Scientific Experimentation and Evaluation

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PART I

I Aim

Associate the terms given in the description of the soft tissue measurement experiment with appropriate terms from the slide "2B: Formalization general terms".

II Description

- **Measurand :**
  - Force in the axial direction
- **Measurement :**
  - Torque(N)
- **Measuring Principle :**
  - Strain Gauge
- **Measurement facility :**
  - PI hexapod
  - Monocarrier drive
  - Indentation tool
  - Simulab complex tissue model
  - ATI Mini40 force sensor
  - EPOS2 motor controller
- **Device Under Test (DUT):**
  - Tissue Analogue
- **Sensitivity :**
  - Axial force resolution of 0.04N
- **Measurement System :**
  - EPOS2 motor controller
  - Indentation tool
  - FT sensor
  - NI DAQ
- **Meter :**
  - FT sensor

- NI DAQ

- **Measuring method:**
  - Displace the material using the indentation tool.
  - Measure the applied force using FT sensor.

PART II

I Aim

The aim of this project is to construct a LEGO NXT differential drive robot and measure the observable end pose variation for three different trajectories: an arc to the left, driving straight and an arc to the right.

The experiment of measuring the end pose can be done in three ways :

(a) Measuring the pose manually using a pen

(b) Measuring the pose using a pen attached to the robot

(c) Measuring the pose using markers and Computer Vision

II Experimental Setup

To reproduce the above experiment the following equipment are needed :

(a) White A1 Sheet

(b) Camera - Microsoft

(c) Assembled robot - Lego NXT

(d) Pens for marking

(e) Scales for measuring the length

(f) Vision markers

The general steps to setup the experiment are as following :

(a) Place the White A1 sheet on a flat surface. Try to remove any bends in the sheet and keep the paper as flat as possible. This will be called the 'map' on which the robot will move on. The measurement system is made of the robot, scale and a paper.

(b) Mark the center of the A1 sheet using the scale and a pencil.

(c) Draw the template drawing of the "floor space" taken by the robot as shown in the figure. Concept of "Behavior-shaping constraint" is used to prevent wrong initial placement of the robot.

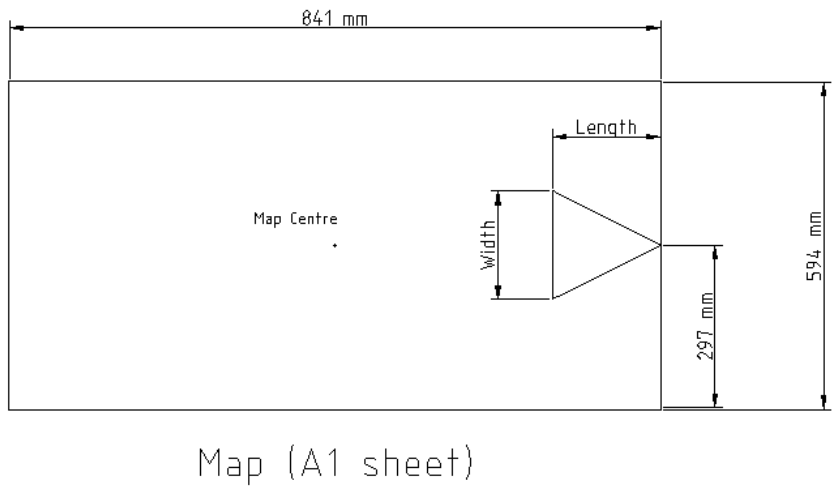

Figure 1: Template drawing of the Map along with dimensions

(d) Assemble the robot using the manual given with the LEGO NXT box. Install the OS to the controller of the robot. The Lego robot is the device under test(DUT).

(e) We assume that the driving axle is towards the front(leading edge) of the robot and that the robot origin lies in the centre of the driving axle.

(f) Place the robot such that the centre of the robot aligns with the centre of the A1 sheet on one of its shorter edges.

(g) The measurands are the distance between the initial and end positions and the angles between the two poses.

The reference images of the DUT and the proposed marker tracking visualization are given below.

III Experimental Procedure

i) Measuring the pose manually using a pen

i. Procedure

A. The measurement system is made of the robot, scale and a paper. The scale is used to measure the distance of the end pose of the robot relative

Figure 1 : Front View   Figure 2 : Side View   Figure 3 : Top View

Figure 2: Views of the DUT- with approximate dimensions

to the start pose.

B. The robot pose is measured using two markings, one on the centre of the leading edge of the robot and another on the centre of the trailing edge of the robot.
C. The initial pose of the robot is manually marked at the beginning using the pen.
D. The robot is programmed to move using the initial pose and the desired final pose.
E. The distance between the initial and final poses and the angles between the initial and the final poses are calculated using the front and the rear markings. These values can be used to calculate the pose.
F. 20 measurements would be performed for each trajectory. Mean and standard deviation will be computed from the measurement. These measured values would be used to compute the accuracy and precision of the pose variation.

ii. **Expected Problems**

A. There can be errors due to wheel slip which are negligible if the distance travelled by the robot is less.
B. Manual error may occur when marking the pose of the robot using a pen.
C. Parallax error may occur when a marking is made manually using the pen.

D. The robot should not move when the marking is made or it can lead to drawing inconsistent pose markings.
E. Uneven surface of the paper could cause change in trajectory.

iii. **Expected Performance**

A. The precision would not be perfect, but could have a large range since the DUT and the measurement facility are all manual and may involve errors due to direct contact with the apparatus.
B. The accuracy depends strongly on the problems listed for the experiments. The most important problems would be the error due to manual marking where the chances of the contact with the robot are very high. Since the distance driven is maximum 1m, the error in precision and accuracy will lie in the centimeter range.

ii) **Measuring the pose using a pen attached to the robot**

i. **Procedure**

A. The Lego robot, which is the device under test(DUT), is built with a pen mounted in the front, back or the center of the robot.
B. The measurement system is made of the robot, scale and a paper. The scale is used to measure the end pose of the robot relative to the start pose. The path taken by the robot is sketched on the paper by the pen.
C. The initial pose of the robot is manually marked at the beginning along with the alignment of the wheels to measure the angular displacement at the final pose.
D. The robot is programmed to move using the initial pose and the desired final pose.
E. The measurands are the distance between the initial and end positions and the angles between the two poses.
F. 20 measurements would be performed for each trajectory. Mean and standard deviation will be computed from the measurement. These measured values would be used to compute the accuracy and precision of the pose variation.

ii. **Expected Problems**

A. Errors such as wheel slip and internal errors in the robot drive can cause errors in the final calculation.
B. The errors in measurement if the A1 sheet is not properly placed is very difficult to measure.
C. The pen can wobble and affect the shape of the curve and thereby the result.
D. Uneven surface of the paper could cause change in trajectory.

iii. **Expected Performance**

A. The precision would not be perfect, but could have a small range since the DUT and the measurement facility are not changed.
B. There is minimum manual intervention during the actual pose measurement so the major contributor of error will be due to the movement of the pen when the robot is moving.
C. The accuracy depends strongly on the problems listed above. The most important problems would be the error due to wheel slip. Since the distance driven is maximum 1m, the error in precision and accuracy will lie in the centimeter range.

iii) **Measuring the pose using markers and Computer Vision**

i. **Procedure**

A. For this experiment the camera should be placed rigidly directly above the experiment setup such that the full map is visible in the camera frame.
B. Before beginning the experiment the camera should be calibrated and the obtained parameters should be used to compensate for the lens distortion and other errors in the image.
C. Two small markers should be attached on the flat surface of the robot, one on the front and one on the rear of the robot. The markers should be visible in the camera frame captured by the overhead camera. (The two markers should have different ID to distinguish between them)
D. Using Computer-vision the two markers on the robot can be tracked and localized. The centre of the markers can be found and be used to calculate the offset from the actual robot origin using a scale or any other measuring device.

E. The robot is programmed to move using the initial pose and the desired final pose.

F. The initial pose and the final pose can be found by CV and position and pose in the required form can be extracted.

G. 20 measurements would be performed for each trajectory. Mean and standard deviation will be computed from the measurement. These measured values would be used to compute the accuracy and precision of the pose variation.

Figure 3: Example Aruco marker for computer vision

ii. Expected Problems

A. There could be problems due to the setup not done correctly. eg. The paper is not perfectly flat.

B. Camera is not fixed rigidly enough.

C. Camera calibration is not performed correctly.

D. Software related bugs in the logic of the computer vision code.

iii. Expected Performance

A. This experiment accuracy and precision depends highly on the setting up of the camera and the markers correctly.

B. Since the experiment does not rely on any manual intervention or has no moving parts like the pen, the precision is very high.