Journal of Information & Communication Technology
Vol. 7, No. 2, (Fall 2013) 25-31

Towards Design & Development of a Mobile Robot for Nuclear Power Plant Applications

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ABSTRACT

For operation of nuclear facilities in general, and nuclear power plants in particular, it is difficult or next to impossible to access & monitor (high) radiation areas where some emergency/abnormal condition has to be detected or mitigated. Presence of a mobile surveillance robot will be very useful for such a scenario. This work is an effort towards the development of a mobile robot that is intended to be used for remote surveillance. As a first step towards development of the mechanical carrier, a four DOF (degree of freedom) articulated robotic arm, and mobile base is developed. All joints of the manipulator are revolute joints. DC motors have been used to empower the joints with the help of gears. Spur gear and planetary gear head have been used to increase the torque at joints and to reduce the speed. Complete mechanical designing in software, casting procedures and fabrication are the main parts of this prototype.

INSPEC Classification : C3390, C3390C, C3355, C7420

Keywords : Inverted Pendulum, Fuzy Logic, Fuzzy-PID, Comparison, Matlab

*The material presented by the authors does not necessarily portray the viewpoint of the editors and the management of the Institute of Business and Technology (IBT) or Karachi Institute of Power Engineering.

1. Introduction

During nuclear power plant operation, it is difficult or nearly impossible to access & monitor high radiation areas where some abnormal condition has to be detected or followed, For example, heavy water (D2O) leakages at places where no or limited CCTV facility is available in nuclear power plants.

It is suggested that the Presence of a remote surveillance/monitoring device such as a mobile robot in the target area may be very useful. It can be controlled through an operator who will be controlling this robot from outside the containment. This robot will be capable of sending the minor details through the images that can be used to detect the leakages.

2. Scope of Project

Today everything is going towards automation and robots are being utilized to do hazardous and routine jobs. Scope of this project has no limits as robots are used practically in every field from commercial to social purposes. This manipulator has been indigenously made at PIEAS/KINPOE and it has given a good understanding about designing in software and fabricating it physically. Different algorithms can be applied to this manipulator to see different types of motion and velocity profiles. As there are always chances of improvements, this design can be further improved by using different materials to reduce its weight, adding more joints, increasing gear ratio to increase torque etc. The manipulator can be programmed in many modes to visualize different trajectories of end effector.

This device is intended to be placed at Plant Collection area/moderator area inside the Boiler room/Containment building (inaccessible areas) so that operational team can visualize the whole area that is out of reach from fixed CCTV cameras already installed in the containment building.

3. Proposed Robot Design

The proposed design of robot is 4 DOF (Degree of Freedom) articulated robotic arm to be placed on a mobile platform. Articulated robotic arms have only rotational motion at joints. The platform gives the robotic arm freedom of motion on smooth/rough surface.

The mobile manipulator remotely controlled by tele-operator both in supervised or direct tele-operated paradigm. The operator would be sitting in another place could give instructions to robot to do the task. The robotic arm could do any task upon requirement for example it can send the information of the on board cameras to the tele-operators where humans cannot work.

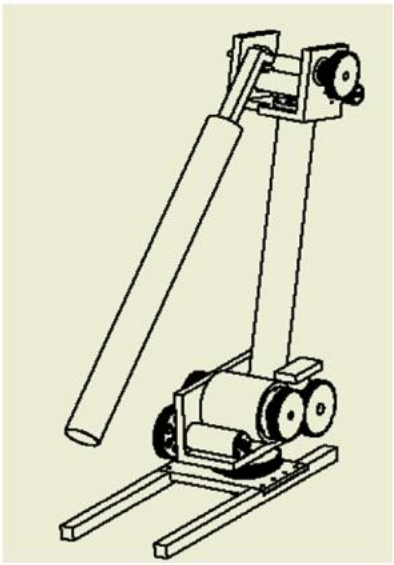

Fig 1: 4 DOF manipulator arm

3. Project Breakdown

This project is a part of large project whose aim is to design and development of articulated robotic arm with end effector mounted with camera and mobile platform. This project has three phases first phase includes design and development of mobile base, articulated robotic arm and its end-effector and second phase includes control hardware and control algorithms design. Third phase includes the testing of the complete project. The project breakdown is shown in Fig.

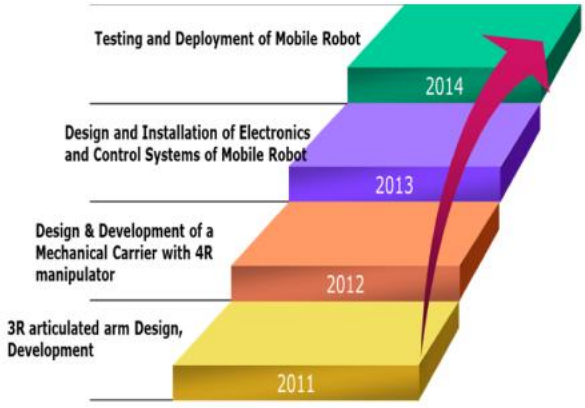

Fig 2: project plan

4. Methodology

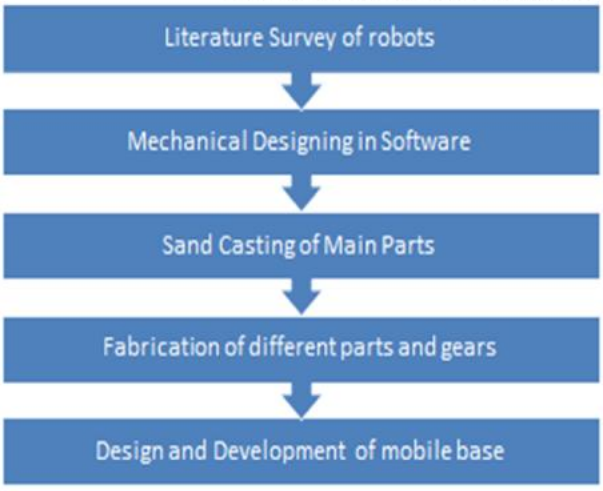

Fig 3: project plan

5. Mechanical design

Mechanical design is the most important part in the field of robotics as the design describes the whole behavior of robot. It is crucial to first completely develop the robot design in the software before fabricating it physically. More sophisticated designs are being built around the world due to advancements in robotics. Mechanical design can be divided into parts.

6. Fabrication of robot and Assembling

The fabrication and assembling of mechanical parts of robot has been done in PIEAS mechanical workshop.

7. Shoulder base housing

The design and assembling has been discussed in systematic way. First base house holding was designed in software. After that by using the dimensions taken from inventor a pattern of it was made by using Acrylic material. It was then casted by sand casting in Mild aluminum. As the piece was large so it was hard to cast.

After casting, base house holding part was given to workshop for machining to get it into desired dimensions. Milling machine is used for this purpose. Then marking is done according to the dimensions. Marking is very sophisticated job as whole fitting will be dependent on it.so we have to be very careful during marking. Marking shouldn't be done in hurry. After this holes were made by using drilling and lathe machine in the housing

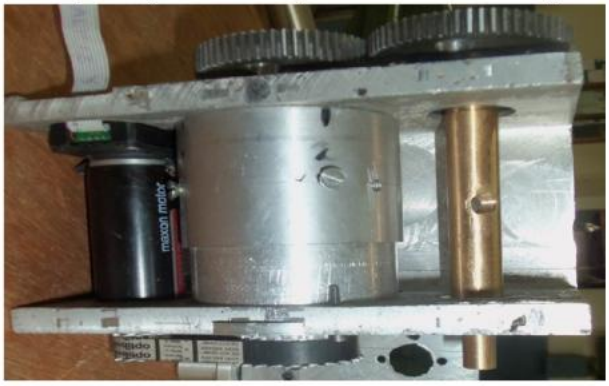

Fig 4: Shoulder housing with all fittings

After that pulley, spur and planetary gears were developed to transfer power from motor to shaft. These gears and pulleys were first designed in software for reduction of speed and increasing torque. Gears were made in Mild steel to give them strength to transfer high torque. While pulleys made of aluminum to minimize the inertia. The current design uses the planetary gear head with reduction ratio of 1:625 Modules 0.5. It is made up of Mild steel to transfer high torque. To transmit the speed from motor to planetary gear head we used the pulleys with reduction ratio 1:2.timing belt of 8 XL is used.

Maxon DC motor 60 Watt was used to drive the shoulder joint with speed of 7200 rpm. This speed was reduced by gears 360 times to increase its torque by the same amount. After the fabrication of all parts bearings, gears and shaft were fitted to make a one complete shoulder joint.

8. Elbow joint

After fabrication and fitting of Shoulder base housing, elbow joint was made. U-Shaped aluminum piece was casted and machined into exact dimension. It was fitted with bearings, motor, spur gears and shaft to make a complete joint. Gear train with 1:11 reduction ratio was used to rotate the elbow shaft. They were designed in Module 1. Second aluminum rod was fitted with elbow shat as link 2. After completion of elbow join whole part was attached through aluminum rod to shoulder base joint to make a complete four DOF articulated robot.

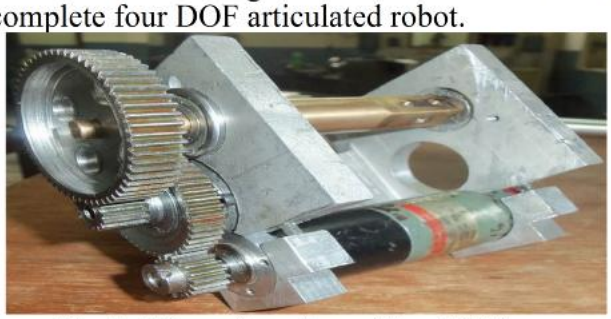

Fig 5: Elbow housing with all fittings

9. End effector

We use rectangular aluminum rod to make the housing of end effector.by using milling machine we get the required dimensions as obtained from software. Then after doing marking we drilled the holes the housing to fit motor and shaft. 3.8W DC motor is used in end effector. Then we make brass shaft and spur gears with ratio 1:3.

After that we make aluminum plate on which a high resolution camera will be mounted in future. After the fabrication of all parts bearings, gears and shaft were fitted to make a one complete part. Then it is fitted on link 2. After complete fitting the end effector was tested on full load. It was running smoothly. The current of motor was not exceeding than the rated current at full load. It can move up to 180 degree.

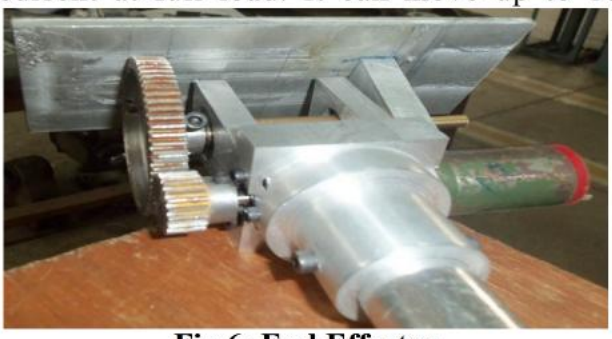

Fig 6: End Effector

10. Manipulator Links

Manipulator consists of two links. Links are made up of Aluminum pipes. Base link is connected with a base housing from bottom. We have provided two degrees of freedom i.e. heaving (moving up and down) and rolling (Rotation about central axis of manipulator). Base housing is 72mm in length and 90mm in height.

11. Mobile base

For a surveillance robot it's very essential to have an efficient mobile base. All areas should be approachable for it. I first start from the structure of the base which is made of 1*1.5inch of MS rectangular hollow rod. Rectangular shape structure of 26*12inch is made by this MS rod using welding procedure. Then two MS shafts of 368mm lengths were made according to the drawing. Aluminum housing for 6205z bearings were made using lathe machine. Four tyres of hard plastic were used in the base. Two sets of pulleys and belts were used to transmit the power from motor to shaft.

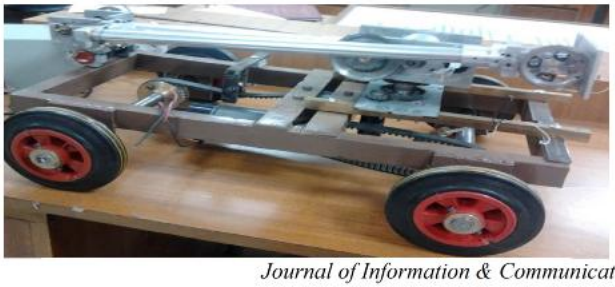

Fig 7: Mobile Manipulator

12. Conclusion and Future Work

This work is part of the larger project which includes completed design and development of four degree of freedom articulated robot manipulator and fabrication of its control system cards. The mechanical designing of robotic manipulator, mobile base and end effector was done in Autodesk Inventor and is fabricated. All specifications of design were fulfilled such as gear ratio, gear fittings, bearing fittings etc. Sand casting procedures were also the part of fabrication process.

Future work includes the kinematics, dynamics and development of the control system for this tele-operated robot and its testing. As there is always some room for improvements so modifications can be done in this mechanical design to make it more efficient. Moreover different materials needed to be investigated for effective use in radioactive environments and to reduce the weight of arm.

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