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COLLABORATIVE ASSEMBLY BETWEEN HUMANS AND SERIAL ROBOTS USING MINIMAL COMPUTATIONAL RESOURCES

Under the supervision of:

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Collaborative Assembly between humans and serial Robots using minimal computational resources

**Dec. 2021**

**overview:**

With the latest circumstances the world is witnessing, Robots and AI have been used in many fields to enhance social distancing. Combining this with the huge development in industry 4.0 and the huge data that is available. Recently, robots have been used in factories and manufacturing processes a lot. However, a lot of tasks still need human existence. And here we are introduced to a new challenge in the collaboration and interaction between humans and robots!

**Question 1: What is the main problem that you are solving? Why did you choose it?\***

**Main problem we are solving:**

Our project mainly aims to solve the problem of collaboration between humans and robots taking into consideration the cost of the entire system. We also try to optimize the system in order to be available for a wide range of small, middle, and wide scale businesses while at the same time maintaining the reliability and efficiency of the system.

Our project can be used in different industries including:

* Scheduled tasks that requires small assistance or guidance.
* Assembly processes that need high accuracy in some tasks or currying of heavy loads.
* Assembly processes that require balance between the expensive HW and complex SW / models with AI.

We believe that the importance of collaborative assembly is centered on human existence with robots in various missions. The collaboration is needed to enhance the safety and accuracy of the process.

Future production plants will see more and more the presence of humans actively collaborating with robots. In such contexts the behavior of humans is not fixed. Therefore, the problem is to plan the robotic activities accounting for the predicted human intentions.

**Question 2: Give a brief overview of the current solutions that you found in your literature survey.**

# CURRENT SOLUTIONS:

The idea of performing normal industrial tasks after covid is a huge area of research. To perform tasks that need two operators, there are a lot of solutions including:

* The use of two armed robots. However, this solution is high in cost and does not involve humans which are needed in many applications.
* Human in the loop solutions is used however it requires the use of expensive sensors to:
  + Measure the distances of the surroundings and accordingly estimate the human pose and obstacles found.
  + Measure the joints’ torque that is used to estimate the contact between the human and the robot and perform the needed motion control actions.
  + Question 2: Give a brief overview of the current solutions that you found in your literature survey.

**Question 3: Describe how your proposed solution will be used and operated in a real-life environment?**

# FUNCTIONAL DESCRIPTION OF OUR SOLUTION:

The actual picture of our proposed solution for collaborative assembly projects using serial robots is the use of ABB IR120 serial robot controlled using ROS with our own algorithm to perform assembly missions to assemble a gearbox. This mission includes object detection, human detection, torque estimation, trajectory control, and complex system modeling. The robot is equipped with a gripper for manipulation of certain tasks including pick and place tasks

# EXPECTED IMPACT OF OUR SOLUTION:

Concerning the social impact, our human-in-the-loop system for assembly processes will substitute many workers, especially in tasks that need more than one operator. This will enhance the social distancing guidelines.

Commercially, as it helps in competing against similar highly expensive systems it is expected to help in the growth of our global economy (developing countries).

As industry 4.0 is progressing day by day, the interaction between humans and robots is increasing too. Our solution may encourage more R&D teams to dig into such fields thus, encouraging companies to invest in their products.

**Question 4: Describe the high-Level architecture and the main software and hardware components of your system. (You can use block diagrams)**

**Our Solution System is mainly divided into 3 main modules described as follows:**

## Architecture:

This module is considered the pillar of the system as it is responsible for establishing the communication between the mainboard and other processors/ sensors in the robot, interfacing the hardware modules like that of the Z-Camera, motors, and manipulation actuators; this is in order to apply abstraction concept and ease their usage with other modules. Finally, the Architecture module is responsible for integrating all system modules together.

## Perception:

Perception is one of the most crucial modules in the system, it is responsible for the vision-based tasks where it receives the cameras feed, filters this feed to eliminate distortion and noise, pre-processes it to make it easier to extract and identify features and landmarks, and finally processes it to identify objects of interests “parts to be assembled” and human.

We also look forward to calibrating the Z-camera for more accurate depth estimation. In this module, we aim to combine both traditional computer vision and deep learning to obtain the best results.

## Robot Control:

Adjusting the control of the robot is essential for acquiring the best results. Our control system will be developed using two approaches:

* PID controller with linear feedback.
* Non-linear control theory.

Concerning the PID approach, it is used for the actuation of the motors and the **trajectory tracking** can be achieved using an Adaptive model predictive controller to control the position of the robot.

**Question 5: What are the technology platforms that you intend to use in building your system, such as operating systems, programming languages, backend/frontend stacks, AI models, etc.?**

# DEVELOPMENT ENVIRONMENT DESCRIPTION

The development environment of our solution primarily depends on software simulation tools (ROS – Gazebo, MATLAB) where we simulate our system design giving expected inputs while adding noise and disturbances that our robot might encounter in the real environment. Our Deep learning model is trained on google [Colaboratory](https://www.google.com.eg/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjBzZqsmPHtAhUxZxUIHUw0BDsQjBAwBXoECAYQAQ&url=https%3A%2F%2Fresearch.google.com%2Fcolaboratory%2Ffaq.html&usg=AOvVaw09SNaqHWSGDkZVCZpHuuTZ) notebooks to benefit from the fast GPUs to speed up the training process and to acquire the best results.

Our control algorithm is developed using MATLAB Simulink to simulate the robot behavior when applying an adaptive model predictive controller (AMPC).

Our perception algorithm is passed on python especially using sklearn,

The second part of the development process is the real testing, where we deploy our algorithm on ABB IR20 in the robotics and control lab Ain Shams university to assemble a gearbox mechanism and validate our simulation results.

Our programming language is mainly python especially

**Question 6: Compared to the existing solutions that you have read about, what are the new ideas that you intend to develop and include in your solution?**

# OUR SOLUTION AND WHAT IS NEW:

We Offer affordable collaborative assembly algorithms with the same functionalities and are computationally efficient as those products offered by current Human in the loop systems. Our system targets especially startups and middle range businesses based in developing countries – as our country is considered one of them.

Our project enhances:

* + Social distancing.
  + Limits operators’ injuries due to carrying loads or non-ergonomic environments.

**Question 7: Describe your team’s system development methodology and quality assurance process.**

# Development Cycle

Using multi phases of design reviews, simulations, testing, and validation.

1. The design reviews which are done with doctors from faculty of engineering Ain Shams University. (Dr. Mohamed Ibrahim – Dr. Shady Maged)
2. Simulations:
3. Assembly, motion analysis, and interference analysis using SolidWorks.
4. Simulating the electrical systems using Proteus.
5. Control and perception module simulation using MATLAB and Gazebo
6. Testing:

* Mechanical Integrity:
* Gripper test.
* Weight and size, stress, and rigidity considerations.
* Manipulation kit efficiency.
* Electrical Kit Operation
* Testing camera.
* Manipulation kit testing (gripper action, etc.)
* Software testing
* Control testing using prepared control scenarios
* Perception testing (detection modules, depth estimation)
* Prequalification mission execution

# Development Plan

|  |  |  |
| --- | --- | --- |
| **ACTIVITY** | **PLAN START** | **PLAN DURATION** |
|  |
| *General Tasks* |  |  |  |
| **Literature Review** | 6-Nov | 14 |  |
| **Thesis & Presentation** | 2-Feb | 7 |  |
| *Hardware and Prototype Tasks* |  |  |  |
| **Prototype Design** | **27-Nov** | **7** |  |
| **Prototype manufacturing** | **4-Dec** | **7** |  |
| **Prototype assembly** | **11-Dec** | **2** |  |
| **Prototype testing** | **13-Dec** | **2** |  |
| **Tool Selection** | **1-Dec** | **2** |  |
| **Tool Design** | **4-Dec** | **7** |  |
| **Tool manufacturing** | 11-Dec | 2 |  |
| **Tool assembly** | 13-Dec | 2 |  |
| **Tool testing** | 20-Dec | 2 |  |
| **PCB design** | 8-Dec | 7 |  |
| **Pneumatic system design** | 8-Dec | 2 |  |
| **Circuit simulation** | 15-Dec | 3 |  |
| **PCB manufacturing** | 18-Dec | 7 |  |
| **Pneumatic components purchasing** | 18-Dec | 1 |  |
| **Control unit assembly** | 24-Dec | 2 |  |
| **Control unit testing** | 26-Dec | 2 |  |
| *Perception Tasks* |  |  |  |
| **Camera Position** | 27-Nov | 7 |  |
| **Camera Selection** | 27-Nov | 7 |  |
| **Human Detection** | 4-Dec | 7 |  |
| **Human Interfacing** | 11-Dec | 21 |  |
| **Testing** | 6-Dec | 30 |  |
| **Parts Detection** | 4-Dec | 7 |  |
| **Testing** | 15-Dec | 21 |  |
| **Vision Integration** | 15-Dec | 14 |  |
| **Control Integration** | 15-Dec | 3 |  |
| **Testing** | 20-Feb | 30 |  |
| *Control Tasks* |  |  |  |
| **Testing moveit commander APIs on the robot** | 27-Nov | 7 |  |
| **Setup the environment on gazebo simulation** | 27-Nov | 14 |  |
| **trajectory planning** | 1-Dec | 10 |  |
| **adjust trajectories with the vision input and feedback** | 15-Dec | 3 |  |
| **position high level control** | 1-Dec | 15 |  |
| **control pick and place gears and shafts** | 25-Dec | 7 |  |
| **motion control integration with force and torque sensors** | 27-Dec | 6 |  |
| **calibration the end effector** | 21-Dec | 5 |  |
| **control the end effector within the sequence** | 24-Dec | 4 |  |
| **Estimating the joints torque** | 27-Nov | 20 |  |
| **Integration with vision feedback on human work envelope** | 25-Dec | 4 |  |
| **mission planner** | 1-Jan | 15 |  |
| **Integration** | 1-Jan | 20 |  |
| **Thesis 1 Submission** | 2-Feb | 1 |  |
| **Fault monitoring and modifications to the algorithm** | 3-Mar | 30 |  |
| **Design Review (1)** | 3-April | 5 |  |
| **Thesis 2 Submission** | 3-Mar | 30 |  |