LEGO NXT-based Robotic Arm

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***Abstract**: This paper presents a 3 DOF robotic arm. The arm's end effector was equipped with a pen, and the robot was constructed so that it can draw on a paper sheet with the attached pen. The robotic arm is constructed using LEGO NXT. The purpose of the development was to create a control system of the servo motors for the robot, as well as the inverse kinematics, used for moving the arm. The NXT controller is using the LejOS firmware for optimal motor control, while inverse kinematics is being calculated on a PC connected to the NXT via bluetooth. The robotic arm is used in education projects, and several further student projects have been inspired by the results of this paper.*

1 Introduction

The robots play an important role nowadays in the industry, research, and their growing number is due to their wider and more extensive use in different areas. In order to make them tangible for students, they should also be well applied in education in the field of technical and information sciences. This paper deals with a 3DOF robot arm made from the popular LEGO-NXT, which can be controlled remotely via the Internet. The LEGO-NXT robot arm is made up of building blocks, so it can be easily further developed. The arm pivot movement of the servomotors in stock ensure that the positioning ones own software carried out by the inverse-kinematics, Bluetooth and other technologies. In this paper we present a model of a robot arm, which was built out of LEGO-NXT. We designed the structure and the software. The robotic arm can be controlled from a PC, via bluetooth. The coordinate data on the PC side software is sent to the articulation angles of the displacement of the NXT brick. The NXT-Brick in the joint area of engine positioning. Following chapters discuss in detail the background of robotics, LEGO NXT-operation and how we applied our solution to these. The goal of the robot arm is to provide a robotic platform that can draw on a paper

sheet, with the purpose of educational use in the field of robotics and robot programming. The rest of the paper is organized as follows. Finally, Section concludes the paper.

The paper is based upon the paper of the authors published in [1].

2 Background

2.1 LEGO NXT

Lego NXT [2] is a very popular robotics kit released by the Lego company. It is very easy and intuitive to build robotics hardware with the available lego pieces, and the controller provided gives full control over the actuators and sensors of the kit, allowing fast and efficient software development.

The Lego NXT control block has an embedded computer, some buttons, 4 inputs and 3 outputs. The main processor is an Atmel 32-bit ARM processor with 256 KB FLASH, 64 KB RAM, 48 MHz, and there is an Atmel 8-bit AVR co-processor, ATmega48 4 KB FLASH, 512 Byte RAM, 8 MHz. The NXT's three output ports (A, B, C) allow for attaching motors, while the four input ports allow for attaching sensors and a USB port to download programs from your computer to the NXT. A wireless Bluetooth connection is also available for for uploading, downloading programs, as well as for real-time data communication and control.

The programming of an NXT brick can be done in many ways. The simplest way is to use the LabView extension of the software that comes with the kit. For advanced users, a c-like language with an extensive API is also available, called NXC. LejOS is an alternative operating system on the NXT brick, which allows development in Java. No matter which language is used, the NXT can be applied to implement robotics tasks from beginners to advanced software developers. The bluetooth connection of the NXT opens the gate for higher levels of intelligent autonomous behavior, which can run on a remote PC, controlling the NXT via a wireless link.

The advantages above were the main reasons why the Lego NXT kit was applied in the implementation of the robot discussed in this paper.

2.2 Inverse Kinematics

The inverse kinematics problem is simply stated as, "Given the desired position of the robot's hand, what must be the angles at all of the robot's joints?" This is in contrast to the forward kinematics problem, which is, "Given the angles at all of

the robot's joints, what is the position of the hand?" When moving their hands, or even typing this paper, humans constantly solve the inverse kinematics problem without any conscious effort.

Kinematics is the formal description of motion. One of the goals of rudimentary mechanics is to identify forces on a point object and then apply kinematics to determine the motion of the object. Ideally the position of the object at all times can be determined. For an extended object, (rigid body or other), along with linear

kinematics, rotational motion can be applied to achieve the same objective: Identify the forces, develop the equations of motion, find the position of center of mass and the orientation of the object at all times. An articulated figure consists of a set of rigid segments connected with joints. Varying angles of the joints yields an indefinite number of configurations. The solution to the difficult inverse kinematics problem is to find the joint angles given the desired configuration of the figure (i.e., end effector or pen). In the general case there is no analytic solution for theinverse kinematics problem. However, inverse kinematics may be solved via nonlinear programming techniques. Certain special kinematic chains - those with a spherical wrist - permit kinematic decoupling. This treats the end effector's orientation and position independently and permits an efficient closed-form solution. In our Lego NXT robot, there are three joints, and one horizontal rotation axis. These we can move with the nxt and positioning the end effector to the desired position.

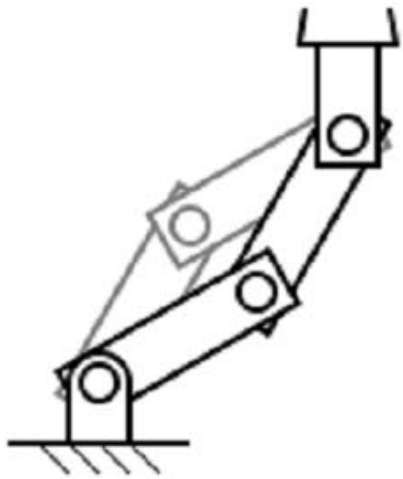

Fig. 1. Positioning problem

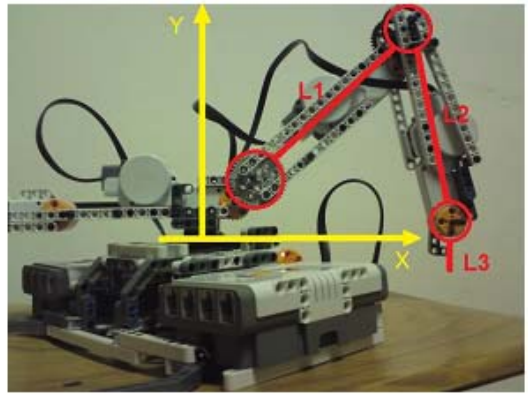

Fig. 2. The robotic arm and coordinate systems

3 Results

3.1 Hardware Design of the Robotic Arm

Robot arms, grippers and end-effectors (devices that attach to the end of an arm such as electromagnets, etc.) are the best ways for a robot to interact with the environment it is exploring. Simple robot arms can have just one motion, while more complex arms can have a dozen or more unique degrees of freedom. Lego Mindstorms based robots is one of the best way of amateur robotics building-packed with the latest in servo motor technology, microcontrolled hardwares and remote controllers. The most important advantages of using Lego Mindstorms lego elements provides a simple way to rebuild the architecture in the development phase anytime [3]. We built a robot arm using LEGO-NXT. Two LEGO-NXT bricks are used to handle the motors and connect to PC over bluetooth and USB cable. Four servo motors work together to position the endpoint of the robotic arm. Because we must have four motors, we must use two lego bricks, and synchronize them. Six batteries provide the energy for each NXT Bricks, and these batteries discharge in a few minutes. So we used a better way to keep the power on the maximum continuously. Batteries were replaced with a power supply. We tried many unofficial Lego NXT Brick Firmwares. One of them is called LejOS that we chose because of it's advantages. We used a programming library called NXT.Net for controlling NXT Bricks so we decided to create pc side software in .Net Framework.

3.2 Software Design

The program that we created to control the robot arm using inverse kinematics includes the NXT.Net library (NxtNet.DesktopLib.dll), the InverseKinematics library (IKLib.dll) and the host program (nxt.exe). NXT.NET is a .NET library written in C sharp 3.0 that enables host applications to control the LEGO Mindstorms NXT from managed code via Bluetooth connection. NXT.NET contains a desktop and a mobile library and sample desktop Windows Forms and Windows Mobile Pocket PC applications. It is created by the Hungarian MSDN

Competence Center. NXT.NET contains the following components:

- NxtNet.DesktopLib and NxtNet.MobileLib are two class libraries with the same feature set compiled as a desktop and as a mobile component. The library enables the host application to control a LEGO Mindstorms NXT robot via a Bluetooth connection.
- NxtNet.DesktopApp is a .NET Windows Forms desktop application that is built using the NxtNet.DesktopLib component and enables the user to test the library features and remotely control a LEGO Mindstorms NXT robot from a PC.

- NxtNet.MobileApp is a .NET Compact Framework mobile application that is built using the NxtNet.MobileLib component and enables the user to test the library features and remotely control a LEGO Mindstorms NXT robot from a Windows Mobile 5.0 Pocket PC.

NXT.Net library (NxtNet.DesktopLib.dll) enables the host to connect to the NXT, query general parameters (brick name, version, Bluetooth address, free flash memory, battery level, keep alive time), initialize sensors and query sensor values. The program module of controlling the robot arm (IKLib.dll) uses trigonometric functions which computes the alpha, beta, gamma and eta degrees from the specified x, y, z coordinates for the motors. Alpha, Beta and Eta degrees used for vertical and horizontal movement, Gamma for positioning the end-effector.

We built our own three degree of freedom robot arm that uses our software developed for inverse kinematics, so it can position the end-effector.

3.3 The Robot Arm in Operation

First step: switch on the NXT bricks. Second step: set the robot arm in the base position for the software that compares the workspace from this point. Third step: Set the coordinates to positioning the end-effector.

3.4 Testing and Evaluation

We had to rebuild the robot arm several times to make it stable. Rotation of robot arm We tried a lot of gear to make the rotaion precise. Finally we decided to use a wormgear to solve this problem. Motor moves, degree problems NXT-G firmware was unable to convert degrees to tacho values. We figured out we need an other operating system on the NXTs. Finally, we found LejOS firmware, and replaced the original with it. Multiple NXT Bricks connected to PC In the first times it was a problem to connect multiple Bricks to one PC at the same time. Using NXT.Net solved this.

Using Lego NXT to build our robotarm has had many advantages: easy hardware and software developement, hardware variability, Bluetooth support, highly accurate motor control. Working on this project we have gained experience, and we expanded our knowledge. In the future we would like to work on and develop multiple degrees of freedom robot arms.

References

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