Hekateros™: A Desktop 5 Degree-of-Freedom Robot Arm for the Small-Scale Manipulation Robot Chess Challenge

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Abstract

RoadNarrows has entered the "desktop-size" 5 degree of freedom robot arm, Hekateros, in the Small-Scale Manipulator Challenge, at the 2011 AAAI conference. Hekateros is utilizing a variety of sensors and software to successfully perceive and manipulate the chess game.

Introduction

The RoadNarrows robotic arm project Hekateros™ is a research and development effort to design, prototype, and ultimately commercialize a low-cost, high-quality, "desktop-size" robotic arm. The software design consists of a scalable high-level intelligence framework applied to robotic manipulators, and to implement robust and real-time algorithms that take advantage of highly parallel computing environments. Application computations will integrate seamlessly across wireless and wired networks of heterogeneous robotic and computer systems. The goal is a highly capable, computationally scalable, low-cost intelligent robotic arm platform for research and light industry, which can easily be adapted to a variety of complex applications.

Hekateros is currently in the second phase of the prototyping stage. The first prototype was designed, constructed, and presented at "AAAI-10 Robotics Workshop: Enabling Intelligence through Middleware" at which the arm and the was well received. The AAAI-11 Small-Scale Manipulator Challenge chess competition is a perfect challenge for demonstrating Hekateros's capabilities, as well as driving the arm's development and testing.

Robot Platform

Hardware

Hekateros is a fixed-base, 5 degree-of-freedom robotic arm. The arm is built with high strength ABSplus plastic using additive 3D printing technology to obtain a strong and light-weight manipulator. All load bearing rotating joints have high quality steel bearings.

The 5 rotary joints are driven by Dynamixel servo actuators coupled with timing pulleys and belts. An on-board camera, located at the end-effector, coupled with embedded vision algorithms is used to perceive the chess board and the changing state of the game. Hekateros manipulates the chess piece using a custom end-effector designed specifically to grab one chess piece at a time, without disturbing the rest of the pieces. Joint positions and accuracy are controlled with optical encoders located directly on each joint. This increases the accuracy at each joint, thus increasing Hekateros' ability to locate and manipulate chess pieces.

Software

The system hosts a Gumstix Overo Computer-On-Module operating embedded Linux. RoadNarrows' open-source BotSense™ software package provides a client-server framework to remotely interface to the proxied devices over IP. The Hekateros provides both Ethernet and WiFi network connectivity. Botsense supports a scalable software architecture with an open API. Also preconfigured on Overo are a 5+ DoF inverse kinematic solver and the Open-source Computer Vision software OpenCV. The OpenCV libraries provide a rich set of calls to support on-target, application-specific vision processing.

Figure 1: Hekateros Arm

Finally, the Message Passing Interface (MPI) package to support High Performance Computing is available. MPI is a de facto standard method to support parallel computing clusters.

Technical Approach

In order to properly complete a chess move, the robot platform needs to perceive the chess board, determine the move made by the other team, make a decision on what move to make next, and then properly manipulate the chess pieces in order to carry out the completion of the move. In order to perform these complex tasks, RoadNarrows has designed a system to utilize embedded vision algorithms and smart kinematics.

Perceive The Chess Board

Instead of using a typical off target camera system (one which is mounted directly above the chess board), RoadNarrows has mounted a camera directly onto the end-effector. At the beginning of each turn Hekateros moves to a set position(s) above the board to allow the camera to take a picture or set of pictures of the current state of the game.

Determine Opponent Move

The opponents move is determined by using complex vision algorithms to analyze the images taken by the on-board camera. The vision algorithms utilize edge detection software to determine where the chess pieces are currently located within the board as well as within each square. This information is then compared to data stored about the previous move to determine where the opponent moved their piece.

Determine Move

Hekateros software uses a standard chess playing algorithm to determine the next appropriate move based on the determined information from the previous steps.

Manipulate The Chess Board

Manipulating the chess board is a task that utilizes every aspect and capability of the Hekateros arm, including vision, precision, accuracy, kinematics, agility, computing power, and real time decision making. The arm is precise, accurate, and agile enough to reach the entire chess board, locate a piece, and move the piece without disturbing the rest of the pieces or board. The arm navigates the board, picks up the designated piece or pieces and moves them based on knowledge of the board and inverse kinematic telling each joint where to move. The camera location, at the end-effector, allows the system to make real time adjustments in order to properly align and pick up each piece within the square it is located. This convenient camera location alleviates the problem of the chess pieces orientation and compensates for any misplaced pieces.

Notes

BotSense™ middleware development was supported in part by the National Science Foundation STTR Phase II Grant IIP-0848762.

References

RoadNarrows home page:
http://www.roadnarrows.com/

RoadNarrows Research and Engineering Projects:
http://www.roadnarrows.com/r-and-d/