Research Statement

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My research is in the general area of mechatronics, robotics, artificial intelligence and control. My research program reflects and highlights the applicability of these subjects to a diverse and varied domains and fields. My research approach emphasizes exploiting physical insights in a mathematically rigorous manner, and experimental verification of our theories. My main research thrust in the past few years can be categorized into the following groupings with some overlap:

I) Deep learning and optimization techniques applied to robot vision system for detecting and grasping known objects

Robotic systems is a very wide used systems in our live todays. It is not used in industrial applications only, but it also become an essential part of our daily live. Merging new control systems such as artificial intelligence with robotic systems convert the robot from a reprogrammable agent to an intelligent agent.

Converting an industrial robot arm from a reprogrammable robot to an autonomous one is a big challenge facing robotic systems research community. To make robot smarter, it need to see, think and act. So, in our work, we try to achieve this.

First, I designed a 2D robot vision system that is able to recognize an object moving on a conveyor and detect it orientation to be able to pick it then place it in a predesigned pallet. The proposed vision system is integrated with the real-time external control algorithm framework of the robotic arm Mitsubishi MELFA RV-2SDB based on C++ software. This way is possible for object detection and object orientation recognition moving on a conveyor, with no earlier knowledge of the pose and the orientation.

Then, I designed a 3D stereo vision system to recognize and detect an object in 3D space. Many different techniques are applied for the 3D robot vision system such as traditional Singular Value Decomposition SVD, optimization techniques, and end-to-end deep learning. This system is able to achieve 6D pose estimation for the object. The output is enhanced and the error is decreased using optimization techniques. A novel optimization technique is introduced to be used in addition to 2 other optimization technique.

In order to be not trapped in local minimum point, I employed novel optimization technique which is based on particle swarm optimization. The proposed method succeeded in modelling the system setup resulting in the success of the estimation of the six degree of freedom pose of objects, without the need for determination of neither the intrinsic and extrinsic parameters of the stereo vision.

To overcome the hitches of the calibration constrains, a novel approach using deep neural network has been developed, trained and implemented for our stereo vision system. The experimental result shows that the presented methods are successful in

achieving improvement for accuracy, flexibility, and intelligence in vision-guided industrial robot applications.

Deep Neural Network, DNN also known as Deep Learning, DL is applied for our robot vision system. As many of the DNN researchers and practitioners say that the deep learning approach is an empirical approach. So, I applied many different implementation in our system. Different optimizers are used in DNN such as AdaDelta, Adam and AdaMax. Also, the latest activation functions are tested in this work. At the end, we succeeded in getting 6D pose estimation for an object with very small error.

This work propose a novel method for six degree of freedom pose estimation of objects based on deep neural network (DNN) without calibration of the stereo vision system in the application of robot arm pick and place. Furthermore, the stereo vision used is low-end vision system placed in custom-made setup. In the training phase of the DNN, the robot was set to auto collect data in pre-defined workspace; this workspace is defined dependent on the spatial feasibility of the robot arm and the shared field of view of the stereo vision. The speeded up robust features (SURF) algorithm is employed to detect and to locate the four edges of the objects in the streaming of vision system, for being the input of the DNN.

II) Experimental study on the operation and control of a 6 axes (DOF) robot in assembly line

This work presents an extensive experimental study on the operation and control of 6 degrees of freedom (DOF) Robot in an assembly line. The Robot is a Mitsubishi RV-2SDB. The assembly line is a FESTO product. Both parts are of the STDF Grant No. 2663 in the Automatic Control Lab of the Electrical Power and Machines Department of the Faculty of Engineering - Cairo University.

Programming of the Robot unit using MELFA-BASIC V to accomplish the required tasks is discussed in view of path and controller parameters. Two case studies have been designed and programmed using the SW package of the Robot. The first case is a free motion between an initial space position and a target position, then executing an assigned task. This task is using the Robot gripper in writing a word, where three mode of motion are implemented: first, second and third. Comparison between output data for each mode: timing, performance, and accuracy have been presented. The second case is a cyclic assembly task. The robot is used to assembly a single acting cylinder (cylinder body, piston, spring and cap).

Experimental results showing the motion of each joint, world coordination values, related positions, speeds and servo motor current and voltage are given for both cases. The operation and control of the Robot actions have been analyzed for different parameters and limits. Conclusions indicate the effect of controller and path parameters on the accuracy, timing and performance in executing the required tasks. Programming of Robot to execute the above two case has been developed using the available package. A sequence of steps has been followed to realize the needed trajectory and executing the needed tasks.