Title of your MDM project

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May 27, 2024

Mathematical and Data Modelling 3

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Declaration of AI use

Use this text to explain how AI such as ChatGPT or Github's Copilot was used to generate any project outputs, such as code or sections of the report. You will not be penalised for using AI. However, you are expected to be transparent about how it has been used and to use it responsibly.

1 Introduction

The National Health Service (NHS) offers free and confidential talking therapies, delivered by accredited practitioners, to address common mental health problems such as stress, anxiety, and depression [1]. They offer treatment specifically tailored to each individuals needs, with options including guided self-help, cognitive-behavioral therapy (CBT), and counseling [1].

In England, one in four people will experience some kind of mental health problem each year, with one in six experiencing a common mental health problem (like anxiety and depression) in any given week [2]. Talking therapies help people to deal with these problems. The NHS talking therapies were accessed by nearly 1.2 million people in 2021/22, and an expected 1.9 million people will access this service by the end of 2023/24 [3].

This report uses data collected from the NHS and machine learning techniques, such as regression and correlation analysis, to help identify correlations, trends, and outliers between different metrics (ie number of referrals, waiting times) [4]. The results highlight the findings of using these techniques, with the discussion delving into the respective limitations of each method.

Through the identification of these correlations, trends, and outliers, the NHS and its providers of talking therapies can target their spending and resources in the most effective way. This will allow for the improvement of patient care and increased recovery rates.

2 Methods

2.1 Pearson's and Spearman's

Pearson's correlation coefficient is good way to initially analyse correlations between different metrics in the data. Pearson's measures the linear relationship between two variables. Values range from -1 to 1: -1 indicates a perfect negative linear relationship, 1 indicates a perfect positive linear relationship, and 0 indicates no linear relationship. The limitations of Pearson's are that it cannot measure a non-linear relationship between 2 variables and it cannot distinguish between the dependent and independent variables.

Spearman's rank correlation coefficient is a statistical test that uses a ranking system to assess the degree of correlation existing between two sets of data. The two sets of data are placed in rank order next to each other so that they can be compared statistically [5]. Instead of the actual values of observations, the Spearman's correlation coefficient uses the rank of the observations when ordering observations from small to large, hence the 'rank' in its name. This usage of the rank makes it robust against outliers [6]. Also, a matrix of p-values is created for testing the hypothesis of no correlation against the alternative hypothesis of a non-zero correlation. A p-value of zero indicated that the probability is less than the significance level of 0.05, it shows rejection of the hypothesis that no correlation exists between the two columns.

3 A physics-based model

It is common for an MDM3 project to be divided into a few sub-projects. These sub-projects usually address some aspect of the main problem using different modelling approaches. These sub-projects can be described in sections. The titles of these sections should be concise but descriptive.

Usually this paragraph would give an overview of the first modelling approach and explain how it fits with the overall project and objectives.

3.1 Governing equations

You might want to use a subsection to describe the technical aspects of the modelling approach, e.g. the equations. All equations should be numbered and properly punctuated as if they are part of the sentence. Be sure to justify the modelling approach and any assumptions, simplifications, or approximations that are made. Lengthy calculations should go into appendices. For example, do not show the steps required to obtain a solution to a differential equation in the main text; only show the solution. The text below is an example where a physical model is being used.

The motion of a charged particle in an electric field is given by

$$m\ddot{\boldsymbol{r}} = q\boldsymbol{E}, \tag{1}$$

where m, q, and $\boldsymbol{r}$ are the mass, electric charge, and position vector of the particle, respectively, and $\boldsymbol{E}$ is the electric field. Overdots represent differentiation with respect to time. The electric field $\boldsymbol{E}$ is due to the presence of an electrically charged sphere of radius a and charge Q located at the origin. We assume the particle always remains far from the sphere, $|\boldsymbol{r}| \gg a$. In this case, the electric field can be approximated by Coulomb's law [7] as

$$\boldsymbol{E} = \frac{Q}{4\pi\epsilon_0}\frac{\boldsymbol{r}}{|\boldsymbol{r}|^3}. \tag{2}$$

Here, ϵ_0 is the electric permittivity of free space.

3.2 Results and discussion

One way to structure your report is to present the results of the first modelling approach in a subsection that immediately follows the technical description of the approach. The results can also be discussed in this subsection.

Figure axes should have appropriate labels (with units where needed). Legends should be used when multiple curves or data sets are shown in the same figure. The font sizes in figures should be roughly the same as the font sizes in the text. If you really want to go the extra mile, look up how to use LaTeX fonts in your figures; this is possible with both Matplotlib and Matlab.

Figures and tables must have captions. Captions should be short. Captions should not provide explanations; that is what the body of the report is for. Figure captions go *below* the figure. Table captions go *above* the table.

Good discussions are critical and insightful; they go beyond simply stating the trends in the figures and/or tables. Rather, the trends are explained in terms of the underlying processes or situations being modelled. Results should be interpreted in the context of the original problem. Distinction-level discussions will also establish links to the existing literature and previous results.

4 Second modelling approach

Additional sections can be used to describe additional modelling approaches. If statistical modelling is used, then be sure to run your simulations multiple times and report the mean and variances of your results. If using machine learning, make sure you explain how you've split your data into test and training data, report validation results, and explain how you've chosen hyperparameters. Regardless of your modelling approach, you should provide enough details for all of the results to be reproduced. Moreover, you should also provide convincing evidence that your approach is working correctly.

5 Conclusion

All reports must end with a conclusion. It is common for the conclusion to *briefly* summarise the report (e.g. in a few sentences). However, *the conclusion is much more than a summary.* This is where you should reflect on the results of your modelling and make conclusive statements relating to the modelling objectives/questions that you established in the introduction. The conclusion is one of the most important parts of the report and it carries significant weight.

To help formulate the conclusions, imagine that the text you are writing is for the problem presenter. Try to answer the following: what has your work achieved from the perspective of the problem presenter? How will your work help them?

It is okay if your work is not able to get to the answer the presenter wanted. If this is the case, then you can use the conclusion to outline potential ways that your work could be extended in the future to arrive at such answers. When discussing avenues of future work, ensure that these are both feasible and clearly relevant to the aims of the problem. If you are proposing an extension to a model as an area of future work, then justify why this model extension is necessary and critically assess what would be achieved from it. That is, imagine that you are 'selling' this extension to the problem presenter.

The conclusion should be around half a page to one page in length.

The 12-page limit stops here. Figures *are* included in the 12-page limit. Do not move key figures to the appendix.

A An example appendix

Appendices are used to add *non-essential* material that supplements or extends the material contained in the main report. You can use appendices to add things like:

- Derivations of mathematical models or solutions
- Long tables of parameter values
- Extra simulations, analyses, figures
- Extra details of numerical methods/implementations
- Validation of numerical methods, e.g. by comparison against known solutions

The main body of the report should be completely self-contained and understandable without the appendices. All of the main messages, equations, figures, discussions, etc must occur in the main text. Ask yourself the following: can I read the report from start to finish without needing to look something up in an appendix? If not, then an appendix contains some essential material that must be moved to the main body.

Material in the appendices will not be assessed, although proper use of appendices will be. Any essential material that is placed in an appendix will be considered as missing from the report and marks deducted. All material in the appendices is expected to have proper formatting (e.g. figures and tables are captioned and discussed in a block of text). In addition, all of the material in the appendix should be referred to in the main text.

There is no page limit on the appendices.

Do not add code to the appendices; this is what the GitHub repo is for.

B Another appendix

You can have multiple appendices.

References

[1] NHS. Nhs talking therapies. https://www.nhs.uk/mental-health/talking-therapies-medicine-treatments/talking-therapies-and-counselling/nhs-talking-therapies/, .

[2] Mind. Mental health facts and statistics. https://www.mind.org.uk/information-support/types-of-mental-health-problems/statistics-and-facts-about-mental-health/how-common-are-mental-health-problems/.

[3] NHS. Nhs talking therapies, for anxiety and depression. https://www.england.nhs.uk/mental-health/adults/nhs-talking-therapies/, .

[4] NHS. Psychological therapies, reports on the use of iapt services. https://digital.nhs.uk/data-and-information/publications/statistical/psychological-therapies-report-on-the-use-of-iapt-services, .

[5] https://www.oxfordreference.com/display/10.1093/acref/9780198568506.001.0001/acref-9780198568506-e-6625. [Accessed 08-12-2023].

[6] Roemer J Janse, Tiny Hoekstra, Kitty J Jager, Carmine Zoccali, Giovanni Tripepi, Friedo W Dekker, and Merel van Diepen. Conducting correlation analysis: important limitations and pitfalls. *Clinical Kidney Journal*, 14(11):2332–2337, May 2021. ISSN 2048-8513. doi: 10.1093/ckj/sfab085. URL http://dx.doi.org/10.1093/ckj/sfab085.

[7] Peter Heering. On Coulomb's inverse square law. *American Journal of Physics*, 60(11): 988–994, 1992.