

COMP2043.GRP INTERIM GROUP REPORT

Team02
Machine Learning Dataset Parsing
Tool

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1 Description of the Problem

Team02's project is centered around a system that classifies datasets by the best type of machine learning approach to take in order to best analyse the data. It is proposed that the system will be able to parse a dataset, analyse its features and propose a type of machine learning (supervised, semi-supervised and unsupervised), as well as a more specific algorithm, that can best model the dataset based on the analysed features.

The client intends to use the project as both a prefilter for machine learning and as a teaching aid, and so the program should be able to provide useful information as to how the machine learning approach was derived. However, it should be noted that being an expert in the field, the client expects his knowledge to be captured in the system. As such, any useful information provided by the system would be used to aid the teaching of students and should therefore be suitable for someone that is not an expert in the field.

Datasets that the program will analyse will be provided by the client, however the system should be able to parse and analyse newly uploaded datasets with the same level of accuracy.

2 Background Information and Relevant Research

2.1 Machine Learning

The team has to figure out how many machine learning methods would be provided in our website, their respective principles, and how and when to use each one. There exist many open source machine learning toolkits such as H2o [1], Weka [2] and various Python and R packages. These machine learning toolkits could be used to analyze different datasets. In this early stage of the project, the team has chosen to use Weka to understand each machine learning method.

2.2 Understanding Machine Learning Algorithms

Section 4.2 lists the machine learning algorithms that the system will be able to produce as output. The team felt it would be beneficial to have a basic understanding of each algorithm and where it is most useful. Some background research was conducted into each algorithm.

Self-Organising Map (SOM)

K-Means Clustering

K-means clustering classifies a set of data into k clusters (where $k > 0$) by assigning it to a centroid (central location of a cluster). This is achieved by assigning it to the nearest centroid. When each data point has been assigned,

k centroids are recalculated and the datapoints are reassigned. This process of defining and assigning to new centroids is repeated until no data points move.[3]

Principal Component Analysis

Linear Regression

Neural Network

Artificial Neural Network (ANN) is a machine learning method simulating information processing of a human brain to build a mathematic model. The model consists of processing elements (neurons) which each have an activation function. ANNs require a large amount of examples as training data and test data to complete the model, like the process of human learning. It has advantages in processing amounts of fuzzy nonlinear data.

Multiclass Neural Network

Random Forest Regression

Logistic Regression

Logistic Regression is a method for binary prediction when the outputs are dichotomous (true or false). The weight of independent variables can be deduced by Logistic Regression when the binary outputs (dependent variable) are provided. The probability of output can also be predicted by the regression model. It is generally used for data mining, disease analysis and economic projection.

Multiclass Logistic Regression

Nave Bayesian Network

Nave Bayes is a sorting technique based on Bayes theorem. It sets characteristics of data as tags and assume that the tags are mutually independent on probability. Then the Nave Bayes Classifier sort the objects and calculates probability according to these tags. And the objects can be sorted to known classes or demonstrate the probability of an object belonging to a class.

Support Vector Machine

Support Vector Machine (SVM) is a method used to sort and regress. SVM is a development of binary liner classifier. For the nonlinearities, SVM transforms the sample into higher dimensions so that the sample can be linerly analyzed because of high dimensional features.

Self-Training

Self-Training is a semi-supervised learning method. It divides first divides sample data into labelled and non-labelled subcategories. Because of high accuracy

of classifier, the model can be used to label the unlabeled data sets. Then the unlabeled data can be deleted. The Algorithm will repeat these steps until the datasets not change any more.

Forced Clustering

Anti-Learning

Anti-learning is used when the accuracy of a trained model's output is worse than random outputs even if no overfitting or over training occurred.

3 Requirements Specification

Following meeting with the client and discussing initial user requirements and system requirements specification, as well as subsequent meeting revising both requirements, the team and the client have agreed on a set of requirements.

3.1 User Requirements

1. Parse datasets and suggests the best machine learning approaches for modeling that dataset.
2. The user will supply datasets to be analysed.
3. The system will need to be appropriate for use as both a prefilter for machine learning and as a teaching aid.
4. The user requires a degree of data visualization in the front end.
5. The user requires a comprehensive, extendible database. The database should allow the user to:
 - 5.1. upload datasets
 - 5.2. provide relevant information about the datasets
6. A rule-based approach will initially be sufficient to ascertain what the ideal machine learning approach is for each dataset. The user should be able to affect the decisions made by the rule based system by providing additional information on the structure and complexity of the data.
7. The client has significant knowledge of machine learning methods and some of this knowledge will be captured to facilitate the decision making process.

3.2 Functional System Requirements

1. The system will require a database which can store the data in every dataset
 - 1.1. The user can upload the dataset.
 - 1.2. The datasets are available for users to download.
 - 1.3. Information about the dataset (what type of data, whether or not there are missing values) can be provided by the user and stored as metadata with each dataset.
 - 1.4. The datasets need preprocessing to find details about the data. These details must be stored as metadata with the dataset. Details will be characteristics of the datasets which help decide the best machine learning approach. Such details could include:
 - 1.4.1. The type of data
 - 1.4.2. Size of the dataset
 - 1.4.3. Number of features
 - 1.4.4. Number of target outputs provided with the data
 - 1.4.5. Whether or not there are missing values
 - 1.4.6. Whether the labels are categories or values
 - 1.4.7. Complexity of the dataset
 - 1.4.8. Complexity of relations in the dataset
 - 1.4.9. Whether or not the dataset is structured
 - 1.5. The customer needs to be able to add and delete information stored in the database.
 - 1.6. The original data must never be altered. Any pre-processing or analysis may be available to the user, but the user must also have access to the original data they provided.
2. The system must be able to analyze a dataset and provide the best machine learning approach to model the dataset.
 - 2.1. The reason why that approach is best needs to be provided to the user.
 - 2.2. The system will have different catalogues of machine learning. Each catalogue provides the algorithm for the machine learning and the sample datasets.
 - 2.3. The system must have a search engine which can search for both the datasets' name and machine learning approaches.
3. The system must provide different types of data visualization
 - 3.1. Bar charts
 - 3.2. Scatter graphs

3.3. Images

3.4. Interactive visualization at the result page

4. The system should have different mapping opinions for finding the ideal machine learning method:
 - 4.1. Rule-based system
 - 4.2. Deterministic mode
 - 4.3. Probabilistic mode
5. As a long-term goal, the system could actually model the data using the decided machine learning tool and provide a visual output of the model for the user.

3.3 Non-Functional System Requirements

1. Accessibility

- 1.1. The user should be able to upload data using multiple types of input, for example both the mouse and the keyboard.
- 1.2. The system should be accessible on multiple different platforms.

2. Data integrity

The original uploaded data should never be changed. If there are mechanisms in place which change the data, these should not affect the original data

3. Data Retention

Data stored on the sever should only be kept there for 30 days as a limit.

4. Extensibility

The system should be able to cope with data of no more than 200MB.

5. Performance:

The system should be able to analyse new data sets in no longer than 1 minute.

6. Privacy and Security:

Data uploaded by a user must have the option to be kept private to the user who uploaded it.

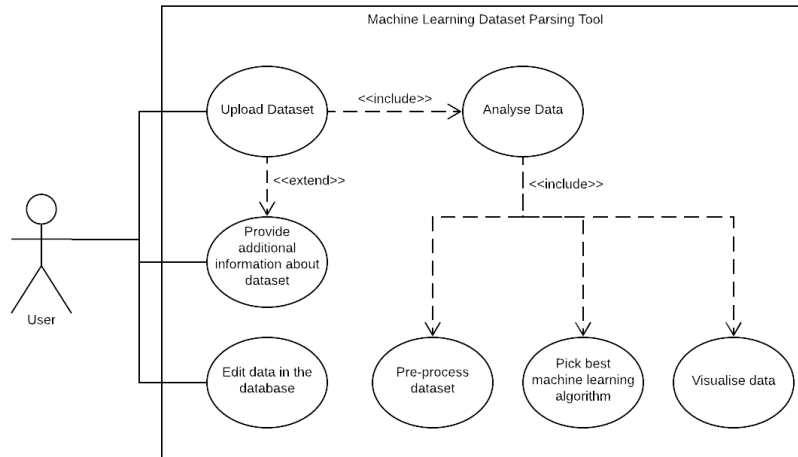


Figure 1: Simple use case diagram of the system

3.4 Modelling Requirements

Following the elicitation of user and system requirements, the team decided it was useful to model both. A simple use case diagram was created first, shown in figure 1.

The use case diagram clearly shows how the user will interact with the system. Due to the nature of the system, much of its complexity is hidden from the user and therefore the user does not have many use cases. Regardless, the use case diagram is an important part of the requirements gathering process as it makes it easier for the client to visualise their interactions with the system.

4 Initial Design Ideas

4.1 Front End Design

The user interface prototype is designed to accommodate the user requirements. The home page will contain some information about the project, what it does, and how to use the tool. The navigation bar, available on all pages of the site, contains links back to the home page, as well as to a page where users can see a list of datasets and analysis of a dataset. From the home page, the user can choose to log in, see a list of the datasets in the system or upload a new dataset. New users need an account to log in if they want to keep datasets private or delete datasets they have uploaded. This feature will not be present in the first iteration of the project as it is not part of the core functionality, however the button will be in the front end, although not functional.

Clicking on the Datasets link takes the user to the Datasets page. In the

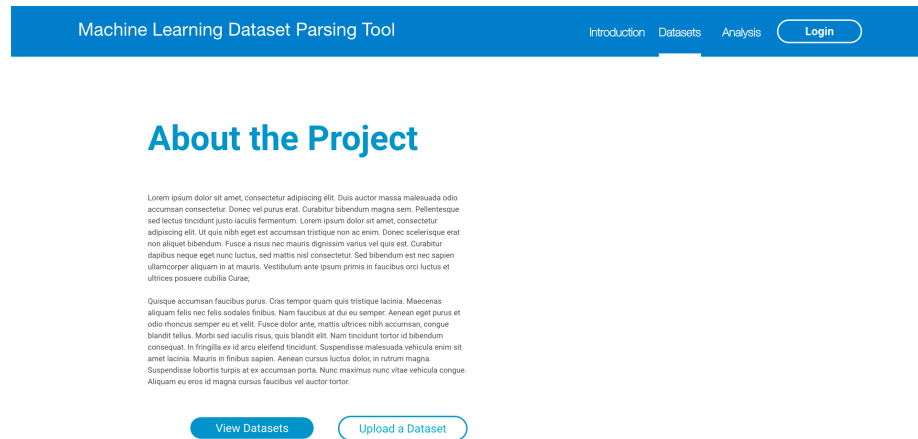


Figure 2: The Home Page of the system

left part of the page, all files in the database list can be seen. Double clicking on a dataset takes the user to the visualisation page for that dataset. From the Datasets page, the user may also choose to upload a new dataset for analysis. There exists a search bar, clearly visible in the top right corner, where the user can search for datasets in the database by name.

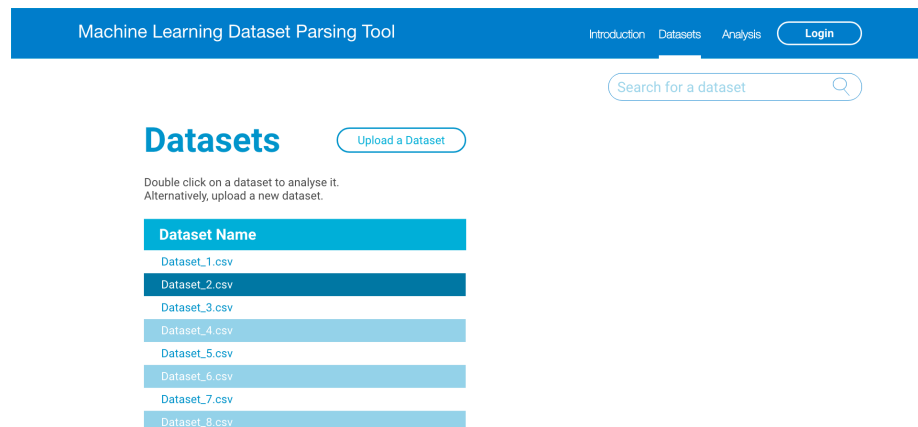


Figure 3: The Datasets Page of the system

When a user double clicks on a dataset, they are taken to a page where the

dataset is analysed. The main function of the Analysis page for a dataset is to show the best machine learning algorithm for that dataset. The dataset's name can clearly be seen at the top of the page. More information about the dataset is available on the page, such as the features extracted by the data pre-processing routines outlined in section 4.3. Moreover, the user can see the decision tree and the route taken through the decision tree to get to the machine learning algorithm that was chosen. This is helpful for when the system is being used as a teaching aid, as it shows how the machine learning algorithm was decided. The user can also influence the decision made by changing the features that were extracted using the Edit button. A download and delete button are also available, however the delete button will only be available to the user who uploaded the data set in future iterations. Clicking the download button will download the raw data, in CSV format (see section 5.4). From the analysis page, the user can go to a page where the datasets are visualised.

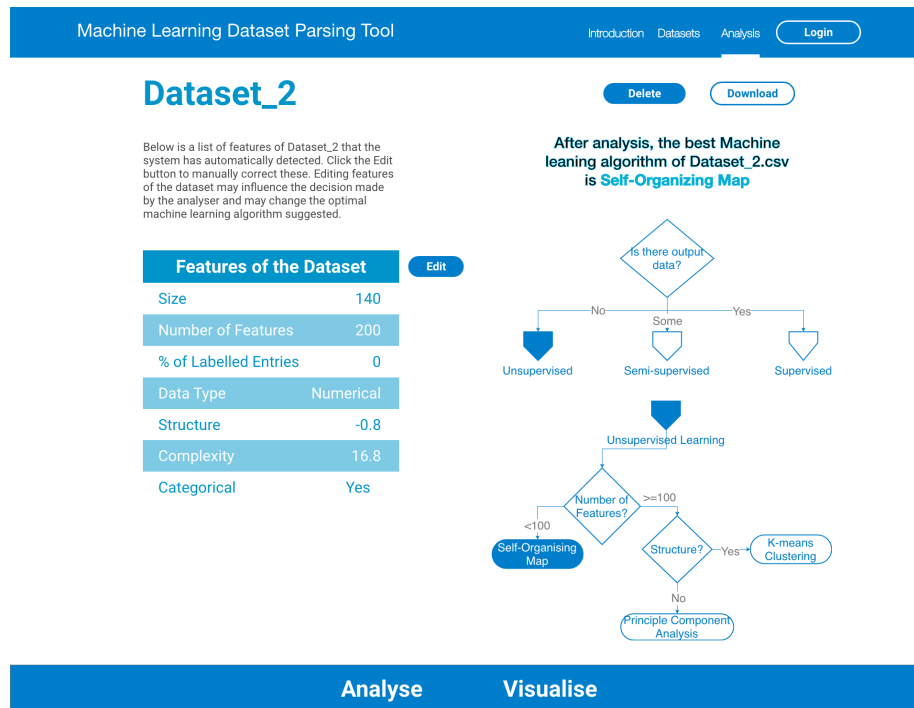


Figure 4: The Analysis Page of the system

In the Visualisation page, the name of the dataset being visualised is shown at the top. The user can choose different types of visualisation for the dataset, such as the raw tabular data, bar charts or scatter graphs. The user can swap between these modes of visualisation, depending on the type of data that the dataset contains. At the bottom of the visualisation page, the user can choose to show the analysis page for that dataset. As data visualisation is not part of

the core functionality, this feature will also not be present in the first iteration, but the group has accommodated for it in the design.

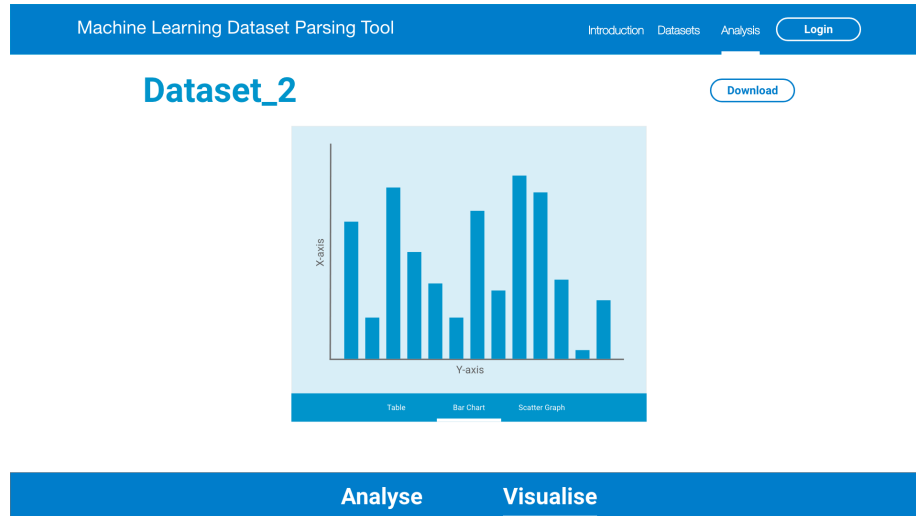


Figure 5: The Visualisation Page of the system

4.2 Picking the Machine Learning Approach

The final goal of the project is to analyze datasets and automatically suggest the best machine learning tools by using our machine learning analyzer. The analyzer will initially be composed of a Decision Tree, which will identify the best machine learning approach based on features of a given dataset.

The short-term goal is to classify dataset into three broad categories: Supervised Learning, Unsupervised Learning and Semi-supervised Learning according to whether there is output data in the dataset. In order to provide a prototype to the client, the system will pick a random machine learning approach. This will let the client have an idea of what a working system would function like.

The team decide to provide 17 potential machine learning tools:

- Multiclass Neural Network
- Linear Regression
- Random Forest Regression
- Sum Regression
- Logistic Regression
- Neural Network

- NB or Sum
- Anti-learning
- Self-Organizing Map
- K-means Clustering
- Principle Component Analysis
- Forced Clustering
- Self-Training
- Deep Learning
- Recurrent Neural Network
- Time Delay Neural Network
- Feature Selection Principal Component Analysis

The most suitable tool will be suggested from this list of machine learning methods by using decision algorithm in the second iteration of the project, after the prototype.

The website will display the selected most suitable machine learning tool for each dataset uploaded by client. In the long term, the team hopes that the website will be able to analyze the dataset by using the best machine learning tool and visualize the output. However, the team and client are both aware that given time constraints, it may not be possible to implement all 17 algorithms, and as such it was agreed with the client that although it would be useful to have, it is not part of the core functionality.

The decision algorithm will be used to determine which is the best analyzing algorithm for datasets. First of all, the algorithm will determine whether the dataset is supervised; according to whether there is output data in the dataset, the dataset will be divided into three categories: Unsupervised Learning, Semi-supervised Learning and Supervised Learning, as can be seen in figure 6.

If the dataset has no output data, it is classed as an Unsupervised Learning problem. Within Unsupervised Learning, if there are lots of features in the dataset, suggest using a Self-Organizing Map to analyze. Otherwise judge whether the dataset have structure or not. If they have structure, suggest K-means Clustering to analyze, otherwise suggest using Principal Component Analysis. This decision is modelled in figure 7.

If the dataset is completely labelled with output data, divide it into Supervised Learning. If the outputs are categories divide the dataset to Classification. Else if the outputs are continuous values, divide the dataset to Regression.

If the dataset is best modelled by classification, determine how many categories the dataset contains. If dataset contains 3 or more categories, determine if the dataset is simple or not. For small complex datasets, suggest Multiclass Neural Network or Random Forest Regression. For simple large dataset, suggest

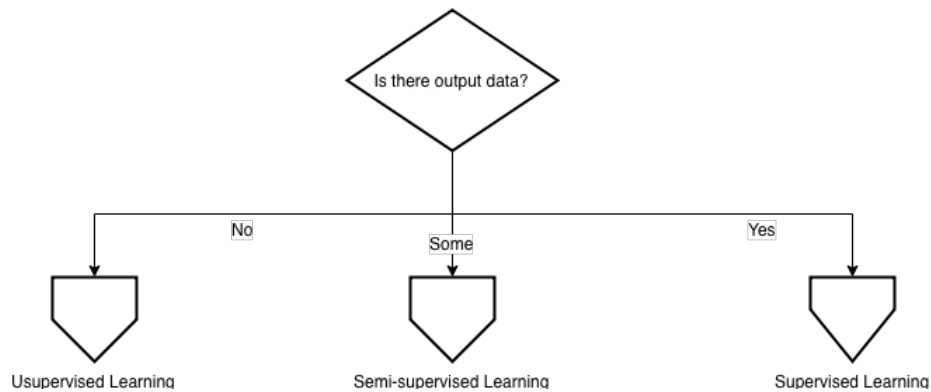


Figure 6: Deciding the class of machine learning to use

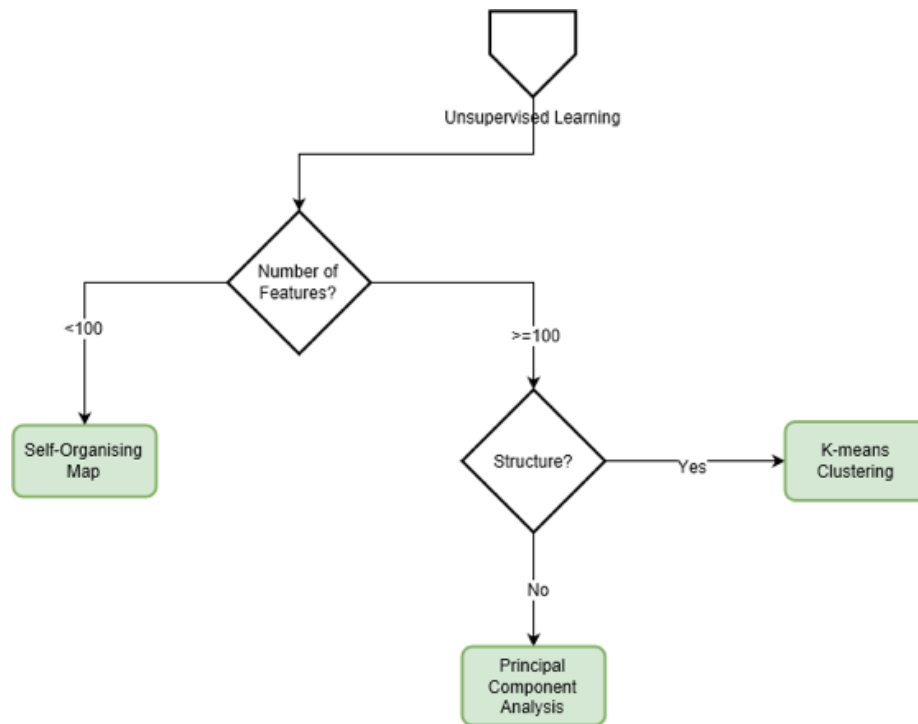


Figure 7: Deciding which unsupervised learning technique to suggest

using Multiclass Logistic Regression to analyze. If the dataset only contains less than 3 categories, determine whether the relation in the dataset is simple. If the dataset has simple relations, suggest Logistic Regression. Otherwise determine how many features in the dataset. If the dataset has less than 100

features, suggest Neural Network, otherwise suggest Nave Bayesian Classifier or Support Vector Machine. If, after modelling the data using a Nave Bayesian Classifier or Support Vector Machine, the output is worse than a guess, suggest Anti-learning.

If the dataset is composed of values (regression), also determine the dataset simple or not, if it is a simple large dataset, suggest Linear Regression. Else if a complex small dataset, suggest Random Forest Regression and Sum Regression. Figure 8 vizualises this set of decisions.

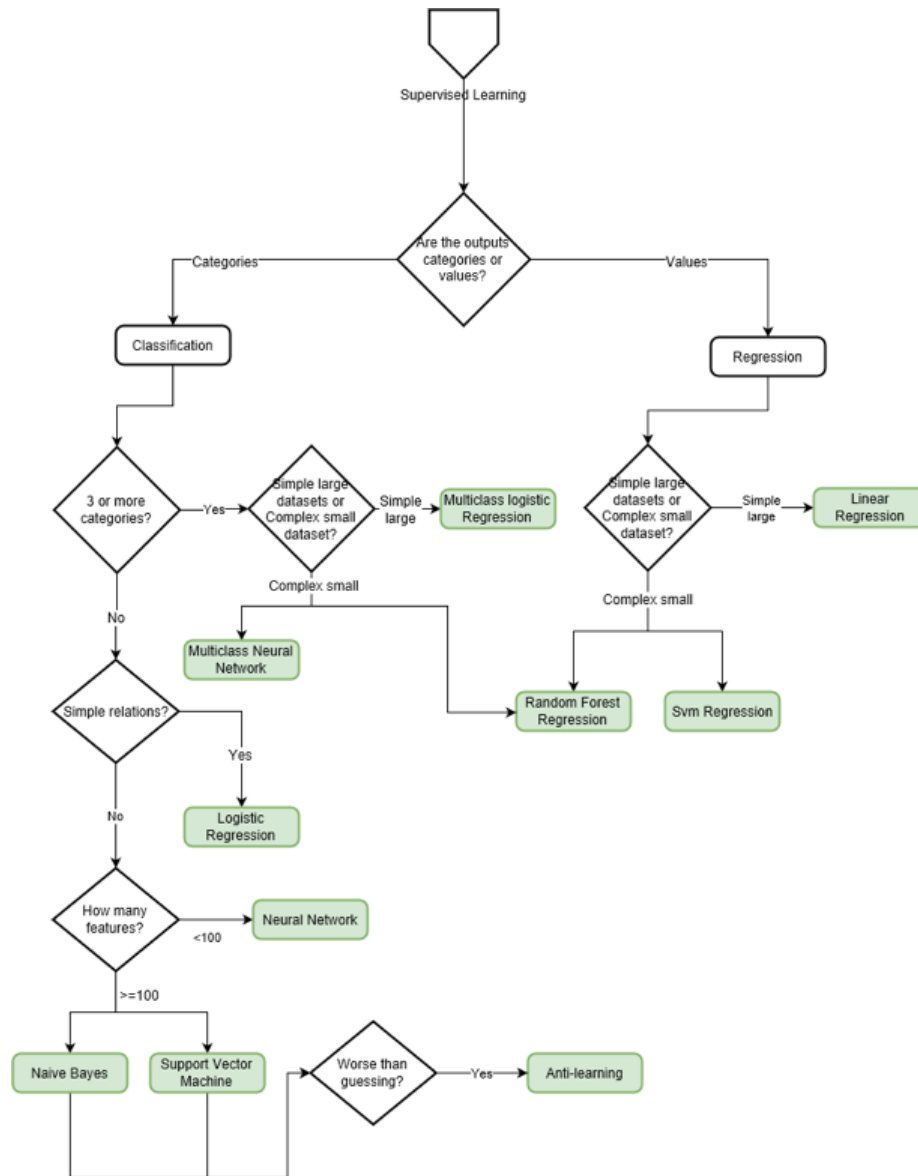


Figure 8: Deciding which supervised learning technique to suggest

4.3 Data Representation

Section 5.4 outlines the allowed file types in the system. However, data preprocessing is needed in order to choose the most suitable machine learning algorithm, as it is required that information about the dataset (such as whether or

not there are missing labels, its complexity, whether the output is categorical or not) is available for the decision based algorithm. As such, before data are uploaded to the database, a pre-processing script extracts features and stores them, alongside the data, in an Object. The object has the following fields holding the specified data types:

```
dataset: {
  name: string,
  headings: list of strings,
  number-of-features: integer,
  values: matrix of values,
  missing-values: list of coordinates,
  original-values1: matrix of values,
  anomalies: list of coordinates,
  labels: list of strings,
  missing-labels: list of integers,
  data-type: string,
  size: integer,
  labels-ratio: number ( $0 \leq x \leq 1$ ),
  is-categorical: true / false,
  categories2: list of strings,
  complexity: number,
  structure: number ( $-1 \leq x \leq 1$ ),
  relations: list of features
}
```

A short explanation of each field is provided below where the name-value pair does not make it obvious:

- **values**, **original-values**: the original data (and potentially imputed data) from the input CSV file, stored as a matrix
- **missing-values**, **anomalies**: the coordinate into the **values** or **original-values** matrices where missing or anomalous values can be found
- **labels-ratio**: the total number of rows of data divided by the number of missing labels
- **complexity**: a numerical score of the complexity of the dataset, based on the average bias-corrected variance of each column
- **structure**: a numerical score of the average correlation coefficient of each column
- **relations**: list of columns that could be related, determined by pairs of columns with high correlation coefficients

¹This field will only exist if there are missing values, where the missing values are imputed in the "values" field, but a copy of the original values is kept in the "original-values" field

²This will only exist if the data is deemed categorical

5 Key Implementation Decisions

5.1 Programming Languages

When deciding which languages would be most suitable for the project, a few aspects that were considered were functionality, familiarity and convenience. Functionality was the main concern, given that the system is a web-based project. Therefore, the group needed to choose a language that could interface easily with a web application. Familiarity made this decision more difficult, as only one group member was familiar with JavaScript, which is the main language used on the web. As such, the group had to pick a range of languages that accommodated both the functionality needed as well as the experience level of the group members. Convenience therefore became an issue, as all group members had to ensure that code in one language could easily interface with code from another language.

Apart from HTML and CSS, both of which are essential to any web application, a few languages discussed are listed below.

1. **JavaScript** is a web scripting language. JavaScript enables interactive web pages and thus is an essential part of web applications. It is a dynamic[4] weakly typed language. Its primary purpose is to provide interactivity and have programmatic control over elements on a web-page [5]. As a simple web-based project, most functionality needed at this stage can be implemented by JavaScript. JavaScript also has an extensive collection of libraries, as well as a server-side runtime environment (Node.js [6]), which makes it suitable to use in the back-end of a web application. As discussed in section 5.3, a NoSQL MongoDB database was chosen, and Node.js contains a library (Mongoose [7]) which makes implementing the database easy with a Node.js framework.
2. **PHP** is a scripting language tailored for the web [8]. PHP code can be integrated into Java, C and Perl and can be embedded into HTML code. It is weakly typed[9] and has a high developing efficiency to complete an activity web page. It is easy to learn, the source code can be found easily on webpages. It also can connect MongoDB. It could be used to develop server-side functionality of the project.
3. **Java** is the language the group is most familiar with. There exist good Integrated Development Environments (IDEs) such as Eclipse and IntelliJ which we have all used before. It has a security structure and easy to debug. But the code would be more verbose than other languages and it is more difficult to make connection with HTML webpage. In other words, Java is suitable for some big projects that need precise design. Java code could be implemented on webpages with Java Server Pages [10], but this would add a lot of unnecessary overhead.
4. **Python** is a language with simple structure. It is easy to master and can implement functions in fewer lines code. The shortcoming is that it

is unfamiliar to the group, and so choosing it might cause unpredictable problems such as environment building which lead to the work goes slowly. Python code can be implemented on webpages via the Common Gateway Interface (CGI) [11].

Due to both convenience and functionality, as described above, the group decided the main language used to implement the system would be JavaScript. It should be noted that due to limitation in its ability to perform machine learning algorithms on large datasets (a task that languages such as Python and R are very well established in), the group may have to incorporate other languages. However, JavaScript proves both convenient and capable enough for the first iterations of the system. Due to its low learning curve and past experience in the group, it will not be too difficult for everyone who needs to use it to learn enough to produce a capable system.

5.2 Design Pattern

As outlined in section 7.1, the group has divided the workload into three parts: Machine Learning, Database Implementation and Front End Development. These three elements of the system loosely fit the description of the *Model-View-Controller* (MVC) design pattern [12]. This allows for better code organisation and maintainability [12] by separating responsibilities within the codebase. The three key components of the MVC design pattern are outlined below:

- **Model** This is where the data of the system is stored. The Model has no access to the View or the Controller, and is only responsible for storing the data. This is essentially the Database part of the project.
- **View** The View is what is presented to the user. This is how the user interacts with the system: the Front-End. Although the user interacts with the View, the View has no responsibilities apart from to display the data in the Model.
- **Controller** The Controller acts as the bridge between the Model and the View; it updates the View when changes happen to the Model, and updates the Model when the user interacts with the View. This is the Machine Learning section of the group's work division. The controller is responsible for all logic in the system.

Although the MVC design pattern is being employed in this project, the project need not adhere strictly to it. Its ideas and philosophies are useful in that they allow separation of concerns thus creating more maintainable code, however the project does not lend itself well to a strict implementation of the pattern given that its main concern is data processing.

5.3 Database Design

5.3.1 NoSQL vs SQL

Heterogenous big data benefits from NoSQL for a few reasons. Firstly, there is no predefined schema that the data has to conform to, which is useful for our application as it will have to save data from a multitude of different data sources in the same data store. It is not possible to index all the data efficiently beforehand, and therefore a large schema that all datasets will conform to cannot be defined. Even if this was easily possible, a large schema would waste a lot of space, as most datasets would only use a small subset of the schema. This would also make searching the database very inefficient, as it would be resource inefficient to have to search through potentially hundreds of unused fields.

Removing schemas also makes the database faster to query [13]. Because each dataset is stored in one document rather than spread across multiple tables, the program knows exactly where to look for the data set rather than having to search through multiple tables. This helps when having to search through a lot of datasets to find the data set of interest.

5.3.2 Lack of Relations Between Datasets

The data sets that our program will use contain almost no relations. As such, using a relational database would waste a lot of the functionality associated with relations, and cause a lot of unnecessary overhead. Instead, a non-relational database will just store data sets independently of each other. Querying the database will simply involve returning a JSON object, with no links to other data sets.

5.4 Accepted File Types in the System

When studying Weka, the team found that there are many file types that machine learning tools could use, for instance Arff data files, CSV data files, XRFF data files, amongst others. After some research into the UCI Machine Learning Repository [14], the team decided to use CSV data files to store datasets into the database and to be used by the machine learning tools. This decision was also agreed upon by the client, who stated that CSV file types would suffice for the core functionality of the system. Other file types were welcomed, but not required.

CSV files were chosen as they make it convenient for the team to transform the .data files and .name files found on the UCI repository into a single file. CSV files are also easy to store in the NoSQL database. Knowing the format of the data is useful for data pre-processing and analysing.

6 Problems Encountered

6.1 Testing

7 Time Planning and Project Management

At the very start of the project, time planning was discussed but was not followed or enforced as much as it should have been. As such, a Gantt Chart was devised and is shown in figure 7. This Gantt chart has helped us stick to deadlines and structure our work.

Alongside the Gantt chart, the team has a Kanban board which is hosted on Trello.com [15]. Scrum was discussed as an alternative approach, but Kanban was chosen for some reasons outlined below:

- Teams using Kanban can cope with mutable requirements flexibly. Teamwork will continue with changing project environment.
- Formal and informal meetings can be held as frequently as needed and agile working process can be pushed favorably by team communication.
- Due to the main process of the project having been decided, Kanban is a good system as it allows us to visualize every stage of work and everyone's processing.
- For a team with less development experience, it is difficult to deliver an executable program in a short time. Scrum would be difficult to practice because of its demand on techniques and experience.
- Scrum needs to stipulate working time for every iteration, which is difficult for teams with less development experience. Kanban only displays stage missions but not time limits.
- Scrum needs to declare a Product Owner, Scrum manager and Team which might cause confusion in an inexperienced team. Kanban can make team members focus on their work and research.

After agreeing that Kanban would be more suitable to our team's needs, a Kanban board was created on Trello. Trello was chosen as it makes collaboration a lot easier. Being a web based tool, it made it easy for us to manage our workflow from all of our devices, as well as accommodating remote work and management. It also allows team collaboration as it allows people to join the Trello board, which was an essential feature the team needed in order to be able to manage its work collaboratively.

7.1 Division of Work

Rather than everyone playing a role in every aspect of the project, it was decided it would be easier to divide the work into three distinct subgroups. The project was divided into three main sections: *Front-End Development*, *Machine Learning* and *Data Pre-processing and Database Development*. It was decided that Hao and Xinyang would be responsible for Front-End Development, Boyan and Xinjie for Machine Learning and Marios for the Data Processing and Database. The division was made based on both past experience with technologies needed for that area, as well as personal preference. As such, there was no conflict in deciding who would be responsible for what area.

Dividing the project in this fashion allowed the team to be able to divide workload more efficiently, as any task could be categorised into one of the three areas of the project and assign the task to the correct person(s).

Following this division of labour, it was decided that the Kanban board would be better organised if there was a list for each section. Therefore, three lists ("To Do", "Doing" and "Done") were created for each are of the project, as well as one set of lists for "Other" tasks that had to be done (for example, adding a section to the report, drawing diagrams). This project management workflow kept everything atomic, where everyone was only responsible for a small subset of tasks. It also kept people focused, as everyone could find the correct list for their section and pick up "To Do" tasks that correspond to their section of the project.

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