MECHANICAL ENGINEERING

Data-Driven Methods for Engineers (MECH0107)

- Coursework 1 -

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Coursework Brief and General Instructions

Module code	MECH0107
Module name	Data-Driven Methods for Engineers
Module lead	Dr Lama Hamadeh
Academic year	2024/25
Term	Term 2
Individual/group assessment	Individual
Page count limit	8 Pages
% contribution to module	40

Submission Date

Please see the submission portal on Moodle for the due date for this assessment.

Page Count Penalty

Work that exceeds the word/page count by more than 10% will be reduced by 10 percentage points. This must not take the mark below the Pass Mark. Any material in addition to the 10% excess may not be taken into account in grading.

Eligibility for Delayed Assessment Permit (DAP)

This assessment is eligible for Delayed Assessment Permit.

Use of Generative AI

1. This assignment is classified as Category 2 where AI tools can be used in an assistive role.
2. You are not permitted to use AI tools for code writing or generate any idea related to your coursework.
3. You can use these tools to receive feedback on or proofread your code.
4. You can use these tools to explain error messages generated by your code.
5. You can use these tools to check your written English's grammar and/or spelling.

6. If you use any of these tools, you need to state the tool name, the output, and how you used it within your submission.
7. Please note that if you fail to adhere to these instructions, you might face academic misconduct and receive a 0 mark in this assessment.

Submission

1. Submission requirements:
   (a) **Report:** Submit a single `.pdf` file. The report must not exceed 8 pages. See the end of this brief for the required contents of the report. You should **NOT** add snippets of codes into your report to explain how these are implemented, as this would make the report very long. This is why the codes and comments should be self-explanatory.
   (b) **Code:** Submit all relevant code files that you have used. Please name your code files in a simple-to-follow manner. Your code files should be commented on, and the comments should be clear.

   You should **put everything (codes AND your written report)** into a zip folder, then submit the zip folder onto the submission point on Moodle. Note: please do not submit .rar file – only .zip is allowed.
2. Anonymity requirements:
   - Do not include your name, student number, or any identifiable information in any part of your submission. This includes your report, and your code files.
3. The marking rubric is available on Moodle.
4. The dataset that you will be working on can be found in Moodle.

Module's Intended Learning Outcomes

1. Identify the foundational concepts of artificial intelligence, machine learning, and data-driven modeling and their applications in science and engineering systems.
2. Develop and refine various supervised and unsupervised algorithms and appreciate their underlying mathematical backgrounds.
3. Examine the reliability and robustness of data-driven models
4. Extract features and patterns from data and discover new knowledge from it.
5. Identify the need to use neural networks and deep learning algorithms in some applications, compare their efficiency with machine learning algorithms, and interpret their predictions.

Coursework 1

Spring Pendulum: The Theory of Hybrid Systems

1. Introduction.

In the area of dynamical systems, an elastic pendulum (also called spring pendulum or swinging spring) is a physical system where a piece of mass is connected to a spring so that the resulting motion contains elements of both a simple pendulum and a one-dimensional spring-mass system, as shown in Fig(1, a). For specific energy values, the system demonstrates all the hallmarks of chaotic behavior and is sensitive to initial conditions. At very low and very high energy, there also appears to be regular motion. A set of coupled ordinary differential equations governs the motion of an elastic pendulum. This behavior suggests a complex interplay between energy states and system dynamics. For example: the force responsible for the spring motion is always directed toward the equilibrium position and is directly proportional to the distance from it. That is, $\mathbf{F} = -\mathbf{kx}$, where $\mathbf{F}$ is the force, $\mathbf{x}$ is the displacement, and k is a constant. This relation is called Hooke's law. On the other hand, the pendulum is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. Therefore, the system is much more complex than a simple pendulum, as the properties of the spring add an extra dimension of freedom to the system, hence the name: hybrid system.

2. Problem.

Suppose a hybrid system that contains a spring-mass system that makes two types of oscillations: a pendulum motion, i.e., a rotation in the $x - y$ plane, and a simple harmonic oscillator along the z direction, as shown in Fig(1, b). The motion is captured by three different cameras positioned in three different orientations. The data is stored as three video files and then turned into Matlab datasets with the format of `.mat` [1]. The three dataset files are named `cam1.mat`, `cam2.mat`, and `cam3.mat`, which refer to the dynamics captured from the first camera, second camera, and third camera, respectively. You can access and download the three datasets from Moodle.

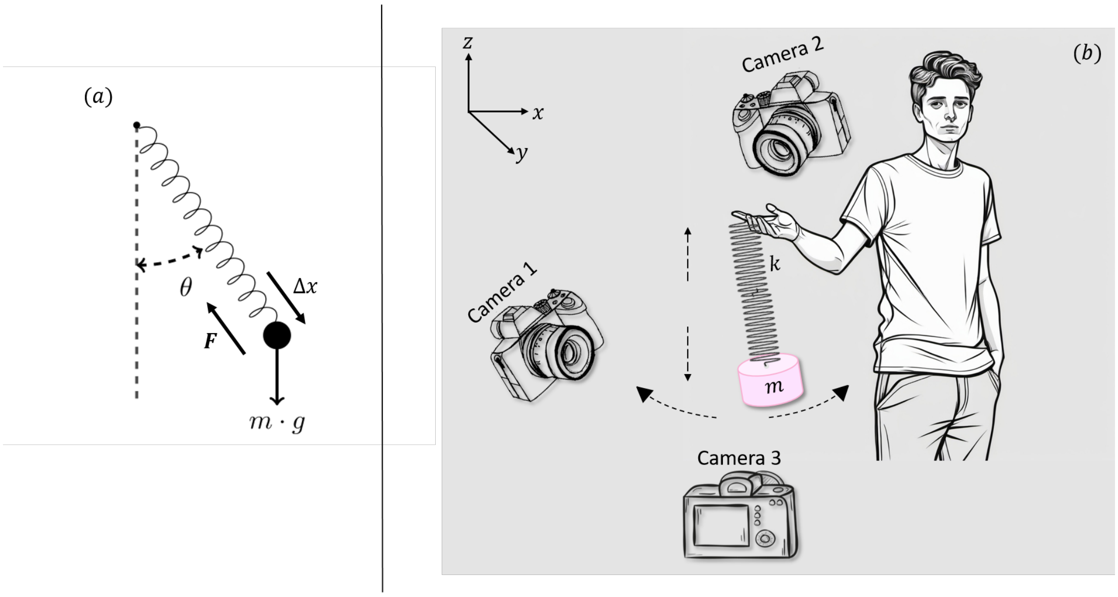

Figure 1: A spring-mass system oscillates in two types of oscillations: a pendulum motion in the $x - y$ plane and a simple harmonic oscillator along the z axis. The motion data of this system is captured by three cameras from different angles.

3. Coursework.

After downloading the datasets, analyse the dynamics and the underlying physics of this system using Matlab or Python programming language. This analysis should:

1. **implement** the necessary image processing methods on the captured frames of each camera for the aim of motion tracking and optimal feature/dynamics extraction.

2. **build** a reduced-order model using a dimensionality reduction method to identify the governing degrees of freedom that dominate the nonlinear dynamics of this system.

3. **discuss** the results and the physics behind them.

4. Report Writing.

The submitted report should not exceed 8 pages.

The report should include the following sections:

1. **Introduction and Problem Statement.** Describe the physics of the hybrid system and the problem/system presented in the provided datasets. Explain your analysis steps and how you intend to approach the problem.
2. **Methodologies.** Explain all the methods you intend to use to analyse this system in terms of image processing and dimensionality reduction.
3. **Results.** Present and visualise your results.
4. **Discussion.** Discuss your results and whether the used methods produce meaningful results.
5. **Conclusion.** Add a brief conclusion to your report by summarising the overall analysis and proposing alternative methods to enhance the performance for better and more accurate results.

If you are using any references, add them to the "References" section at the end of the report. This section is NOT included in the page count.

End of Coursework

References

[1] Nathan Kutz. Harmonic oscillator and pendulum video datasets. https://drive.google.com/drive/folders/1SQ77P5t5RUWCSucmk4jPFbufFMX8VrJG, 2013. Online; accessed 04 November 2024.