— Sort Pattern **A** —

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

This exam paper must not be removed from the venue

School of Information Technology and Electrical Engineering
Mid-Term Quiz

METR4202: ROBOTICS & AUTOMATION

S e p t e m b e r 2 0 , 2 0 1 7

First Name: _____ **Last Name:** _____

Student Number: _____

Examination Duration: 60 minutes

Reading Time: 10 minutes

Exam Conditions:
This is an Open Book Examination

Electronic Materials Permitted In The Exam Venue:

- No Internet Connected Devices (laptops, phones, etc.)
- Calculators - Any calculator permitted - unrestricted

Instructions To Students:

- Please be sure to place your name and number on **ALL** pages
- Please answer **ALL** questions.
- ⇨ **ALL** Answers **MUST Be Justified** ⇦
  (answers alone are not sufficient)

Thank you! :-)

Q	Mark
1	
2	
3	
4	
5	
6	

Total _____

This quiz consists of Multiple Choice, Short Answer, and Worked Problems. **Please Answer <u>All</u> Questions** below on the quiz paper. Answers must be neat and clear. All answers (except for multiple choice) **must provide a brief justification**. You may use the back of each sheet as scratch paper if needed. The total quiz is worth 100 points.

Part I: Robot Arm Kinematics (& Frames in Space)

1. A One Dimensional Robot for Question One [10 Points]

To get started, imagine a one-dimensional rotary (1R) robot.

(a) If this robot arm rotates about the z**-axis**, what would its **rotation matrix** (i.e. $\boldsymbol{R}_O^T$) from its Origin {O} to the Tip {T} be for a given rotation value θ^*?

(b) Instead, if this robot arm rotates about the line $\boldsymbol{y} = \boldsymbol{x}$ (in frame {O}), what would its **transformation matrix** (i.e. $\boldsymbol{T}_O^T$) be for the same given value θ^*?

2. A Clean Take on Manipulation [25 Points]

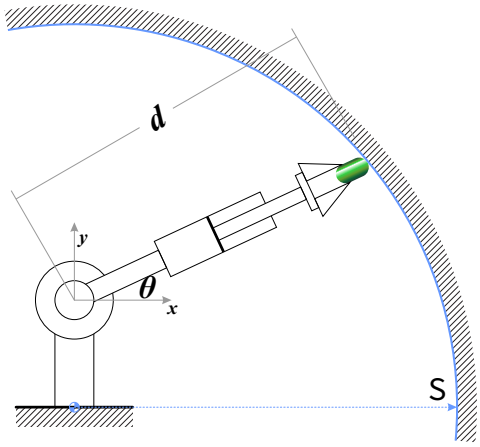

Figure 1: A RP manipulator is used move a sponge to clean a curved surface
(Assume, if needed, that the robot base is placed at the centre of curvature of the surface)

A planar manipulator (Fig. 1) is used to move a sponge along a surface (S) for cleaning. For this arm, please:

(a) Establish and state a joint space ($\boldsymbol{q}$) and workspace ($\boldsymbol{W}$) for this arm

(b) Derive the forward kinematics of this arm (i.e. $\boldsymbol{W} = f(\boldsymbol{q})$)

(c) Derive the inverse kinematics of this arm (i.e. $\boldsymbol{q} = g(\boldsymbol{W})$)

(d) Derive the Jacobian matrix ($\boldsymbol{J}$) associated with the coordinate transformation from joint displacements ($\boldsymbol{q}$) to endpoint positions ($\boldsymbol{W}$).

(e) The endpoint is required to move along the surface (S) at a constant velocity $\left(\bar{C} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix}\right)$. **Please compute** the corresponding joint velocities in terms of the joint displacements and $\bar{C}$.

3. Null Spaces Dualities [10 Points]

(a) What does the Null Space of the Jacobian ($N(\boldsymbol{J})$) inform about Endpoint Velocities $(\dot{\vec{\boldsymbol{x}}})$?

(b) What does the Null Space of the Transpose of the Jacobian ($N(\boldsymbol{J}^T)$) inform about the Joint Torques ($\boldsymbol{\tau}$)?

Part II: Sensing Kinematics

4. Getting Around the Hough Transform [10 Points]

Please **briefly** explain the difference between the rectilinear and polar forms of the line Hough Transform. What is a **principle advantage and disadvantage** of using the polar form over the rectilinear form?

5. SNR: SIFT, Noise and Rotors! [25 Points]

Figure 2: An Aerial Image of the Florida Keys
(Source: NOAA, Hurricane IRMA Imagery Dataset – https://storms.ngs.noaa.gov/)

Harvey, a video drone enthusiast, wants to make an aerial image (i.e. perform photogrammetry) of a region after a hurricane (such as the post-Irma Florida Keys). He proposes to use SIFT feature matching. To alleviate motion blur, he uses a downward-facing, high-frame rate camera.

(a) Can a SIFT feature descriptor exist without an initial "Harris corner" point?
(if so, *why?*, if not, *why not?*)

(b) Because of the short exposure time (due to the high-frame rate), the pictures are corrupted by **moderate** levels of salt and pepper noise. Will SIFT matching still work?
(Please briefly explain. If not, what can be done to make it work?)
[Hint: How does SIFT achieve scale-invariance?]

(c) What constraints (*if any*) does the use of SIFT place on changes in **altitude** of the flight?
(Please briefly explain.)

(d) What constraints (*if any*) does the use of SIFT place on changes in **attitude** (aerial vehicle orientation) of the flight?
(Please briefly explain.)

(e) Can Harvey use a Quad-Rotor (i.e. an aerial vehicle that has cross-coupling between its roll, pitch and yaw and forward motion axes) to get the mosaic via SIFT?
(Please briefly explain.)

6. Truth in Robotics! [20 Points]

Please state if the following statements are generally **TRUE (T)** or **FALSE (F)**
(Kindly circle the answer Ⓣ or Ⓕ, a brief justification may be *optionally* added below)

(a) **If** $R \in SO(n)$, **then** $det\ R = +1$ **[T | F]**

(b) A 3R manipulator cannot be redundant in 3D space **[T | F]**

(c) For a 3R planar arm having an overall Transformation Matrix ($_OT^E$) from the origin $\{O\}$ to the endpoint $\{E\}$, its inverse kinematics can be found directly from the inverse Transformation Matrix (T^{-1}) **[T | F]**

(d) A line is the axis of a pencil (one-parameter family) of planes **[T | F]**

(e) A perspective transformation can map a sphere into a paraboloid **[T | F]**

(f) As the focal length increases the effect of perspective is weaker **[T | F]**

(g) The key idea in a Hough Transform is to map a (difficult) detection problem into a (simple) peak detection problem. **[T | F]**

(h) **If** the colour of one object in the scene is known, **then** the colour can be normalized to it **and then** this colour can be used as a global feature. **[T | F]**

(i) SIFT is **invariant** to small changes in lighting **[T | F]**

(j) An edge detector often excels at finding corners **[T | F]**

Extra Working Paper