can do monotonous tasks without getting tired. However, in power plant applications, the objective is more to extend the presence of robots or to enable them to reach areas where the thermal or radiation environment limits the presence of a human. Robots do tasks such as handling heavy radioactive loads and performing tricky repair and maintenance operation in contaminated areas. Presently, a number of sophisticated robots have been developed for use in power plants [6].

Robot teleportation is one of the crucial features that is highly desired. However, much depends on the reliability of operation since failures are extremely costly. The cost may be in terms of money, time, and more importantly dose received by the operators. If the failed system cannot be repaired remotely, it has to be removed and decontaminated from the environment. Again, both the removal and decontamination are costly. If the failed system cannot be disassembled remotely, human are exposed to hazards [7]. If the failed system cannot be brought out of the hazardous environment, we need to repair it at site, which involves complete decontamination involving long time exposure to human
workers. This at some extent, explains the reluctance of using robots in the power plant industry. Despite the above mentioned issues, research continues into developing and testing teleoperated mobile robots for three main reasons. First, to avoid unnecessary dose to human operators, Secondly, since many power plants are in ageing phases, and their safe operation may require unanticipated inspections, repairs, or replacements. Finally, modern and upcoming plants are being designed with remote maintainability as a design feature [8-9].

Certain inspection and cleaning work need to be done in hostile environment such as areas which are contaminated or in crapped location, making it difficult for patrol personnel. Given these situations, satisfactory observations cleaning and inspections may not be carried out due to time limitations. In addition with this, there is a need to observe inspection and clean the areas inside the vessel which are inaccessible to personnel during boiling water reactor plant operation [10-11].

II. AN OVERVIEW TO ROBOTIC APPLICATIONS

Robots are increasingly being integrated into working tasks to replace humans. They are currently used in many fields of applications including office, military tasks, hospital operations, industrial automation, security systems, dangerous environment and agriculture. Several types of mobile robots with different dimensions are designed for various robotic applications. The robot has been designed for the purpose of aiding rescue workers. Common situations that employ the robot are urban disasters, hostage situations, and explosions. The benefits of rescue robots to these operations include reduced personnel requirements, reduced fatigue, and access to unreachable areas [12]. The robot is built to discover areas which people cannot reach. Robots are extensively used in various industrial applications. However, in power plants, use of robots is limited due to safety issues and considerations. Very few applications have been reported in the available literature known to the authors, which are used in power industry among more than a million worldwide. Over the years, use of robotics has been reviewed and evaluated in several studies.

In [13], the authors reported a low cost consumer robot such as home cleaning robot along with the design of robot which operates semi or fully autonomously to perform services useful to the well being of human and equipment, excluding manufacturing operations. The authors have been using different software engineering techniques, integrating new paradigms in the service robot development process as they emerged. In [14], the author proposed a robotic cleaner navigation system using FPGA and FSM approaches, which detect the force between robot and obstacles. Research continues about different locomotion and adhesion methods for climbing robots and presents characteristics, challenges and applications for these systems [15]. In [16], the authors discussed flying robots along with light weight RGB-D camera, that deals with challenging scenarios and poor environments. They also presented a floor cleaning robot equipped with Swedish wheels. It can be used in crowded places such as houses, train station, airport etc.

In [17], the authors presented report on the situation at Fukushima and present lessons that were learned involving multirobot operation by workers. Workers with no prior experience with robots operated multirobot in dynamically changing environments. Also, a novel outdoor cleaning robot using on board vision based auto navigation is proposed in which the track driven and cleaning mechanisms are designed for cleaning task in outdoor rough terrain. In [18], the authors discussed about using already available robotic solutions to deploy innovative systems in order to fulfil industrial objectives to provide a means to help measuring several physical parameters in multiple points by autonomous robots, able to navigate and climb structures, handling sensors or special non destructive testing equipment. The objective is to increase the efficiency of the installation by improving the inspection procedures and technologies.

In the sections to follow, first, we describe robot design process, then its block diagram. At the end, we conclude by mentioning future direction of this project.

III. ROBOT DESIGN PROCESS

There are following phases which need to be considered while designing a robot:

A) Problem Description
The first thing in designing a robot is identification of the purpose for which it has to be built along with specifying requirements.

In our case, the task is to provide access to confined inaccessible and hazardous places inside the power plant duct system. It implies that there should be an environment sensing and real time reporting system on board on the robot along with on board power supply for movement, sensing and transmission system [19]. The robot should be compact in size and low weight as it has to move in various ducts and narrow cavities in plant.

B) Proposed Design
In this phase, it is required to specify details that the proposed design should have. The proposed design should have following details:

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• How the robot will move in the environment?
• What are its power requirements?
• What type of sensors is used?
• How it is controlled?

C) Robot Fabrication
It is proposed to use AutoCAD for designing mechanical designs of robot. It is designed to move forward, right, left and reverse direction. The controller, camera and vacuum cleaner attached to the robotic arm are processed locally [20].

D) Robot Programming
Following the fabrication stage, it is required to program the microcontroller in ‘C’ language. The programming also involves the design of interface.

E) Control Logic
The main function of microcontroller is to control the movement of robot in all directions. For making it to move in a particular direction, the ‘ON’ logic will be given to the wheels that push the carrier to move in that specific direction [21-22].

F) Environmental Mapping
The camera will be situated on the robotic chassis. This on board camera would be used to map the environment, by capturing images, accessible to the operator through remote Graphical User Interface at the operator end[].

G) Cleaning Operation:
To achieve this, we have created a vacuum cleaner on the robotic arm, attached to the robot chassis using following essential components:
• An intake port, which may include a variety of cleaning accessories
• An exhaust port
• An electric motor
• A fan
• A porous bag
• A housing that contains all the other components

Vacuum cleaners pick up dirt by driving a stream of air through an air filter [21]. The power of the vacuum cleaner’s suction depends on a number of factors. Suction will be stronger or weaker depending on:
• The power of the fan: To generate strong suction, the motor has to turn at a good speed.
• The blockage of the air passageway: When a great deal of debris builds up in the vacuum bag, the air faces greater resistance on its way out. Each particle of air moves more slowly because of the increased drag. This is why a vacuum cleaner works better when the bag is just replaced than during vacuuming for a while.

• The size of the opening at the end of the intake port: Since the speed of the vacuum fan is constant, the amount of air passing through the vacuum cleaner per unit of time is also constant. No matter what size the intake port has, the same number of air particles will have to pass into the vacuum cleaner every second. If the port is made smaller, the individual air particles will have to move much more quickly in order for them all to get through in that amount of time. At the point where the air speed increases, pressure decreases, according to Bernoulli’s principle, the drop in pressure translates to a greater suction force at the intake port. Since they create a stronger suction force, narrower vacuum attachments can pick up heavier dirt particles than wider attachments [22].

H) Power Scheme
The robot would be operated by using carrier mounted two rechargeable batteries. Two 6 V batteries are connected in series to supply 12 V to DC motors driving the wheels. 12V supply is converted to 5V (for circuitry) voltage regulator.

I) Operator Control
Remote operation enables an operator to sense and manipulate an object from remote locations. This is an essentially useful feature where the operator has to work around in hostile environments or confined spaces where human access is difficult or not possible. The control strategy of the proposed robot is based on the theme that the operator will operate and control it remotely. There would be a GUI, providing interface between the robot, and the human operator. Thus, the operator will act as a supervisor, and will give instructions to the robot by using the user interface [23].

![Figure (1) RF Transmitter and Receiver Section](image-url)
J) Testing
Testing is the most crucial phase. A mock up would be developed to test robot before deployment.

K) Evaluation
Evaluation includes testing and verifying the design specifications by the client or user. It is planned to use it by clients at auxiliary building areas outside the power plants first, and then in the actual field areas.

IV. SOFTWARE ROBOT DESIGN

The robot software complements the hardware architecture of the robot by providing basic low level hardware control that include reading the sensors value and controlling the motor speed.

i) C Program:
It is a powerful, feature rich development tool for PIC microcontroller. It is designed to provide the programmer with the easiest possible solution for developing applications for embedded systems, without compromising performance or control.

ii) Visual Basic Program:
This is used for Interfacing between PC and the stair-climbing Robot. Microsoft Visual Basic 6.0 is used in this paper because of its easy programming, easy displaying of visual elements, availability. It is one of the most popular programming languages and it is easy to implement functions using it.

iii) ATMELE 89S52:
It is used as the brain of the robot that can be programmed by connecting the serial port of the computer to microcontroller. Microcontroller reads data from sensors and computer through RF transceiver and decoder/encoder. It is given dc supply as an input, an IC is used to smooth dc input to the microcontroller. According to the inputs received from sensors, microcontroller drives dc motor and hence the arm by which inspection and cleaning operation will be done.

[24-25].

V. RELATED WORK

An inspection and cleaning robot is designed as per the requirements. The flow chart of designed robot is shown in figure 2, which clearly depicts that a robot will act accordingly to the pictures captured by the camera, inbuilt to the robotic chassis [26]. The designed hardware of robot is shown in figure 3.

VI. CONCLUSION

The research in power plants robotics has been in for long period of time but emerging trend is to deploy reliable and humanly-controlled robots inside facilities.
that could carry out tasks that assist humans. The main reasons are to reduce risks and limits to workers. In this paper, an inspection and cleaning robot is designed which is guided at remote location to perform required tasks in various places of power plants. It is easy to operate and reduces risk to human lives in dangerous places of plants. Our proposed robotic application may serve in multipurpose scenarios such as providing access to confined and humanly inaccessible spaces. The designed application of robotics can also be utilised for cleaning in emergency interventions. The fabrication and electronic hardware development of this robot is successfully done.

REFERENCES


