UTS

SEAT NUMBER:

STUDENT NUMBER:

SURNAME:
(FAMILY NAME)

OTHER NAMES:

Examination Conditions:

It is your responsibility to fill out and complete your details in the space provided on all the examination material provided to you. Use the time before your examination to do so as you will not be allowed any extra time once the exam has ended.

You are **not** permitted to obtain assistance by improper means or ask for help from or give help to any other person.

Misconduct action will be taken against you if you breach university rules.

Declaration: I declare that I have read the advice above on examination conduct and instructions for this exam. In addition, I am aware of the university's rules regarding misconduct during examinations. I am not in possession of, nor do I have access to, any unauthorised material during this examination. I agree to be bound by the university's rules, codes of conduct, and other policies relating to examinations.

Signature:

Date:

41014_v1 Sensors and Control for Mechatronic Systems

Time Allowed: 120 minutes.

Reading time: 10 minutes.

Upload time: 30 minutes.

Reading time is for reading only. You are not permitted to write, calculate or mark your paper in any way during reading time.

Open Book
Programmable AND Non-programmable Calculators Permitted
MatLab or other coding software permitted

Permitted materials for this exam:

Drawing Instruments
Lecture notes

Materials provided for this exam:

Please print the exam paper by yourself and write your answer on the print. Or write your answers on blank paper.

Students please note:

All answers are to be legibly written in ink. Answers written in pencil will not be accepted. Pencil may only be used for drawings, sketches and graphs.

Do not open your exam paper until instructed.

Rough work space

Do **not** write your answers on this page.

There are two questions in this examination paper (30 marks in total). Please print the exam paper by yourself and the answers should be given on this examination paper in the space provided. Otherwise, please directly write your answers on blank paper or in a word document. After finish answering the questions, please photocopy your answers (scan or take pictures) and convert it to PDF, or directly submit the word document, or convert the word document to PDF, then submit via UTSOnline.

This is an open book, take home final exam. Lecture notes and other materials are permitted to use in the exam. MatLab or other programming software is also permitted to use, but only for helping on calculations.

Question 1: (16 Marks)

Suppose you have three bank accounts with different banks. In each month, for Account 1, you will pay C% of your balance of last month for daily expense, and transfer D% of your balance of last month to account 3; for Account 2, you will transfer E% of your balance of last month to Account 1, transfer F% of your balance of last month to Account 3, and save your salary in this account (Account 2); and for Account 3, you will pay the mortgage from this account. (C is the last digit of your student ID times 10 (if C = 0, then change to C = 50; if C>=80, then change to C = C-20); D = 100-C-20; E is the second last digit of your student ID times 10 (if E = 0, then change to E = 40; if E>=90, then change to E = E-10); F = 100-E-10.) There are no other transactions. Suppose the state of the system $x(k)=[x_1(k), x_2(k), x_3(k)]^T$ is the balance of each account at month k. For each month your salary is $u_1(k)$ and the mortgage you need to pay is $u_2(k)$, which are the input $u(k)=[u_1(k), u_2(k)]^T$. And your initial balance of the three accounts are $x_1(0)=20{,}000$, $x_2(0)=8{,}000$ and $x_3(0)=22{,}000$.

For example:
If a student's ID is 10588945, then C = 5*10 = 50, D = 100-50-20 = 30, E = 4*10= 40, F = 100-40-10 = 50.
If a student's ID is 10588998, then C = 8*10-20 = 60, D = 100-60-20 = 20, E = 9*10-10 = 80, F = 100-80-10 = 10.
If a student's ID is 10588900, then C = 50, D = 100-50-20 = 30, E = 40, F = 100-40-10 = 50.

(1.a) Please model it as a linear discrete-time system.

(1.b) What is the solution of the state x(k)?

(1.c) Analyse the stability of the system.

(1.d) Analyse the controllability of the system.

(1.e) Briefly describe how to design the optimal state feedback control by using Linear Quadratic Regulator (LQR).

Question 2: (14 Marks)

Figure 1 shows a simple visual servoing system which has a single camera on the end effector of a robot arm. The end effector of the robot arm can be controlled to a desired position by using the camera observing the pattern on the table.

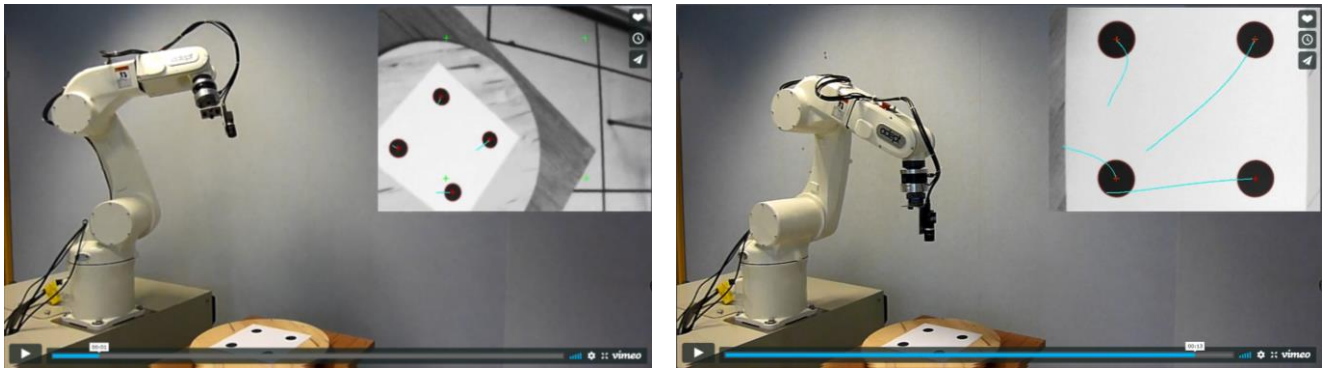

Figure 1 Visual Servoing with Eye-in-Hand camera configuration

(2.a) Suppose the parameters of the camera are: image resolution of (1280*1024), principle point (640, 512), and focal length (950, 950). The current camera pose is: rotation R = I (identity matrix), translation $T = [5, 15, 3]^T$m in the world coordinate frame. And the current depth Z from the pattern to the camera is Z = 1.5m. The current locations of the four features in the image are: (25, 80), (A, 25), (80, B), (A, B). Where A and B are the first three digits and last three digits of your student ID (If A<400, then A = A+ 400; If B<500, then B = B+500). We want to control the robot to move the camera with the desired locations of these four features in the image as: (10, 10), (800, 10), (10, 800), (800, 800). $\lambda = 0.15$ for $\dot{e} = -\lambda e$, where e is the re-projection error. What is the camera velocity? (Please write the progress of solving this problem and the necessary equations, with the calculations/values of the necessary variables, vectors, and matrices.)

For example:
If a student's ID is 10588945, then A = 105+400 = 505, B = 945.
If a student's ID is 96588245, then A = 965, B = 245+500 = 745.
If a student's ID is 96588000, then A = 965, B = 000+500 = 500.

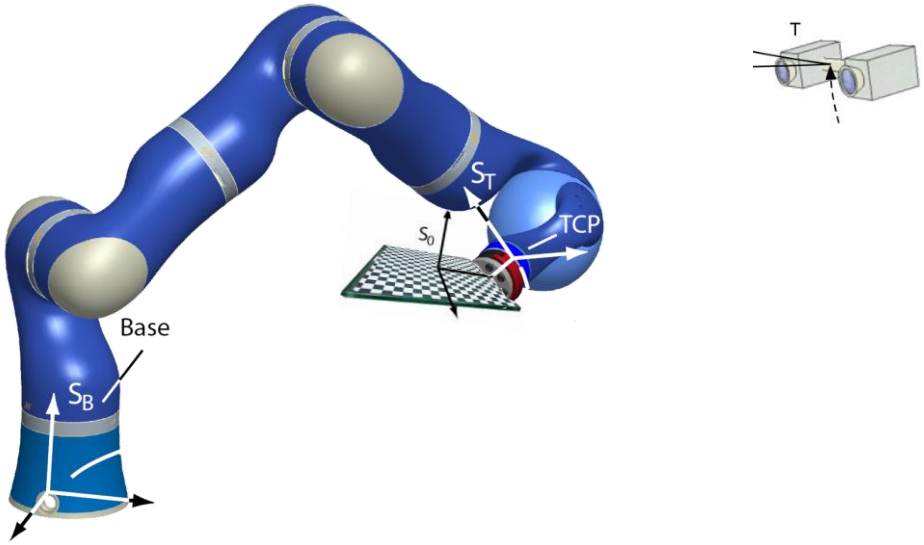

Figure 2 Visual Servoing with fixed camera configuration

(2.b) Figure 2 shows a visual servoing system with fixed camera configuration, with a pattern (calibration checkboard) mounted on the end effector of the robot. It is important to obtain the relative pose between the end effector and the pattern, as well as the relative pose between the global camera and the base of the robot. Briefly describe how this hand-eye calibration can be done to obtain 1) the relative pose between the end effector and the pattern; 2) the relative pose between the global camera and the robot base.