Decision support backend module for commercial ERP system

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

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II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce:
Modul podpory rozhodování pro komerční ERP systém

Název bakalářské práce anglicky:
Decision support backend module for commercial ERP system

Pokyny pro vypracování:
1. Get acquainted with ERP systems and provided DB export
2. Design a solution with the following features:
   1. Imports data from the MS SQL database
   2. Provides endpoint for basic statistic information of the imported data
   3. Converts the imported data to dataset, usable for machine learning
   4. Provides at least 3 various classification or regression methods
   5. Allows cross-validation and 2:1 test/train split
   6. Allows asynchronous (non-blocking) training of the classifier
   7. Provides basic health (utilization) information
   8. Allows export of the trained model
   9. Allows classification using the trained model
   3. Implement the solution (C# programming language is preferred)
   4. Create small testing dataset and verify the solution works as expected
   5. Unit test and document the project
   6. Test the solution with another provided DB

Seznam doporučené literatury:

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Student bere na vědomí, že je povinen vypracovat bakalářskou práci samostatně bez osi pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v bakalářské práci.

Datum převzetí zadání: 6. 5. 2019

Podpis studenta:
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Declaration

I declare that I have created this project independently and that I have listed all sources of information used within it in accordance with the methodical instructions for observing the ethical principles in the preparation of university theses.

In Prague on May 13, 2019

........................
Abstract

The goal of this project was to create a decision support module for the company Asseco Solutions, which develops ERP systems. This module allows importing data from a database, creating a dataset suitable for training of classifiers, training of classifiers and then using the trained model to classify new data. The application was developed mainly using the programming language C# and application framework Asp.Net Core 2.2. There were three different factory data on which functionality was tested.

Keywords: Classifier, C#, ERP, Asp.Net Core, Machine Learning

Supervisor: RNDr. Štefan Dušík, Ph.D
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Chapter 1

Introduction

1.1 ERP

The acronym ERP stands for enterprise resource planning. It is a process used by companies to manage and integrate the important parts of their businesses. ERP systems tie together, define a plethora of business processes and enable the flow of data between them. What primarily distinguishes ERP software from stand-alone targeted software is a common central database from which the various ERP software modules access information, some of which is shared with the other modules involved in a given business process.

An ERP software system can integrate planning, purchasing inventory, sales, marketing, finance, human resources, and more.

1.2 Financial forecast

Financial forecast is an estimate of a future financial outcome for an organization. It estimates future income and expenses for a business over a period of time. By analysing an organization’s current financial position and other factors, a properly developed financial forecast presents an assumption of how the organization will perform in the future.

1.3 Motivation

One of the problems of manufacture companies is production optimization. They can not expect that the same number of pieces will be sold from each product. Because of this reason some materials and semi-products lies in warehouse for long period of time, that can mean significant fixation of finances and inefficient use of the storage capacities.

According to [5] the production planner who makes decisions about what products and when they will be produced, does not focus on warehouse status but makes decision based on:
• leadership priority
• current orders
• available resources
• estimated needs
• own experience

However using historical production data and statistical methods, we can create a certain assumption about warehouse status for the future. This assumption can help production planner with making a decision whether to add a semi-product to the manufacturing chain. This can improve productivity and ultimately increase profit of the company.

1.4 Current situation

According to [5] and [6] in the current state there is already functional application which was created by Victoria Eykhmann and Michal Bouška. They implemented the application which can assign a numerical value to the semi-products which are expensive and lies in warehouse for long time. This value is called a penalty, and it represents the value of a semi-product in a warehouse accumulated over time \[1\]. Subsequently, value of the penalty is transformed. During this transformation, the penalty is multiplied by weight for each day, where weight gradually increases from 0 to 1. It reflects a fact, that company does not mind products stored for a short time, instead it minds long-term stored product.

Then the products can be divided into three classes according to their penalty:

• products with low priority
• products with middle priority
• products with high priority

In this project, Michal Bouška created python scripts which can import data from database and transforms them to a dataset suitable for training of classifiers then training and using of classifiers.

The part which was done by Victoria Eykhmann provides graphical interfaces (see the figure 1.1).

\[ \text{penalty} = \sum_{\text{days}} \text{number\_of\_total} \times \text{price\_of\_one} \]
1.5 The goal of this project

The goal of this project is to solve the problem from the motivation section by implementing WEB API using C# language which should help a responsible person to make decisions about manufacture orders.

Figure 1.1: The figure shows the dependence of the parameter price on stock after production vs. penalty value. Colouring is based on price in stock before production (of entered semi-product). Adapted from [6].
Chapter 2
Theoretical part

2.1 Data preparation

In the beginning, it is necessary to prepare a suitable dataset (ETL\(^1\)) for the training of classifiers. In this dataset, the first row has to contain names of attributes set for training and each additional row contains exactly one instance (manufacture order). The following five files (description from \([5]\)) are needed:

- \texttt{manufacture\_command.csv} - contains raw data from Helios database
- \texttt{material.csv} - represents the tree of dependencies of semi-finished products on materials
- \texttt{slozitost.csv} - contains TAC\(^2\) for materials
- \texttt{stock\_load.csv} - contains information about movements of the semi-finished products in the warehouse
- \texttt{stock\_price.csv} - contains the price of the semi-product.

After adding statistical/cumulative data and collecting only important columns the final dataset which is suitable for training will be created:

- \texttt{manufacture\_command\_ex.csv} - contains columns needed for training, evaluating and using of the classifiers, the order of the columns can not be changed(see \([2.1]\) for description and desired structure)

\(^1\)Extract-Transform-Load
\(^2\)The time required to perform an operation on one piece of product in minutes.
2. Theoretical part

<table>
<thead>
<tr>
<th>order</th>
<th>column</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>index</td>
<td>number of the row</td>
</tr>
<tr>
<td>2</td>
<td>command_price</td>
<td>Order price (amount * manufacture_cost)</td>
</tr>
<tr>
<td>3</td>
<td>start_month</td>
<td>Month from date of assignment</td>
</tr>
<tr>
<td>4</td>
<td>nrow_TAC</td>
<td>Number of TAC entries needed to create the product (number of steps)</td>
</tr>
<tr>
<td>5</td>
<td>sum_TAC</td>
<td>Amount of TAC needed to create the product</td>
</tr>
<tr>
<td>6</td>
<td>material_sum</td>
<td>Sum of the materials needed to create the product</td>
</tr>
<tr>
<td>7</td>
<td>material_nrow</td>
<td>Number of materials needed to create the product</td>
</tr>
<tr>
<td>8</td>
<td>parent_pieces_order_count</td>
<td>Number of parent orders at start_date</td>
</tr>
<tr>
<td>9</td>
<td>parent_pieces_order_mean</td>
<td>Number of unique parents in the semi-product tree</td>
</tr>
<tr>
<td>10</td>
<td>parent_pieces_order_max</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>parent_pieces_order_min</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>parent_depth</td>
<td>Maximum depth of parents in the semi-product tree</td>
</tr>
<tr>
<td>13</td>
<td>parent_count</td>
<td>Number of unique parents in the semi-product tree</td>
</tr>
<tr>
<td>14</td>
<td>end_stock_price</td>
<td>Reflects the target money, that are blocked in the storage after finishing the manufacture order</td>
</tr>
<tr>
<td>15</td>
<td>actual_cost</td>
<td>Actual price</td>
</tr>
<tr>
<td>16</td>
<td>ongoing_same_pieces</td>
<td>Sum of products on manufacturing order from ongoing_same_command</td>
</tr>
<tr>
<td>17</td>
<td>ongoing_same_command</td>
<td>Number of running manufacturing order on the day of the production order with the same product</td>
</tr>
<tr>
<td>18</td>
<td>ongoing_all_command</td>
<td>Number of running manufacturing order on the day of the production order entry</td>
</tr>
<tr>
<td>19</td>
<td>ongoing_all_pieces</td>
<td>Sum of pieces from ongoing_all_command</td>
</tr>
<tr>
<td>20</td>
<td>cost_sin_2_6</td>
<td>value of the penalty</td>
</tr>
<tr>
<td>21</td>
<td>start_date</td>
<td>Actual date of start of manufacture command</td>
</tr>
</tbody>
</table>

Table 2.1: Structure of the prepared dataset (suitable for training). Description is adapted from [5].

2.2 Classifiers preparation

2.2.1 Introduction

Machine learning is a scientific study of algorithms and statistical models that computer systems use to effectively perform a specific task without using explicit instructions, relying on patterns and inference instead. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task.

Supervised learning is the machine learning task of learning a function that maps an input to an output based on example input-output pairs. In super-
2.2. Classifiers preparation

Supervised learning, each example is a pair consisting of an input object and the desired output value. A supervised learning algorithm analyses the training data and produces an inferred function, which can be used for mapping new examples. Classification is a supervised learning in which data are used to predict a category. The case where the output is a real value is called a regression.

In spite of the fact that we want to classify the priority (low/mid/high) of new production order which is actually a category, first we need to "predict" the value of the penalty and because of this reason, we will use regression methods. After estimating the value, we will classify the priority into categories based on the given boundaries:

- penalty < 250,000 = low priority
- 250,000 ≤ penalty < 1,000,000 = medium priority
- penalty ≥ 1,000,000 = high priority

Before we can start with training and evaluating of classifiers we need to create train and test datasets. This is done by posting parameters: start_year_train, end_year_train, start_year_test and end_year_test.

### 2.2.2 Used methods

These methods are used from [8]. The reason why I used mainly decision tree based methods lies in the previous work of Michal Bouška [6].

1. **FastTree (Boosted Trees) Regression**
   Trains gradient boosted decision trees to fit target values using least-squares.

2. **FastTree (Boosted Trees) Tweedie Regression**
   Trains gradient boosted decision trees to fit target values using a Tweedie loss function. This learner is a generalization of Poisson, compound Poisson, and gamma regression.

3. **Fast Forest Regression**
   Trains a random forest to fit target values using least-squares.

4. **Generalized Additive Model (GAM) for Regression**
   This GAM trainer is implemented using shallow gradient boosted trees to learn nonparametric shape functions.
2. Theoretical part

The accuracy of the optimal model for three different companies: "hudba", "pribory" and "letadla" can be seen in the following table 2.2.

<table>
<thead>
<tr>
<th></th>
<th>hudba</th>
<th>letadla</th>
<th>pribory</th>
</tr>
</thead>
<tbody>
<tr>
<td>test years</td>
<td>2016, 2017</td>
<td>2015</td>
<td>2017</td>
</tr>
<tr>
<td>accuracy</td>
<td>0.7</td>
<td>0.73</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Table 2.2: The accuracy of the optimal model for three different companies.

2.2.3 Evaluation

Evaluation is divided into two parts:

- regression metrics
- percentage of correct predictions (of priority) on the test dataset

For every model we will count the following regression metrics:

- L1 - the absolute loss of the model
- L2 - the squared loss of the model
- Rms - root mean square loss which is the square root of the L2
- RSquared - the coefficient of determination

Then we will classify the priority of the penalty for the test dataset based on real value and based on the predicted value for every instance in the test dataset. From this information, we will determine a percentage of the correct predictions. Based on this percentage is chosen an optimal model but in the export of classifiers are all models including their evaluation.

2.2.4 k-Fold Cross-Validation

Cross-validation is a resampling procedure used to evaluate machine learning models on a limited data sample. The procedure has a single parameter called 'k' that refers to the number of groups that a given data sample is to be split into. As such, the procedure is often called k-fold cross-validation.

In our case, there is an option to evaluate the model using cross-validation by posting num_of_folds parameter, if num_of_folds is less or equals 1 then the cross-validation will not be performed.
2.3 Classification

New manufacture commands which priority we want to classify have to be in a CSV file containing the first 19 columns (order 1-19) from the table. But in this case, they do not have to be in an exact order.

The resultant file is a CSV file which contains two columns: "index" (to identify the manufacture order) and "priority".

---

3 Comma Separated Value(s) (database export/import format and file extension)
Chapter 3

Analytical part

3.1 Architecture

Software architecture refers to the high-level structures of a software system and the discipline of creating such structures and systems. Each structure comprises software elements, relations among them, and properties of both elements and relations.

This project implements REST API which is an architecture style for designing loosely coupled applications over HTTP, that is often used in the development of web services. A web service is a software system destined to support interoperable machine-to-machine interaction over a network.

3.2 Requirements

The software requirements are a description of the features and functionalities of the target system. Requirements convey the expectations of users from the software product. The requirements can be obvious or hidden, known or unknown, expected or unexpected from a client’s point of view.

3.2.1 Functional Requirements

Requirements, which are related to functional aspect of software fall into this category. They define functions and functionality within and from the software system.

Functional requirements for this project are:

1. import data from database (Microsoft SQL Server)
2. prepare dataset suitable for training of the classifiers
3. create train and test datasets
3. Analytical part

4. training of the classifiers to create a classification model
5. evaluation of the trained models
6. choose optimal model
7. export models
8. use model to classify new data

3.2.2 Non-Functional Requirements

Requirements, which are related to the functional aspect of software fall into this category. They define functions and functionality within and from the software system.

Non-Functional requirements for this project are:

1. training of the classifiers must not blocking the application
2. give the user feedback if the request was successful or not
3. implementation will be based on the C# language
4. delete files once they are redundant from the storage (filesystem in our case)

3.3 Technologies

All technologies used to create this project are open-source.

C# is a programming language developed by Microsoft which is designed for Microsoft’s .NET Framework. This allows developers to take advantage of all the features offered by the .NET API.

The application was developed using ASP.Net Core 2.2 which is a free and open-source managed computer software framework for the Windows, Linux, and macOS operating systems. It fully supports C#. The reason for version 2.2 is that ASP.NET Core 2.x can target both .NET Core and .NET Framework. Besides that .NET Core is cross-platform and open-source there are more advantages to use it instead of .Net Framework as improved performance, side-by-side versioning and new APIs.

For posting parameters such as 'start_year_train', 'num_of_folds', etc. was used JSON which is a lightweight format for storing and transporting data. The big advantage of it is that JSON is a "self-describing" and easy to
For easier use of this API was used Swagger[17] which is tooling ecosystem for developing APIs with the OpenAPI Specification. It gives us option to call web services, shows basic description and input JSON structure. However, swagger cannot generate full documentation for the project. Because of this reason documentation was generated by Doxygen tool.

Doxygen[18] is a tool for generating documentation from annotated C++ sources, but it also supports other popular programming languages including C#. Documentation is generated from the source code (includes xml comments) as html pages where XML[19] is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable and HTML[20] is the standard markup language for creating web pages and web applications.

Based on personal sympathies, for versioning the code I chose Git[21] which is a free and open source distributed version control system designed to handle everything from small to very large projects with speed and efficiency.

In one case (described below) there is a need to call Python 3 script. "Python is an interpreted, high-level, general-purpose programming language. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Python features a comprehensive standard library, and is referred to as 'batteries included'."[24]

3.4 Python part

One of the functional requirements is from the imported data prepare dataset suitable for training of classifiers. In the Michal's Bouška work[6] already exists python script "prepare_data.py" which prepares three files: "days.txt", "data_cont.csv" and "manufacture_command_ex.csv" from the imported data (CSV files). First two files are needed for the preparation of the last one, when the "manufacture_command_ex.csv" contains all needed values for training.

I tried to implement similar functionality in C#. However, for creating this dataset the python script uses Pandas which is: "a Python package providing fast, flexible, and expressive data structures designed to make working with structured (tabular, multidimensional, potentially heterogeneous) and time series data both easy and intuitive. It aims to be the fundamental high-level building block for doing practical, real world data analysis in Python."[23]. After reviewing this python script I found Pandas very powerful tool for this job. Unfortunately, I could not find something with similar functionality for C#. Regardless of that, I have implemented preparation of "days.txt" and "data_cont.csv". On the same machine, preparation of these files lasted about
2 minutes in Python and about 16 minutes in C#. For this reason, I decided for external calling of python script mentioned above.

The following figure shows how calling of python works in C#\(\text{(3.1)}\).

**Figure 3.1:** C# calls python script. Adapted from [13].

### 3.5 Use cases

A use case diagram is a dynamic or behaviour diagram in UML\(^1\). Use case diagrams model the functionality of a system using actors and use cases. Use cases are a set of actions, services, and functions that the system needs to perform. For use case diagram see the figure 3.2.

\(^1\)UML is a way of visualizing a software program using a collection of diagrams.
Figure 3.2: Use case diagram


Chapter 4

Implementation part

4.1 Structure of the project

This application consists of two projects AssecoWebApp.csproj and AssecoWebAppTestProject.csproj. These projects are in the solution AssecoWebApp.sln which is simply a container for one or more related projects. In the AssecoWebApp.csproj is the implementation of the API and AssecoWebAppTestProject.csproj contains unit tests.

![Figure 4.1: Solution’s projects](image)

The following text describes implementation part, unit tests are described in the section 5.2.

Classes in C# have extension ".cs". On the figure 4.2 can be seen two important classes of this application Startup and Program.
The web application starts executing from the entry point `public static void Main(string[] args)` in the Program class where a host for the web application is created.

The Startup class is specified to the app when the app’s host is built. The app’s host is built when Build is called on the host builder in the Program class (see the figure 4.3).

```
public class Program
{
    public static void Main(string[] args)
    {
        CreateWebHostBuilder(args).Build().Run();
    }

    private static IWebHostBuilder CreateWebHostBuilder(string[] args) =>
        WebHost.CreateDefaultBuilder(args)
            .UseStartup<Startup>().ConfigureLogging(logging =>
            {
                logging.ClearProviders();
                logging.AddConsole();
            });
}
```

Figure 4.2: Implementation structure

Figure 4.3: Program.cs class
The Startup class:

- Includes a ConfigureServices method to configure the app’s services. A service is a reusable component that provides app functionality. Services are configured in ConfigureServices and consumed across the app via dependency injection (DI) or ApplicationServices.

- Includes a Configure method to create the app’s request processing pipeline.

ConfigureServices and Configure are called by the runtime when the app starts.

Dependency injection is a software design pattern, which is a technique for achieving Inversion of Control (IoC) between classes and their dependencies. Inversion of Control is a design principle. It is used to invert different kinds of controls in object-oriented design to achieve loose coupling. Here, controls refer to any additional responsibilities a class has, other than its main responsibility. This include control over the flow of an application, and control over the flow of an object creation or dependent object creation and binding.

You can see on the Figure 4.2 that the application is divided into several folders.

The Controllers folder contains controllers which are classes that handle http requests. They take input values from requests and pass these values to services which do the expected job. After the job is finished, the controller shows the response code and needed information.

The Services folder contains services which are classes doing the business logic of the application and are directly called in controllers.

The Handlers folder contains classes which implement functionality used in multiple service’s classes.

Among others classes in the Models folder, there is also the Manufacture class. This class maps the "manufacture_command_ex.csv" (see the table 2.1) as C# class, where column’s names in CSV file reflect attributes in the class.

To understand the way I was working with constants in this project, see following arrangements:

- if the constant is used only in one class then it is defined in the beginning of this class

- constants for saving/loading data on/from filesystem are defined in the PathConstants.cs (Constants folder)
4. Implementation part

- column’s names of the manufacture_command_ex.csv are defined in the ManufactureAttributes.cs (Constants folder)

Resources subfolders:

- Classifiers - helps with training, evaluating of classifiers and defines how the result folder with trained models will look like

- CreatedClassifiers - storage for the trained models

- Datasets - storage for company data

- Python - contains python scripts used in this project, only the script "prepare_data.py" is called directly even though it requires functions from other scripts

4.2 Run the application

To run the application open AssecoWebApp project in console and run the command: "dotnet run". Subsequently, go to the: "https://localhost:5001/swagger/index.html" (see the figure 4.4)

![Swagger UI - Mozilla Firefox](image)

**Figure 4.4:** Swagger start page

On the bottom of the figure 4.4 there are three sections: Classification, PrepareClassifiers and PrepareData. Each of them stands for controller class, e.g. Classification stands for the ClassificationController.cs.
4.3 Data preparation

The purpose of this part is preparation of dataset suitable for training of classifiers (manufacture_command_ex.csv). This job is divided into three steps (see the figure 4.5):

1. import data from the database
2. use imported data to create needed dataset
3. remove "help files" \[1\]

---

\[1\] files imported from the db + days.txt, data_cont.csv

---

Figure 4.5: PrepareDataController’s methods
4. Implementation part

However, specific situations may arise. One of them is that a data specialist may want to check help files so it is not advisable to delete them immediately. Another situation that happened in our case, when for the companies "hudba" and "letadla" imported data from the databases were already available, but connection to databases worked no longer. For these reasons there are two possible scenarios. The first is to do the whole job from importing the data to cleaning the help files, the second is to call these web services separately according to your need.

The following subsections describe how to use these web services properly and what are the their prerequisites.

4.3.1 Import data

To import data from the database there are two prerequisites. First is to setup connection string to the database in the file "appsetings.json". This connection string has to be written in the section 'ConnectionStrings'. The connection string has to have its own unique name, the connection string key which identifies it among the others.

Secondly is that there has to exist a folder where the imported data will be saved. This folder must be placed in the "Resources/Datasets/\{folderName\}". To make it work properly, the "folderName" has to be the same as the connection string key. In the current state, this works only for the company: "pribory". There is already connection string for the company: "pribory" in the appsettings.json and also in the "Resources/Datasets" exists folder with the name: "pribory".

To execute data import, we need to call http GET method on the following route:

\[\text{'api/PrepareData/Import/\{company\}'}\]

where parameter company equals to connection string key and folder name described above. This can be done using swagger as follows (see the figure 4.6):

1. click on: GET /api/PrepareData/Import/company
2. click: try it out
3. set parameter company to: pribory
4. click execute

Once the job is finished, the response code should be 201 (see the figure 4.7) likewise the "pribory" folder should contain the following files: "material.csv", "slozitost.csv", "manufacture_command.csv", "stock_price.csv" and "stock_load.csv".
4.3. Data preparation

![GET](GET /api/PrepareData/Import/{company})

- Connects to db, selects data, saves on filesystem, disconnects from db.

## Parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>company</strong></td>
<td><em>required</em> Selects company which should be used.</td>
</tr>
</tbody>
</table>

string

(path)

- pribory

![Execute](Execute)

- Clear

**Figure 4.6:** Import of data from the db.

## Server response

<table>
<thead>
<tr>
<th>Code</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>201</td>
<td>Response body</td>
</tr>
</tbody>
</table>

Datasets for the company: pribory where successfully created.

![Download](Download)

**Response headers**

- content-type: text/plain; charset=utf-8
- date: Fri, 26 Apr 2019 18:42:50 GMT
- server: Kestrel
- transfer-encoding: chunked

**Figure 4.7:** Successful response for import of data from the db.
### 4.3.2 Prepare dataset

The purpose of this part is to create dataset suitable for training of classifiers (manufacture_command_ex.csv). The company folder must exist in the '/Resources/Datasets/' and it has to contain all five needed CSV files (see the section 2.1). This can be done in two ways. The first is to call Import method (see the section 4.3.1). The second is to put files in this folder manually. In the current state, this can be done for the companies 'hudba' and 'pribory', the needed files are in the folder 'NewDbData'.

In this case the application calls external python script, for this reason the python 3 and a few of its modules must be installed (see the Appendix C).

To do the job we need to call http GET method on the following route:

```
"api/PrepareData/Prepare/{company}" 
```

where parameter company equals to company folder (described in the section 4.3.1).

If the job is finished successfully, the response code will be 201 and to the company folder will be added following files: "days.txt", "data_cont.csv" and "manufacture_command_ex.csv".

### 4.3.3 Remove help files

The purpose of this part is to remove files which are not needed anymore (described in the 4.3). There is only one requirement to do that, in the 'Resources/Datasets/' must be company folder from which the files should be removed.

To do so, we need to call http DELETE method on the following route:

```
"api/PrepareData/Clean/{company}" 
```

where parameter company has same meaning as in the previous two sections.

If the job finished successfully, the response code will be 200 and in the company folder will remain only one file: "manufacture_command_ex.csv".

### 4.3.4 Import, prepare, clean

Following web service merges work done by previous three sections in the one. Because we are importing data from the database, this works only for the company: 'pribory' (same as in the section 4.3.1).

To carry out the job, we need to call http GET method on the following
route:

'api/PrepareData/ImportPrepareClean/{company}'

where parameter company has the same meaning as in the previous sections.

If the job finished successfully, the response code will be 201 and in the company folder will be only "manufacture_command_ex.csv" file.

4.4 Training and evaluation of classifiers

This section describes methods of the PrepareClassifiersController (see the figure 4.8). Before the training can start, train and test datasets must be created. Once the training and evaluating is finished, there will be availability to download classifiers or to remove them from the storage. How to do this is described in the subsections below.

![Swagger UI](https://localhost:5001/swagger/index.html)

**Figure 4.8:** PrepareClassifiersController’s methods.
4. Implementation part

4.4.1 Create train and test datasets

The purpose of this web service is to create train and test datasets. Both of these datasets are subsets of the file manufacture_command_ex.csv, for this reason in the company folder this file must exist.

To do the job we need to call http POST method on the following route:

`api/PrepareClassifiers/PrepareTrainTest`

by the POST method must be send JSON with the name: "data" containing following attributes: "start_year_train","end_year_train", "start_year_test", "end_year_test", "company". See the following figure 4.9 for better understanding.

**Figure 4.9:** Prepare train and test datasets. In this case, train dataset will contain years 2014 and 2015, test dataset will contain years 2016 and 2017 and they will be created from the manufacture_command_ex.csv which is in the Resources/Datasets/pribory.

If the call finished successfully, the response code will be 201 and to the company folder will be added "TrainDataset.csv" and "TestDataset.csv".

4.4.2 Prepare classifiers

This web service will train classifiers, evaluate them and choose the optimal model. Once the job is finished, all models will be saved as zip file
to the folder "Resources/CreatedClassifiers". To carry this out, the must be datasets for training and testing in the company folder (see the section 4.4.1).

To make it happen, we need to call http POST method on the following route:

"api/PrepareClassifiers/PrepareClassifiers"

by the POST method must be send JSON with the name: 'data' containing following attributes: 'company' and 'num_of_folds'. See the following figure 4.10 for better understanding.

Figure 4.10: Prepare classifiers. In this case, for training/testing it expects train and test datasets in the Resources/Datasets/pribory and 2-fold Cross-Validation will be performed.

If the job finished successfully, the response code should be 201. To the 'Resources/CreatedClassifiers' will be added zip file (name from the inputted JSON) with all trained models.

### 4.4.3 Prepare train,test datasets and classifiers

This part combines the work of two previous sections (4.4.1 and 4.4.2) plus it will remove train and test datasets at the end. In this case there is only one prerequisite, the 'manufacture_command_ex.csv' should be existent in the company folder.

To make it happen, we need to call http POST method on the following route:
by the POST method must be send JSON with the name: "data" and with the following attributes: "start_year_train", "end_year_train", "start_year_test", "end_year_test", "company", "num_of_folds".

For example see the following figure:

![PrepareClassifiers](image)

**Figure 4.11:** Creates train and test datasets for training of classifiers, train classifiers and at the end removes train,test datasets. Explanation to the attributes can be seen in the figures 4.9 and 4.10

Once the job finished successfully, the response code will be 200. To the "Resources/CreatedClassifiers" will be added zip file (name from the inputted JSON) with all trained models and from the company folder train and test datasets will be removed.

### 4.4.4 Download trained models

This part describes how to download trained models. The result of this is zip file which contains all trained models, evaluation and optimal model.

To execute this we need to call http POST method on the following route:

"api/PrepareClassifiers/Download"

by the POST method must be send JSON with the name: "data". The
4.5. Use of trained model

JSON attributes must be the same as in the training part, that means if for training was used web service from the section 4.4.2 then the exactly same JSON has to be send for downloading and so on for the web service from the section 4.4.3.

4.4.5 Remove trained models from the storage

In this section two web services will be described, the first will remove all files with trained models from the folder 'Resources/CreatedModels'. The second will remove zip file with models only for the inputted JSON which identifies it.

To use the first option, call http DELETE method (without parameters) on the following route:

"/api/PrepareClassifiers/RemoveAllClassifiers"

Once the job is finished successfully, the response code will be 200 and "Resources/CreatedModels" will be empty.

To use the second option, call http DELETE method on the following route:

"/api/PrepareClassifiers/RemoveAllClassifiers"

by the POST method must be send JSON with the name: "data". For JSON attributes applies the same rules as in the section 4.4.4.

Once the job is finished successfully the response code will be 200 and a zip file with models will be removed from the 'Resources/CreatedModels'.

4.5 Use of trained model

This section describes how to use downloaded models to classify new data. For that the ClassificationController class will be used.

In this part there is only one web service which will carry out the job. To do so, you need to call http POST method on the following route:

"/api/Classification/Classify"

by this method, two parameters must be send, the first has name: "model" and it has to be one of the downloaded models in zip format. The second has name: "dataset" and it has to be a CSV file which should be classified (see the section 2.3 for the description).
To try this out, you can use as a model 'OptimalModel.zip' from the section 4.4.4 (or any other). As the dataset which should be classified you can use 'ClassificationTest.csv' which is in the 'Resources/Datasets'. See the figure 4.12 for better understanding.

After execution, a result file with the predicted priorities should be produced. To download it click on the 'Download File' (see the figure 4.13).

**Figure 4.12:** Classification of new data.

**Figure 4.13:** Classification’s result.
Chapter 5

Testing

5.1 Manual testing

In this section, I have tested the required functionality manually. For every web service which was tested I asked the following questions:

1. Does the web service work as expected with correct input given?

2. Is there a suitable feedback if the input is not correct?

The results can be see in the following table 5.1:

<table>
<thead>
<tr>
<th>row</th>
<th>method</th>
<th>route</th>
<th>Q1</th>
<th>Q2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GET</td>
<td>/api/PrepareData/ImportPrepareClean/{company}</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>GET</td>
<td>/api/PrepareData/Import/{company}</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>GET</td>
<td>/api/PrepareData/Prepare/{company}</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>DELETE</td>
<td>/api/PrepareData/Clean/{company}</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>5</td>
<td>POST</td>
<td>/api/PrepareClassifiers/PrepareTrainTestClassifiersClean</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>6</td>
<td>DELETE</td>
<td>/api/PrepareClassifiers/RemoveClassifier</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>DELETE</td>
<td>/api/PrepareClassifiers/RemoveAllClassifiers</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>POST</td>
<td>/api/PrepareClassifiers/PrepareTrainTest</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>POST</td>
<td>/api/PrepareClassifiers/PrepareClassifiers</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>POST</td>
<td>/api/PrepareClassifiers/Download</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>POST</td>
<td>/api/Classification/Classify</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 5.1: Manual testing results.

There are a few notes to the table above:

1. In the current state, web services can be clearly identified. For this reason post/delete parameters are not mentioned in the table.

2. In the row 6, the web service checks if a file exists and if it does then removes it, there is no bad input here. For this reason, the second question was not answered.
3. In the row 7, there is no input at all. For this reason, the second question was not answered.

### 5.2 Unit testing

Unit testing is a level of software testing where individual units/ components of a software are tested. The purpose is to validate that each unit of the software performs as designed. A unit is the smallest testable part of any software. It usually has one or a few inputs and usually a single output. In procedural programming, a unit may be an individual program, function, procedure, etc. In object-oriented programming, the smallest unit is a method, which may belong to a base/super class, abstract class or derived/child class. In unit testing we want to test methods of one class in isolation. But classes are not isolated. They are using services and methods from other classes. So in that situation, we mock the services and methods from other classes and simulate the real behaviour of them using some mocking framework.

Writing of unit tests was carried out by Xunit which is an open-source unit testing tool for the .NET framework. As the Mocking framework I have used Moq which is mocking library for .NET.

Unit tests can be found in the AssecoWebAppTestProject. To run them, open AssecoWebAppTestProject in console and run the command: 'dotnet test'. There are 20 unit tests and all should pass.

Unit tests were written for public methods of Controllers, Services and Handlers. The following table shows the coverage of that:

<table>
<thead>
<tr>
<th>name</th>
<th>total</th>
<th>tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClassificationHandler</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>CsvHandler</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>DataTableHandler</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>ManufactureHandler</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>ClassificationController</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PrepareClassifiersController</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>ClassificationService</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CleanService</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>PrepareClassifiersService</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PrepareTrainTestDatasetService</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>ImportDatasetService</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PrepareClassificationDatasetService</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5.2: Table showing coverage of tested methods.
5.2. Unit testing

I believe that unit tests should be fast, otherwise it could lead to be skipped by developers. Importing of data and preparation of the dataset suitable for training of classifiers takes a lot of time, for this reason unit tests were not written for this part.
Chapter 6

Conclusion

During this work, I became acquainted with the functioning of ERP systems, two already existing projects that served as a decision support tool for production planner. I also learned about machine learning, cross validation, decision tree method and a few other classification and regression methods. I got acquainted with C# language and ASP.Net Core web framework. Based on the acquired knowledge and instructions for this project, I analysed the problem. Subsequently, I implemented functional REST API which allows importing data from database, prepare a dataset suitable for training of classifiers, create training and testing datasets, train classifiers and then evaluate them, select an optimal model, export models and then use the model to classify new data. I also created documentation for the code. At the end, I tested the required functionality manually and for suitable parts of code I have also written unit tests. I see the application as fully functional and suitable for use.

Additionally, I have to mention one requirement which I failed to fully meet. Although the application is able to create a dataset from imported data which is suitable for training of classifiers for preparation of this dataset there is called python script which was not done by me.
Chapter 7

Further Work

The application is functional and ready to use, yet there are few things to be improved in near future:

1. removing python dependency in data preparation part
2. providing wider range of tests, e.g. integration tests
3. using database as storage instead of filesystem
Bibliography


[22] Python 3.x documentation[online, 2018-5-2] from https://docs.python.org/3/


Appendix A

List of abbreviations

**ERP** - Enterprise Resource Planning

**API** - Application Programming Interface

**ETL** - Extract-Transform-Load

**REST** - Representational State Transfer

**HTTP** - Hypertext Transfer Protocol

**GAM** - Generalized Additive Model

**UML** - Unified Modeling Language

**JSON** - JavaScript Object Notation

**HTML** - Hypertext Markup Language

**XML** - Extensible Markup Language

**PANDAS** - Python Data Analysis Library

**DB** - Database

**DI** - Dependency Injection

**IoC** - Inversion of Control

**APP** - Application
Appendix B

Content of the attached CD

• code
  - AssecoWebApp
  - AssecoWebAppTestProject
  - Documentation
  - NewDbData
  - AssecoWebApp.sln
  - README.md

• text
  - source
Appendix C

Setup of the project

Prerequisites
What things you need to install and how to install them:

ASP.NET Core 2.2
Python 3.7.3
Tkinter

Python modules:

- matplotlib
- numpy
- pandas

Installing
Tkinter:

```
sudo apt install python3-tk
```

For installation of python modules pip3 can be used:

```
sudo apt install python3-pip
```

then install modules using pip3 as:

```
pip3 install <module>
```

Figure C.1: Setup of a project part 1.
C. Setup of the project

Copy of the project
Download or clone the project:

https://gitlab.com/RichardSadlon/assecowebapp

Run the project

Set python path
After downloading the project, in the root directory of the project will be two subfolders "AssecoWebApp" and "AssecoWebAppTestProject". Go to AssecoWebApp and in the file "appsettings.json" change

"Python3Path" : "your python3 exe path"

Run the tests
Open AssecoWebAppTestProject folder in command line and run the command:

dotnet test

Run the application
Open AssecoWebApp folder in command line and run the command:

dotnet run

then go to:

https://localhost:5001/swagger

You can call requests directly from this page.

Figure C.2: Setup of a project part 2.