Project Description

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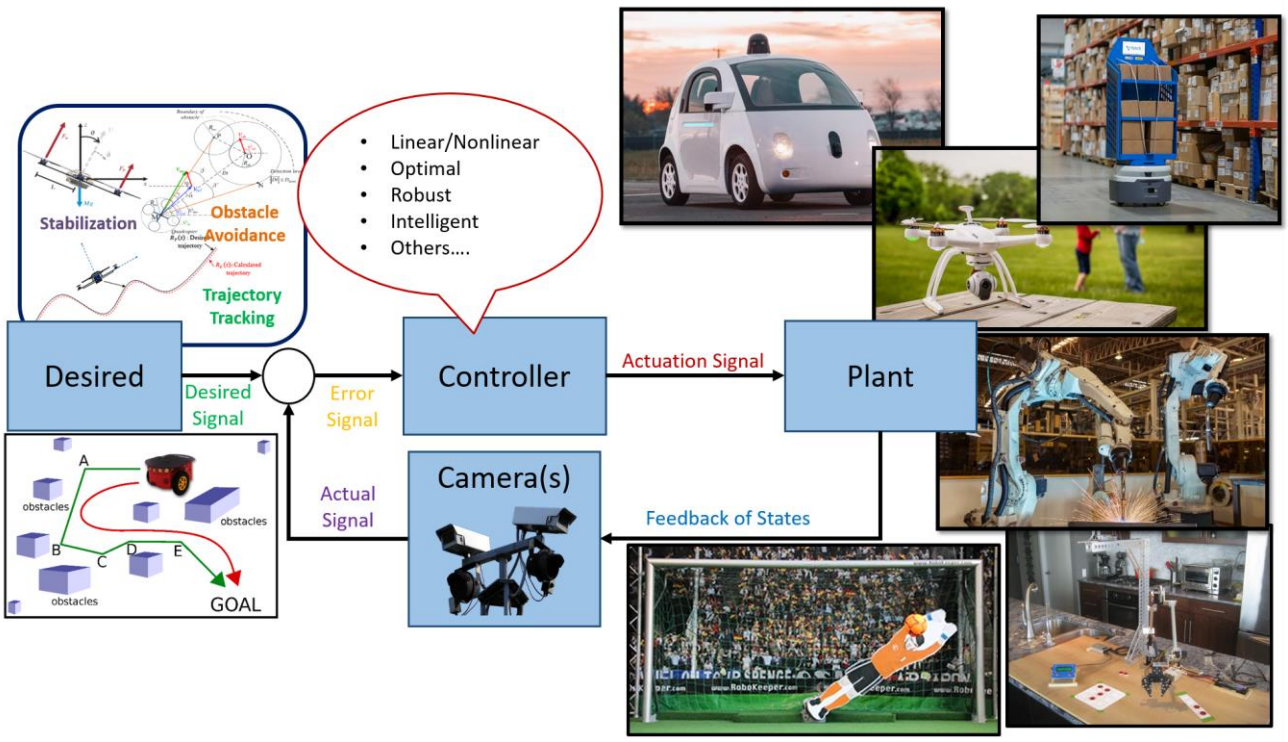
Objective:

The aim of Image Processing for Mechatronics (MCTR1010) course project is to develop a mechatronic system depending on camera(s) as the sensing or feedback element. The objective of the project is to build a fully functioning hardware controlled and actuated based on images acquired and processed using on board or off board camera(s) with a simple hardware model and a simple control algorithm implemented to perform the desirable task(s) correctly.



The project will be divided into several milestones. Each milestone considers the implementation of the image processing task(s) (image filtration, edge detection, morphological operation, segmentation, object recognition, etc.) on your assigned project by which you will perform the image processing operations on a set of images acquired by your designed system serving the goal of the project, in addition to the hardware design and fabrication and control implementation tasks. The competition will be assessed based on the accuracy of the detection and the project requirements.

Details of each milestone and its requirements are provided below.
Note: Further details for each milestone regarding the tasks' implementation and submission links will be announced as separate documents later on during the semester.

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Project Regulations:

- *Project Registration:*
  - Students should construct teams that consists of **4-5 members** cross tutorials. Each team should do one of the following:
    - **Propose a Project:** Write a maximum of **2 pages** describing a project that is proposed out of the provided list. The proposed project should be a Mechatronics system that depends on vision (camera) as the feedback element. Teams that will propose the project should describe the overall project with provided references, images and links (videos, etc.). Teams that will propose a project will receive a **1% BONUS** on the project. The proposed project will be approved by the course instructors.
    - **Choose a Provided Project:** Choose one of the projects provided by the **list of projects** presented below. The list of projects announced has different project ideas for each team to choose from. The projects will be assigned to teams based on the **first come first serve** method (each team will be required to choose 5 different project priorities; these priorities will be considered during the project assignment).
  - Students that are not assigned to teams are going to be **randomly clustered** and get assigned to a random project.
  - Registration of **less than 4 members or more than 5 members will NOT be considered** and the project selection will be canceled.
  - Once the team is formed, **NEITHER changes in the team's members NOR in the assigned project will be acceptable**.
- *The grading of each milestone will be announced separately in each milestone document.*
- *The evaluation process of the milestones will follow two procedures based on the milestone requirements:*
  - ***Online Submissions:*** each team will be requested to submit the requirements of the milestone through **Google forms**. These requirements may include: reports, narrated presentations, codes, videos and others.
  - ***Evaluations:*** N evaluations will be conducted throughout the project, the number of evaluations, method and timings will be announced soon.
  - ***Exhibition (if applicable):*** An exhibition will be conducted at the end of the semester for all the teams to present and demonstrate their work in front of the instructors, TAs, Drs and students. Details of the exhibition will be announced soon.

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Project List:

Image Processing for Mechatronics (MCTR1010) - Projects List	
Project #	**Projects Ideas**
1	Connect Four Robotic Manipulator
2	Tic-Tac-Toe (X-O) Robotic Manipulator
3	Chess Game Robotic System
4	Color-based LEGO Brick Building Robot
5	Goalkeeper Robotic Arm
6	Ping Pong Robotic Arm
7	Golf Ball Playing Robot
8	Color and Shape Sorting Production Line
9	Human/Car/Ball Tracking Robot
10	Hand Gesture Mimicking Robot
11	Lane Keeping and Changing Vehicle
12	Card Matching Robot Arm
13	Human Portrait Drawing Robot

1. Connect Four Robotic Manipulator:

- The objective of the project is to build a robotic arm (1DoF or more) to play Connect Four game against a human being or another robot. The system should be able to detect four-in-a-row (horizontal, vertical, diagonal) every movement, count the number of the chips and search for the maximum consecutive colored-chip. The challenge is to be able to perform the correct moves to win the game based on the image acquired and updated for the Connect Four board in each player's movement. The image should be filtered and segmented based on the color of the chips inserted to be able to perform the correct move. The robot actuators should be controlled accordingly to reach the desired slot and place the chip to win the game.
- *Links for guidance:*
  - *https://www.researchgate.net/publication/317030849_Using_Image_and_Pattern_Recognition_to_Play_the_Game_of_Connect_Four*
  - *https://mechatronicscraze.wordpress.com/2011/11/05/opengl-based-connect-four-game/*

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2. Tic-Tac-Toe (X-O) Robotic Manipulator:

- The objective of the project is to build a robotic arm (3DoF) to play X-O game against a human being or another robot. The challenge is to be able to perform the correct moves to win the game based on the image acquired and updated for the X-O board in each player's movement. The image should be filtered and segmented based on the shape of the chip inserted (X or O) to be able to perform the correct move. The robot actuators should be controlled accordingly to reach the desired location to place the chip to win the game.
- *Links for guidance:*
  - *https://www.youtube.com/watch?v=Oll3xKv4VLU*
  - *https://blog.adafruit.com/2014/07/11/robotic-arm-playing-tic-tac-toe-using-image-processing-in-raspberry-pi-raspberry_pi-piday-raspberrypi/*

3. Chess Game Robotic System:

- The objective of the project is to build a robotic arm (3DoF) to play Chess game against a human being or another robot. The challenge is to be able to perform the correct moves to win the game based on the image acquired and updated for the Chess board in each player's movement. The image should be filtered and segmented based on the chess pieces put to be able to perform the correct move, this can be done by putting different color tags on each piece to differentiate between them. The robot actuators should be controlled accordingly to reach the desired location to place the pieces to win the game.
- *Links for guidance:*
  - *https://www.semanticscholar.org/paper/A-Computer-Vision-System-for-Chess-Game-Tracking-Koray-S%C3%BCmer/2dd2bcaeef6de2c78da93153af879395ea3a8da9*
  - *https://create.arduino.cc/projecthub/ricpd/chess-playing-robot-arm-that-will-beat-you-678035*

4. Color-based LEGO Brick Building Robot:

- The objective of the project is to build a robotic arm (3DoF) to build a LEGO building based on color. The challenge is to be able to differentiate different LEGO pieces colors and choose the correct color to build the LEGO building. The image should be filtered and segmented based on the color of the LEGOs to be able to perform the correct move. The robot actuators should be controlled accordingly to reach the desired location to place the LEGO piece in its correct location.

5. Goalkeeper Robotic Arm:

- The objective of the project is to build a 1DoF robotic arm acting as a goalkeeper performing a rotation motion only to catch or repel the ball. The challenge is to be able to calculate the exact location and speed for the goalkeeper to move with based on the predicted trajectory of the ball obtained based on the distance and speed of the ball extracted from the acquired images of the ball while being shot.
- *Links for guidance:*

- https://www.youtube.com/watch?v=x5r2eot7WvU
- https://www.researchgate.net/publication/265852164_Colored_Ball_Position_Tracking_Method_For_Goalkeeper_Humanoid_Robot_Soccer

6. Ping Pong Robotic Arm:

- The objective of the project is to build a 3DoF robotic arm capable of playing ping pong. This will be done by using a camera sensor to track the flying ball's location and moving the arm in the same location to hit the ball. The challenge is to be able to calculate the exact location and speed for the robotic arm to move with based on the predicted trajectory of the ball obtained based on the distance and speed of the ball extracted from the acquired images of the ball while being shot.
- *Links for guidance:*
  - *(PDF) An application of human robot interaction: Development of a ping-pong playing robotic arm (researchgate.net)*

7. Golf Ball Playing Robot:

- The objective of the project is to build a robotic arm (3DoF) to play Golf against a human being or another robot. The challenge is to be able to track the ball location to correctly kick it by the Golf Bat, based on the image acquired, and make it land inside the hole. This can be done by adjusting the Bat's heading based on the direction the ball should be moving in. The robot actuators should be controlled accordingly to reach the desired location to kick the golf ball inside the hole.
- *Links for guidance:*
  - Golf Robot Learns to Putt Like a Pro - IEEE Spectrum

8. Color and Shape Production Line:

- The objective of the project is to build and control a mobile robot or robotic arm or conveyors that can sort objects based on color and shape in different locations of an arena or a production line. The challenge is to be able to segment the acquired images based on both color and shape and send the desired location accordingly for the robot to grab the object and move to place it in the correct location assigned for this category of objects.
- *Links for guidance:*
  - https://www.researchgate.net/publication/339016669_Identification_and_Sorting_of_Objects_based_on_Shape_and_Colour_using_Robotic_Arm
  - https://www.youtube.com/watch?v=3jbuM10jQtA
  - https://www.researchgate.net/publication/329056573_Object_Sorting_using_Image_Processing
  - http://oaji.net/articles/2017/786-1514455200.pdf

9. Human or Car or Ball Tracking Robot:

- The objective of the project is to build and control a mobile robot that is used to track a moving object which is a ball. The challenge is to be able to control the robot's velocity and heading to track the object as accurately as possible in a given area.

- The acquired images should be segmented based on color or shape of the ball and get the location of the moving ball (centroid location). Then the difference in the robot's pose and ball location should be computed to control the robot to track the desired ball.
- The objective of the project is to build and control a mobile robot that is used to track a moving human or a vehicle in front of it. The challenge is to be able to control the robot's velocity and heading to track the human/vehicle as accurately as possible in a given area. The acquired images should be segmented based on a bar code or color attached to the human/vehicle and get the location of the moving human (centroid location) or using AruCo markers. Then the difference in the robot's pose and ball location should be computed to control the robot to track the desired ball.
- *Links for guidance:*
  - https://www.researchgate.net/publication/313870064_Color-based_segmentation_and_feature_detection_for_ball_and_goal_post_on_mobile_soccer_robot_game_field
  - https://create.arduino.cc/projecthub/junejarohan/ball-tracking-robot-7a9865
  - Stereo Vision-Based Human Tracking for Robotic Follower - Emina Petrović, Adrian Leu, Danijela Ristić-Durrant, Vlastimir Nikolić, 2013 (sagepub.com)

10. Hand Gesture Mimicking Robot:

- The objective is to build a hand mimicking robot that can extract the human hand's motion and mimic this motion based on image processing techniques.
- *Links for guidance:*
  - *https://www.researchgate.net/publication/272509945_Hand_Segmentation_Techniques_to_Hand_Gesture_Recognition_for_Natural_Human_Computer_Interaction*
  - *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5336094/*

11. Lane Keeping and Changing Robot:

- The objective of this project is to utilize a camera sensor integrated on a robot (e.g: scaled vehicle or mobile robot) to keep it in the center of the lane and to be able to change lanes as the lane shifts.
- *Links for guidance:*
  - https://community.element14.com/members-area/personalblogs/b/blog/posts/self-driving-car-automatic-lane-detection-on-a-robot
  - https://www.youtube.com/watch?v=_nEAx1Hvy4Q

12. Card Matching Robot Arm:

- The aim of this project is to utilize a camera sensor to detect similarly looking cards. A robotic arm would be needed to grab the identical card and put it beside its card.
- *Links for guidance:*
  - *https://www.youtube.com/watch?v=INwGT-KG1Ns*
  - *https://arxiv.org/ftp/arxiv/papers/1604/1604.02030.pdf*
  - *https://core.ac.uk/download/pdf/80148185.pdf*

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13. Human Portrait Drawing Robot:

- The aim of this project is to build a robotic arm or system that can be used to detect the human and trace his/her face markers to draw the boarders of the face and some of the captured human details utilizing a camera with some image processing operations as edge detection and others.
- *Links for guidance:*
  - *https://dl.acm.org/doi/10.1145/3483845.3483847*
  - *https://www.mdpi.com/1424-8220/23/12/5589*
  - *https://www.youtube.com/watch?v=G8jidJsiJH8*

***** Note that the links provided for each project are only for guidance for introducing the project idea, steps of the implementation can be changed or modified based on your literature (other references).***

Project Milestones Overview:

- The project weight is 30% (25% Project + 5% Assignments).
- The project is divided into 5 milestones covering all the course content.
- Each milestone is weighted based on the complexity of the requirements.
- All milestones will include a simulation platform for coding. The simulation platform required is either **MATLAB** or **Python** based on our agreement.
- Hardware is a MUST (hardware design and fabrication will be considered in the project grade distribution).
- The project should be an **Embedded System** (all the processing should be performed on a Raspberry PI which will be connect to an Arduino for execution and motor actuation).

Project Milestones Requirements:

Milestone #	Deliverables	Deadline	%
Registration	**Requirements:** • Each team is required to register through a **Google drive link** and choose 5 priorities from list of projects announced. The registration link: https://docs.google.com/forms/d/e/1FAIpQLScQUY_Bo2ulCD23U3x3s4zO2ygPP5HOloSavOWx3qFuBVuCrA/viewform?usp=header • Teams that are **proposing new ideas** should attach a **2 pages PDF document** describing the proposed project out of the provided list. It should be a Mechatronics system that depends on vision (camera) as the feedback element. The PDF file should include the overall project description with provided references, images and links (videos, etc.).	**Friday 15th of February, 2025**	**1% BONUS for Proposals ONLY**

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Milestone 01	**Requirements:** ● **Literature review** on your assigned project. It should be performed with **at least 5 papers** (from 2020 till our mean time), including literature on the project idea, the image processing techniques to be used and possible hardware implementation. ● **Project plan** including the appropriate operations introduced in the course outline that might be used to perform the required image processing tasks for the project (image filtration, edge detection, morphological operations, segmentation, etc.). ● **List of hardware** (mechanical, electrical, electronic, etc.) **requirements**; stating the item, the quantity, the specs, the location to be purchased from and price. ● **Hardware design** using **SOLIDWORKS**. ● **Circuit design** using **Fritzing** or **Proteus** applications. Note that you have to consider the **Raspberry PI in the control loop** as the main decision maker having the image processing code running and sending the control action to a microcontroller (Arduino) to actuate the system. ● **Purchase** project components. ● **Acquire Image** by the purchased camera connected to the **Raspberry Pi.** **To be submitted:** ● Report (Word or Latex format) having the literature performed, project flow and list of requirements, details of acquiring the image. Report templates (Word and Latex) are available on the CMS. ● SOLIDWORKS file of the hardware design. ● Proteus or Fritzing file of the circuit design.	**Tuesday 4th of March, 2025**	**6%**
Milestone 02	**Requirements:** ● Perform **simple processing** as image filtration, geometric transformation, etc. on the acquired image using the chosen coding language. ● **Hardware fabrication** and **circuit** building and **connection** having the vision codes uploaded to the **Raspberry PI** for decision making and sending to the **Arduino** to actuate and close the loop of the system. ● **Simple closed loop** implementation to enable the motor to take an action depending on the image features (ex. Brightness, Darkness, Rotation angle, etc.).	**Tuesday 8th of April, 2025 + Evaluations**	**6%**

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	To be submitted: ● Report (Word or Latex format) having the steps performed with screenshots and illustration. ● MATLAB or Python codes of image acquisition, transformation and filtration. ● Videos for the image processing tasks, hardware design, circuit design performed and the simple closed loop with comments on the results.		
Milestone 03	**Requirements:** ● **Recommend image processing techniques** to be applied on your assigned project to extract the desired features. ● Perform the **image processing tasks that will benefit your assigned project** (ex. edge detection, corner detection, morphological operations, or others to extract the required features) on the **fabricated hardware** as a sequence of processes. ● **State the limitations** in the implementations that you faced in your assigned project. **To be submitted:** ● Report (Word or Latex format) having the steps performed for image processing techniques with screenshots, illustrations and comparisons required. ● MATLAB or Python codes for image acquisition using the microcontroller used. ● Videos for the hardware fabrication and circuit building and connections performed with comments on the results.	**Tuesday 22nd of April, 2025**	**6%**
Milestone 04	**Requirements:** ● Upload codes on the hardware keeping the Raspberry PI in the loop as mentioned previously. This should **finalize the project closed loop system** integrating the image processing approaches performed taking into account the camera as the sensing (feedback element) in the Mechatronic system hardware actuation decision. ● **Compare the performance of the Laptop vs. the Raspberry Pi** in the decision-making process. **To be submitted:** ● Report (Word or Latex format) having the steps performed for image processing techniques with screenshots, illustrations and comparisons required.	**Tuesday 6th of May, 2025 + Evaluations**	**6%**

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	• MATLAB or Python codes for hardware proper performance using the implemented image processing techniques. • Videos for the image processing tasks performed on the hardware and comments on the results.		
Milestone 05 + Exhibition (if applicable)	**Requirements:** • **Finalizing the whole project with a finalized hardware acting as a blackbox** with input images or videos and output control action to motors and actuators. The overall system **MUST be tested and validated using a different set of images indicating different scenarios.** • **Exhibition/Competition** between duplicated project teams. Details of the competition will be announced later. **To be submitted:** • Report (Latex) having the steps performed with screenshots, illustrations and comments. • Narrated Presentation for the whole project • Poster that will be presented in the exhibition. Details of its content will be announced soon. • MATLAB or Python codes for all the implemented image processing approaches. • Videos for the overall integrated system performed with closed loop testing and validation including comments on the results.	**Saturday 17th of May, 2025**	**6%**

Remarks:

** **5 different priorities** should be chosen to maximize the chance to get one of your preferred projects. In case of the unavailability of your selected projects a mail will be sent by the course instructors for the team to choose another project.

** A **detailed description for each milestone** will be provided with all the required deliverables and the submission details (links for submissions will be provided in each announcement).

** Teams can also build a **GUI for image processing tasks**.

** **Note that the materials to be submitted may be modified in each milestone and will be announced separately.**

References:

** MRS Lab YouTube Channel (Learning for Everyone):
https://www.youtube.com/watch?v=MTW_RIb8AoI&list=PLBlPu_4RJ_SXTJm486GJoRq4n22rQsDzC

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