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REPORT

IN

PROJECT FOR COMMUNITY SERVICE

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“AUTONOMOUS ROBOT DEVELOPMENT OPEN SOURCE PLATFORM - THIRD GENERATION (ARDOP 3.0)”

BY

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CONTENTS

AUTONOMOUS ROBOT DEVELOPMENT OPEN SOURCE PLATFORM - THIRD GENERATION (ARDOP 3.0)

INTRODUCTION

ARDOP 3.0 deals with Design and Development of a BMS Humanoid Robot. This is the 3rd version of the humanoid that is under progress. Robots are becoming prevalent in the world today as they are being used in a multitude of different sectors such as surgery, autonomous driving, etc. Intelligent robots that are capable of performing the required tasks are built using a modular approach and by integrating the various subsystems. ARDOP is an open source humanoid robot that would serve as an extensive platform for the development of robotic applications. The aim is to make a full-fledged integrated hardware and software platform so that it can be used for research purposes to accelerate the growth of robotics. The intention is to build an intelligent autonomous robot that would be used to forward research in the fields of computer vision, control, kinematics, motion planning and machine learning. ARDOP would serve as a platform for students and researchers to implement their ideas and algorithms. One of the primary aspects of ARDOP is its ability to perceive and interact with objects in its surroundings. Such a task is achieved by the seamless integration of various domains of robotics, electronics and computer science such as kinematics, computer vision, machine learning, CNN (convolutional neural networks), mapping, localization and navigation. This project can be used in Robotics Research, Computer Vision, Machine Learning and Kinematics.

A Brief History On ARDOP

The first generation of ARDOP was completed in the year 2017, this robot was capable of performing object manipulation. It consisted of a DUO MLX camera (a 3D camera), the body was 3D printed using ABS plastic, inverse kinematics solutions were developed , Convolutional Neural Networks (using CAFFE) was used to implement object recognition using the stereo depth map.

The second generation of ARDOP was developed in 2017-18. This time an alternative approach was invoked to perform object manipulation, the arms were redesigned, the vison system consisted of a Kinect camera and YOLO was used for object recognition, simulations were performed on ROS platforms such as Rviz and gazebo.

LITERATURE SURVEY

Kinematics

Kinematics is a branch of mechanics that deals with the motion of objects without taking into account the forces that act upon them. Hence it is specifically used for pose estimation of objects-to find out their positions and orientations in three-dimensional space. By employing kinematic equations, it becomes possible to find out the joint parameters that would make the structure move in a way that is optimal for the given task. The goal of the kinematic model is to enable the end-effector to reach the desired position to allow for interaction with real world objects. The solution obtained from the kinematic equations are the angle values for each of the joints that would make the end-effector move to the required position with the required orientation .

The forward kinematic model is predicated on Denavit Hartenberg (DH) parametric scheme of robot arm position placement. Given the desired position and orientation of the robot end-effector, the realized inverse kinematics model provides the required corresponding joint angles. Solving an Inverse Kinematics problem analytically means to compute the joint angles by manipulation of the Forward Kinematics equations. An iterative method computes the joint angles by changing the joint angles by small amounts every iteration. At one point, this process would converge and the joint angles would remain constant. The values at this point are taken to be the solution of the Inverse Kinematic problem.

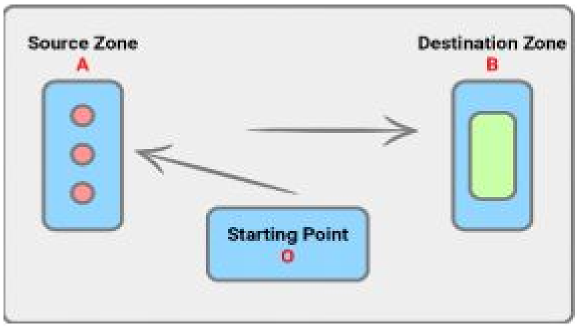
Vision and Perception

The object recognition problem is solved in a plethora of ways today. Computer vision based methods are moving closer into the field of machine learning in order to get more accurate results. The main drawback in using a traditional machine learning approach is that the features have to be manually selected. This is very cumbersome and time consuming process and it significantly reduces productivity. Hence, computer vision algorithms are employed in order to extract features in the images which then can be fed into a classifier. CNNs eliminate the problem of manual feature selection by learning appropriate filters which extract the most influential features for the given data. The paper marked the revival of CNNs by winning the ImageNet challenge, that year by a large margin. The object detection model that we are currently using is YOLOv3 (You Only Look Once). YOLO uses a single CNN network for both classification and localising the object using bounding boxes.

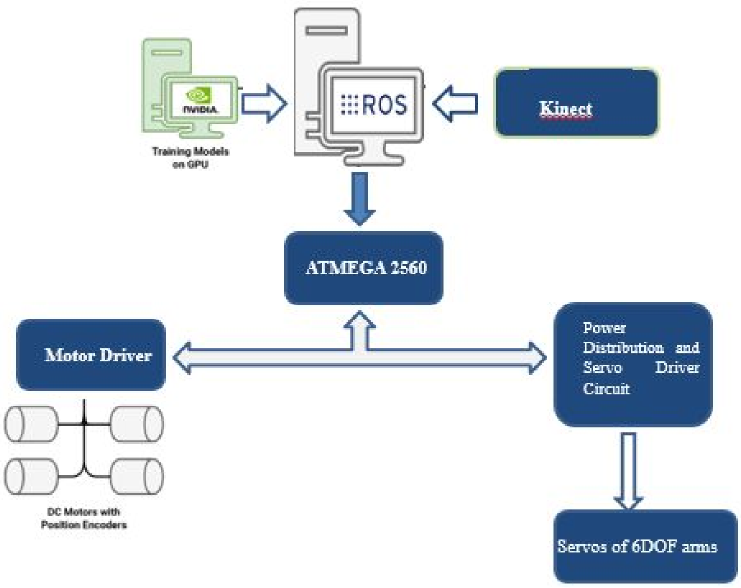
ARDOP 1 and ARDOP2

In addition we are advancing the concepts of the previous generation of ARDOP. The DUO MLX camera in ARDOP1 has been replaced by Kinect in ARDOP2 is continued to the third generation. ROS was introduced to the second generation of ARDOP and is now extended to the third. Improvements are made in the design of the robotic arm the 5DOF arm in ARDOP1 had been increased to 6DOF in ARDOP2, enabling a higher dexterity, this had led to an increase in offset at wrist which decreased the accuracy, in this generation we have developed a 6DOF arm with minimal offset at the wrist, and the weight of the arm has also been reduced increasing the accuracy of the Inverse kinematic solution. A mobile base has been provided which increases the workspace of the robot. CAFÉ was used for object recognition which was replaced by a more YOLO V3 this enabled the detection of up to 80 objects. The use of YOLO V3 has been extended into the third generation of ARDOP.

PROBLEM DEFINITION AND SOLUTION



The problem statement is presented in figure, the robot has to move from the starting point to the source zone where it has to pick up a defined object and move towards the destination zone and place it. The working methodology can be described as shown in the block diagram, the 3D camera (kinect) identifies the object that is to be picked and placed, the object is picked by the arm by performing inverse kinematics, and the process of localization and navigation is performed using SLAM(simultaneous localization and Mapping). Arduino Mega(Atmega 2560) is the microcontroller used. The power distribution and servo driver circuit is comprised of Buck and Boost converters that can regulate power at various current and voltage levels as required by the motors.



PROJECT EXECUTION TIMELINE

Task	Description weeks	1	2	3	4	5	6	7	8	9	10	11	12
1	Development of New 6DOF Robotic arm												
2	Testing of New arm for inverse kinematics (Simulation)												
3	Testing of IK in hardawre												
4	Building the chassis and Hub motor testing												
5	Integration and final testing												

ESTIMATED BILL FOR MATERIALS

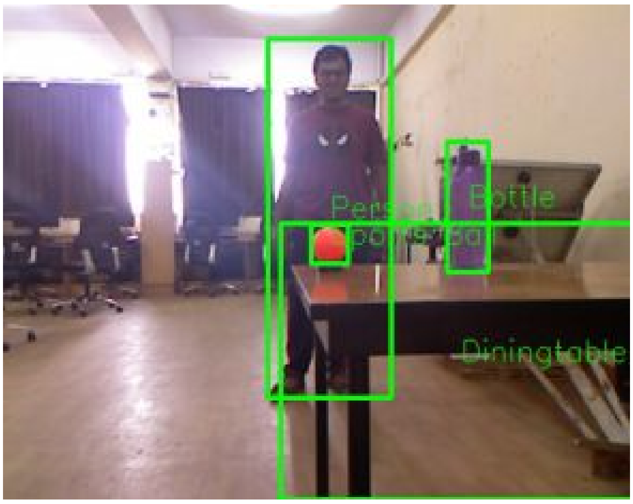
Product Name	Unit price (INR)	No. of units	IGST tax Amount
Ultra Torque Metal Gear 35Kg Coreless Stainless steel pinion Standard Servo motor	2,137	10	3847.5
Servo Extension cable 12’’ Male - Female	28.5	30	153
Metal Horn for Servo 25T	71.25	3	38.48
Multipurpose Aluminium Standard Servo Bracket	114	2	41.04
Aluminium Robotic arm Construction	3500	1	630
Chassis Construction	5000	1	900

Total estimated cost: Rs 36,783.

CURRENT PROGRESS

Vision

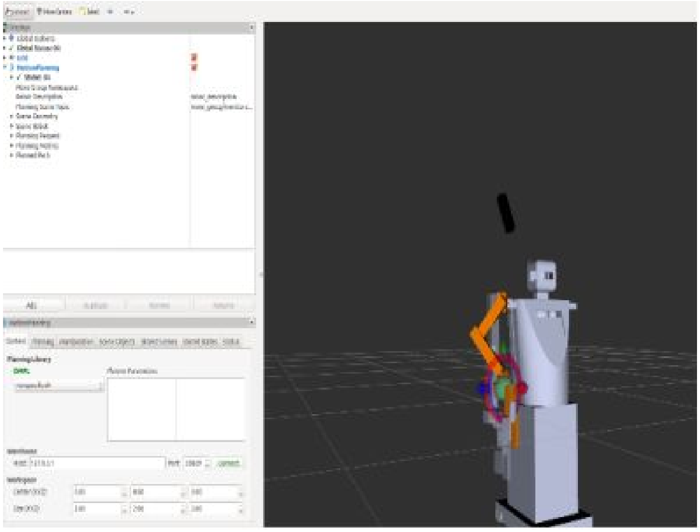
A Kinect Camera has been used for the vision system, this enables the use of openni library for the easy integration with ROS. YOLO has been used for object recognition, object localization has been implemented using the depth information.



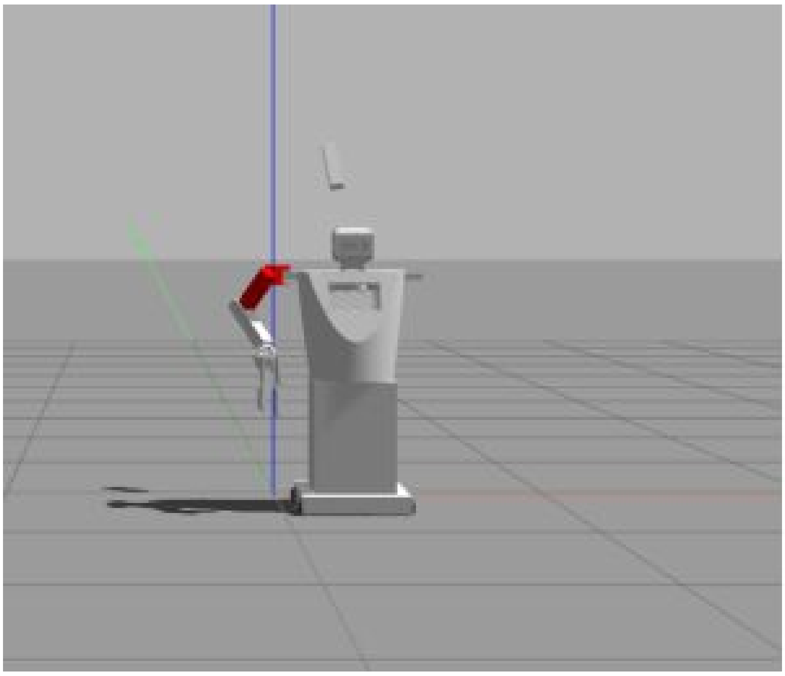
Kinematics

Simulation

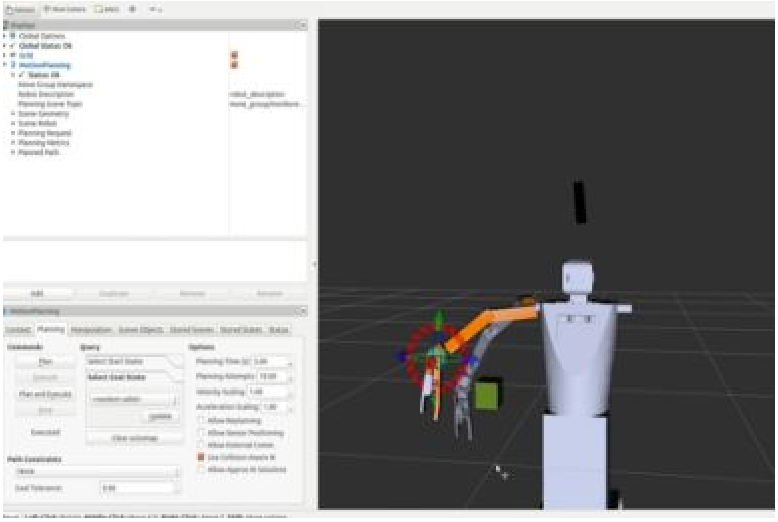
The simulation was started by testing the URDF of the robot that was developed using Solidworks. This model was imported into ROS, and a Moveit Package was built. Moveit consist of IK solvers (Inverse Kinematics) such as KDL(Kinematics and Dynamics Library) , using these libraries the IK was solved. Obstacle avoidance was also employed using collision aware IK. The results of the simulation is shown in the figure



The destination and orientation of end effector has been set using interactive markers



The plan visualized in Rviz is being executed in the simulation and end effector is moved to desired position



collision avoidance is demonstrated the IK is generated and the trajectory is planned such that the obstacle (Cube) , is avoided

Hardware Implementation

The Denavit Hartenberg matrix is the conventional technique that is used to obtain a matrix that describes the forward kinematics of the arm. This technique has been used to develop the forward kinematics for the ARDOP arm. Inverse Kinematics has been developed in 3 unique ways.

1) Integration ROS of simulation and hardware.

2) Geometry based solution.

3) PseudoInverse Jacobian technique.

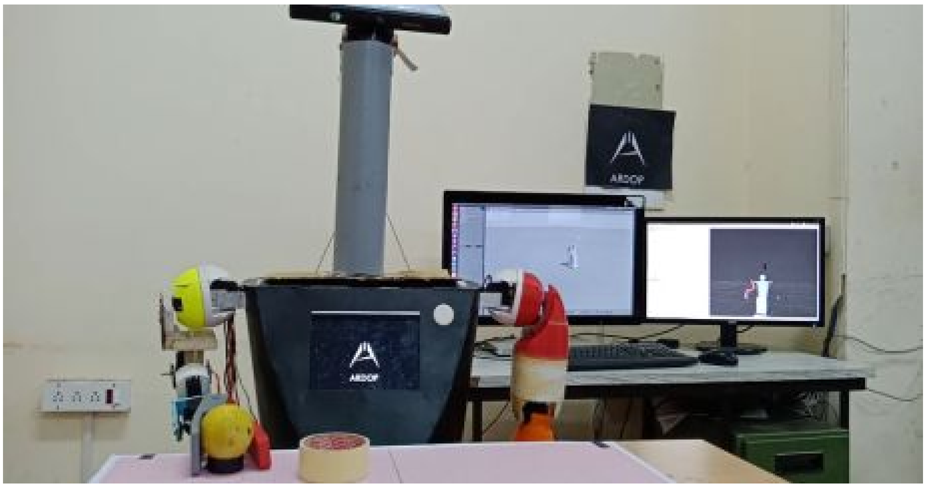
Trajectory planning has been developed using 2 techniques

1) Integration ROS of simulation and hardware.

2) Development of cubic trajectory with via point.

Hardware implementation of the IK to pick and place the ball at predefined locations, the trajectory is planned at such that the obstacle (table) is avoided. The above diagram is only a kinematics test, the camera was not included in this.

Integration of Vision and Kinematics system



The above figure shows the integration of the camera and the kinematics of the arm, the object (ball) is located and is picked. The coordinates of the ring has also been determined.

The above figure shows the place operation of the picked object, as the location of the ring is known the ball is dropped into it.

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GUIDES RECOMMENDATION

REMARKS FROM REVIEWERS