

# An Interactive End-To-End Machine Learning Platform

## Implementation Report

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Requirements Specification	<b>Murat Kurnaz</b>
Design	<b>Mustafa Enes Batur</b>
Implementation	<b>Ömer Erdinç Yağmurlu</b>
QA / Testing	<b>Tarek Gaddour</b>
Final	<b>Atalay Donat</b>

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# **1 Tools**

## **1.1 VS Code**

Code Editor

## **1.2 PlantUML**

Charting software

## **1.3 MikTEX**

Latex compiler and package manager

## **1.4 npm**

node package manager

## **1.5 create-react-app**

an intuitive command line scaffolding application easing the development of react applications

## **1.6 Pipenv**

package manager for Python

## **1.7 Pyenv**

virtual environment manager for Python

## 2 Challenges

### 2.1 Client

#### 2.1.1 Testing Clients

The front-end is written in React and is composed of presentational components (components), stateful components (containers) and hooks. In separating presentational and stateful components from one another we wanted to ease testing. Although testing presentational components took place without a problem using Jest.js snapshots, render tests and some simple consistency tests, stateful containers were harder to test, since they required extensive mocking of React's hook and lifecycle events.

#### 2.1.2 Sensor Data Collection

##### Browser Inconsistencies

*from <https://github.com/PSE-TECO-2020-TEAM1/client/issues/5#issuecomment-817308653>*

There are two main APIs on sensor access in browsers right now, namely the Sensors API, which is incorporated into the web standard and supported by 71.03% of all users worldwide.

On the other hand there is the legacy DeviceMotionEvent API, which was an experimental technology designed before the aforementioned Sensors API was drafted. It is supported by 94.97% of users worldwide (albeit with handicaps).

In this application, we are using the new standard Sensors API, which is only supported by Chrome and Chromium based browsers like Edge, Brave etc. for now. Apple refuses to implement the new API citing privacy concerns, there is no information on why Firefox doesn't implement it. Since on Apple platforms all browsers from all vendors use the Safari Web View, this new API doesn't work at all on Apple devices.

The DeviceMotionEvent API is unfortunately not suitable for use at all. All three different major browsers (Chrome, Safari and Firefox) have a different understanding of what coordinates they return and have no documentation of which units they return the data in.

We've tried to use a polyfill with the branch sensors-polyfill, but were getting totally different results with different browsers (and with firefox totally broken results. Because

of this reason we've decided not to support Apple users at all.

**Magnetometer** Originally we wanted to support Magnetometer sensor too, since it was (supposedly) supported by the browsers we were targeting (on caniuse.com).

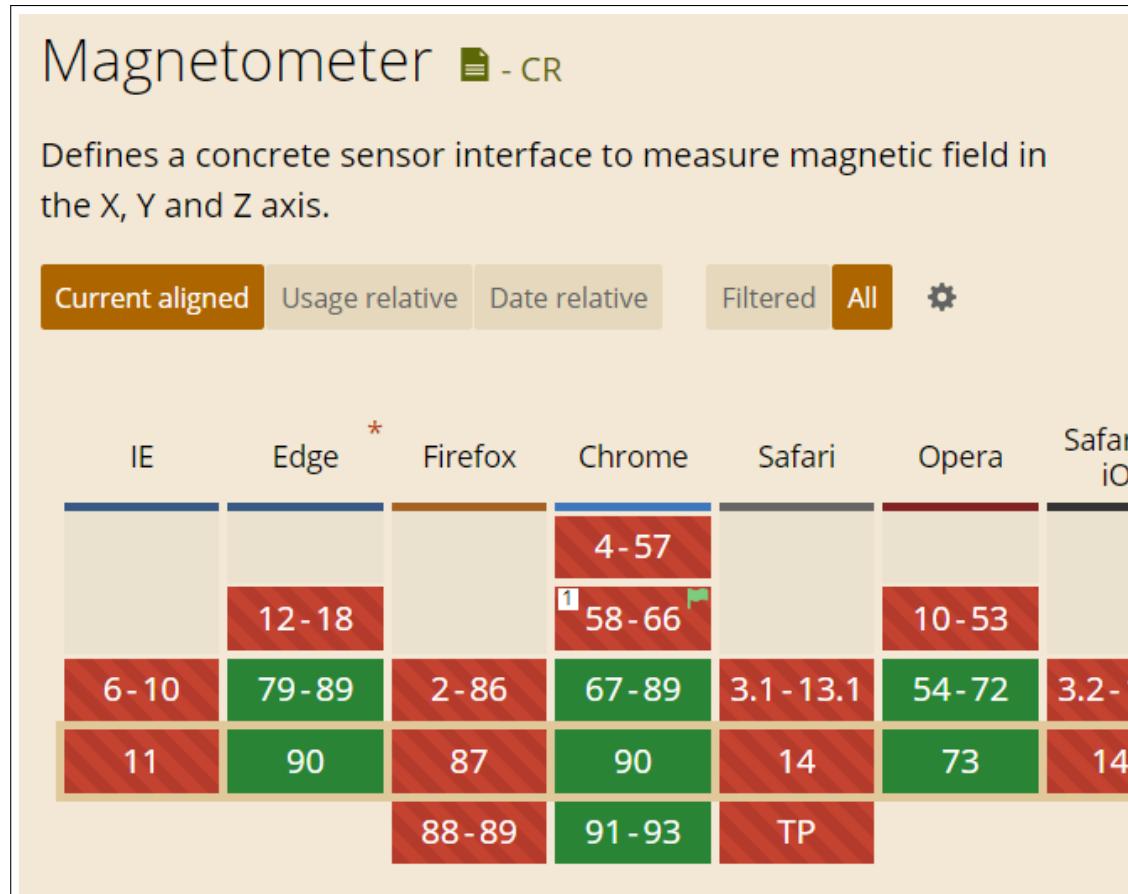


Figure 1: caniuse.com - Magnetometer

After implementing the sensor, however, we've noticed how no matter what we've tried, we weren't getting any data, and after more investigations we've discovered that the 'Magnetometer Sensor' and the 'Magnetometer Sensor API' are two different entities separate from each other, and dropped support for magnetometers.

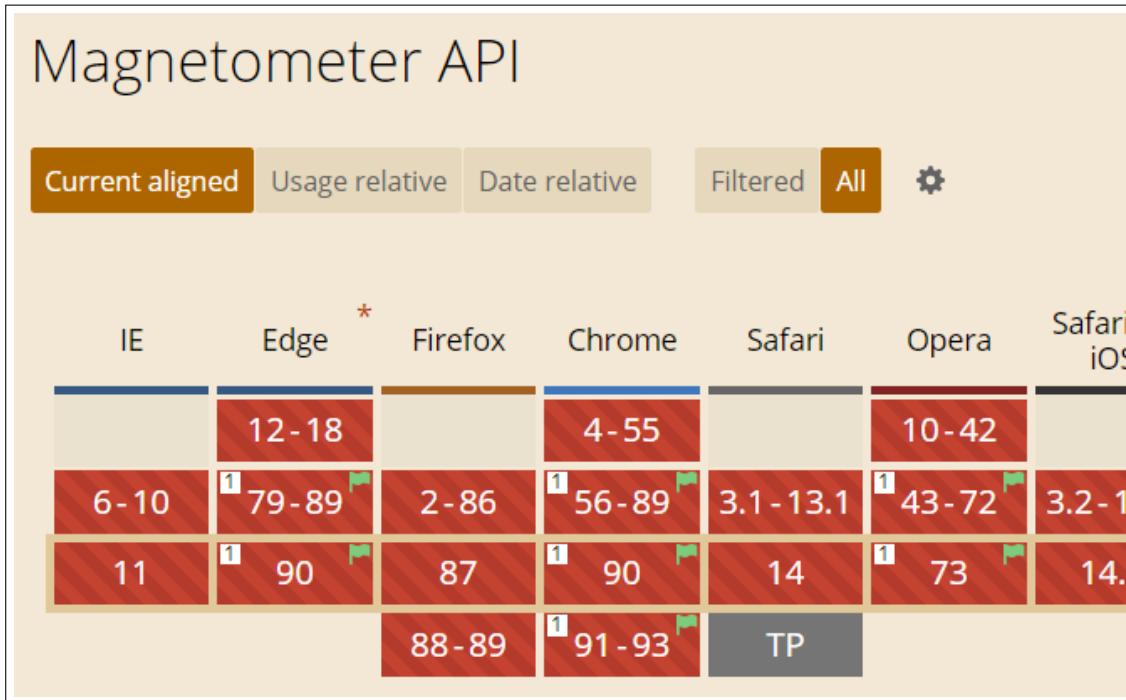


Figure 2: caniuse.com - Magnetometer API

## 2.2 Workspace Management

**Making a Consistent Server and Covering Failure Cases** As the workspace management handles storage of user data, it acts as a bridge between the client and the model management. Thus the validity of these data is a very crucial part of the work. Although the client prevents most of the invalid requests, such invalid requests could be handcrafted and sent to the server or the client itself could possibly generate an invalid data by an error so each request needed to be validated. Finding the error cases and handling them generated a lot of work, because finding the not so obvious error cases needed a general analysis of the action caused by the request on the server and possibly on the model management.

**Performance-Space Trade-Off Decisions** Swaying from the initial design is in most cases undesirable and comes with a cost. However as the implementation phase progressed, it came to light that the initial design fell short on some aspects regarding the functionality (see ??). The app is designed to be scalable so when introducing new changes to the codebase we had to take performance related issues into consideration and it slowed down the progress when the changes had conflicting aspects regarding performance and space.

## **2.3 Model Management**

This was a very challenging part of the project for us, since we had no experience with the libraries that we use (namely scikit-learn) as well as the programming language Python and the machine learning pipeline. Our first attempt showed that our design for the service was not appropriate for the requirements so we had to iterate twice, which included writing the whole service from scratch.

### **2.3.1 Understanding Machine Learning Pipeline**

During the design phase, we had tried to get a grasp of the machine learning process that we were going to implement but we had no real experience with it. This resulted in a very abstract design since we were unsure how different mechanisms interacted with each other. As we experimented with the frameworks, a series of new requirements came into play. This included changes in other components of the system that Model Management depended on like the front-end clients. As a result, we had to constantly communicate with each other, synchronize our works and give feedback to each other. With time, our better understanding of the machine learning process made things easier and allowed us to solve problems quickly.

### **2.3.2 Caching Mechanism and MongoDB Document Size Restrictions**

The first issue that we have faced was the caching mechanism for the processed data which helped the training with avoiding repetitive calculations when possible. Our first naive approach was to store everything in an array. It became quickly apparent that saving the data this way complicated the code immensely and was very error prone. The solution was to store serialized DataFrame objects as a document in the database. During the testing we realized that MongoDB did not allow for documents larger than 16 MB in size. Another framework (GridFS) that wrapped MongoDB allowed us to solve this problem and store files without any size restrictions.

### **2.3.3 Multiprocessing and Serving Many Clients in Parallel**

The biggest challenge of the Model Management service was allowing multiple training or prediction processes take place on the server in parallel. Because of the computing intensive nature of the machine learning processes, it was not feasible to run the training or prediction on the same process that handled the client requests which would greatly reduce the server responsiveness. After a thorough research on possible solutions, we have

decided that the best solution was to spawn new processes for each computing intensive task (i.e. training/prediction), since we discovered that multithreading does not work as expected in programming languages that depend on an interpreter. The hardest part was to synchronize the processes and handle the interprocess communication. The solution for data transfer between the server and the child processes was using Unix Pipes and the synchronization problem was solved by using counting semaphores.

## 2.4 Auth

No notable challenges.

## **3 Statistics**

### **3.1 client**

Lines of code	TBD
Test coverage	TBD
Number of commits	RBD

### **3.2 workspace-management**

### **3.3 model-management**

### **3.4 auth-management**

### **3.5 Total**

## **4 Changes from Design**

### **4.1 Authentication**

No notable changes.

## 4.2 Front-end Clients

### 4.2.1 Single Codebase

In the design document, we'd envisioned two different codebases for the different edge (mobile) and management (desktop) clients. During development, however, it has become obvious that a single codebase with client side routing and bundle separation using tree shaking was more suitable for our application. We are bundling both applications in a single router, and there is no clear separation between each client. During development, special care was given to reduce cross dependencies between both parts to a minimum in order to reduce the bundle size for edge devices.

### 4.2.2 /lib folder

Originally, there were only two auxiliary classes in the whole client (MobileAPI and DesktopAPI), while everything else was a React component. During development, we made use of custom react hooks (/lib/hooks) to refactor common stateful logic into reusable parts. Apart from hooks, sensor data collection needed it's own abstraction over the clunky Web API implementation, which we've placed in /lib/sensors.

### 4.2.3 API endpoints

In order to accomodate changes in the backend, both the Mobile- and DesktopAPI have undergone major changes in the interfaces they implement.

### 4.2.4 Component Library

In the design document, we'd specified Material-UI as the component library that we were going to use. During development we've found it too clunky, heavy and hard to develop with and replaced it with the Evergreen Component Library from segment.io. This component library also comes with it's own opinionated 'CSS-in-JS' styling library, through which we were able to style the application with a rapid pace.

#### 4.2.5 ModelOptions Component

This component faced the most changes during implementation. We'd decided to distribute some model creation options to the sensor-components themselves instead of using the same set of parameters for each component. This had it's implications on the client and it had to be updated accordingly.

The screenshot shows a web-based interface titled 'Workspaces / a / Create new model'. On the left, there are two main sections: 'Accelerometer' and 'Gyroscope', each divided into three sub-sections: 'Accelerometer, x', 'Accelerometer, y', and 'Accelerometer, z' (under Accelerometer) and 'Gyroscope, x', 'Gyroscope, y', and 'Gyroscope, z' (under Gyroscope). Each sub-section contains three buttons: 'Imputation', 'Features', and 'Normalizer'. On the right side, there is a 'Name' field with 'New Model' typed in, a 'Classifier' section with 'Kneighbors Classifier' selected, and a 'Hyperparameters' section with fields for 'Window Size' (10), 'Sliding Step' (5), 'N Neighbors' (1), 'P' (set to 2), and 'Weights'. A 'Log out' button is located in the top right corner.

Figure 3: New ModelOptions

#### 4.2.6 Class/Component Diagram

For the updated component diagram, please see the 'Client Diagram.png' in the same folder as this document. It is also attached at the end of this document.

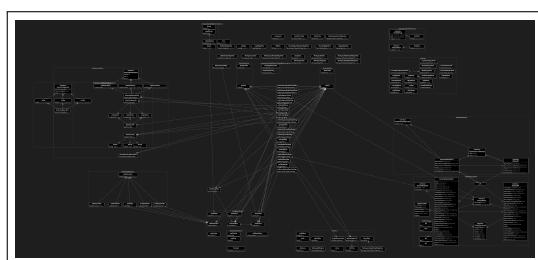


Figure 4: Overview of the updated diagram. Can be found in the appendix in full resolution.

## 4.3 Workspace-Management

### 4.3.1 Label

Label isn't saved as an embedded document anymore. To achieve the same functionality label now keeps the workspaceId of the workspace it belongs to and the number of samples it is the label of.

### 4.3.2 Data Point

ObjectId is now omitted as it is not used and causes disarray in the corresponding responses.

### 4.3.3 Sensor Data Point

ObjectId is omitted here as well on the same grounds. In addition name of the sensor is also added to schema to simplify communication with the client.

### 4.3.4 Sample

Sample does not embed the label data anymore, instead it saves the id of the label. Implementation of setTimeFrames method is also delegated to the workspaceController.

### 4.3.5 Workspace

**SubmissionId** SubmissionId is not saved as a simple string anymore, instead it has its own interface with the field hash as string. This change was done to provide flexibility for possible future use cases, such as making submissionId expire after a while etc.

**Further Additions** Workspace now holds lastModifiedDate to enable model management to cache the machine learning pipeline, sample- and labelIds to speed up database queries/checks.

#### 4.3.6 Routes

**General Changes** Added new bad request responses that explains the error user is getting.

**GET /api/sensors** Removed as it didn't provide any utility other methods didn't cover.

**GET /api/workspaces/workspaceId/samples** Query parameters are changed to show-DataPoints and onlyDate to be more intuitive.

**GET /api/workspaces/workspaceId/samples/sampleId** Response now also includes the timeframes of the sample.

**PUT /api/workspaces/workspaceId/samples/sampleId/relabel** labelName is now passed in the query instead of labelId.

**GET /api/workspaces/workspaceId/labels** Response body now also includes the sample count of the label.

**POST /api/workspaces/workspaceId/labels/create** labelName is now passed in the body instead of the query.

**PUT /api/workspaces/workspaceId/labels/labelId/rename** labelName is now passed in the body instead of the query.

**PUT /api/workspaces/workspaceId/labels/labelId/describe** description is now passed in the body instead of the query.

**GET /api/workspaces/workspaceId/submissionId** This route has been changed to GET /api/workspaces/workspaceId/generateSubmissionId to make its function clear.

**GET /api/submissionConfig** Label objects now include their labelId in the response body.

**POST /api/submitSample** submissionId is now passed in the request body.

## 4.4 Model Management

As described in the challenges section, we had to redesign this service. The main reason is the multiprocessing needs of the application that was unforeseeable for us during the design phase. The complete changelog requires a completely new design document but the following are the most important changes.

### 4.4.1 Router

- Split the Router class into two classes, CommonRoutes and WorkspaceRoutes.  
**Reason:** API endpoints that need authentication are all under a specific workspace, so the split made it easier to handle the authentication of requests. We use an authentication middleware for all workspace routes.
- Removed generatePredictionId method  
**Reason:** We delegate this responsibility to the MongoDB client that generates a new ID for each document that is inserted into the database.
- Removed the trainers and predictors fields  
**Reason:** Trainers map was planned to be used to track the progress. Since each trainer starts in a new process, this was not possible and we used the database for progress tracking instead. Predictors are in a new class PredictionManager described below.

### 4.4.2 Request and Response Classes

- Renamed the data classes.  
**Reason:** The classes now represent the actual content instead of the name of the API endpoint (i.e. TrainReq -> TrainingConfig)
- Separate (sometimes duplicate) classes for domain models and API models  
**Reason:** The first iteration of the service showed us that using the same models for both internal logic and API endpoints are problematic because of the possible changes to the endpoints. By separating the classes, we had the flexibility to change endpoints/parameters without affecting the logic code, since the API models are converted to domain models.
- Added data validation for endpoints  
**Reason:** During the design, the data validation was missing. We have added the

data validation for models with comprehensible error messages that frontend shows the end users.

#### 4.4.3 Database

- Added wrapper classes for database queries

**Reason:** At first we were calling the functions of PyMongo directly in the application code. We thought this was not a good idea as it was not possible to use a different database. With that in mind, we implemented several wrapper classes which implement database queries.

#### 4.4.4 Database Models

- Added (de)serialization methods for database models

**Reason:** We save large data in the database in binary form. (bytes type). To prevent errors during the deserialization because of the unknown type of the binary objects, we added methods that complete the type information for each binary document to database model classes.

#### 4.4.5 Training

- Training a model is handled by a new process

**Reason:** The training of a model takes a notable amount of time, especially if there are a lot of samples. If the main process were to train the model, any requests during the training could only be handled after the training is finished. This was a terrible idea, so a new process is created to handle the training and the main thread is then able to handle other requests during the training.

- Added DataSetManager and TrainingManager classes

**Reason:** The Trainer class which we initially designed was a typical God object in which the training pipeline, all the training algorithms and the database queries are implemented. With separation of concerns in mind, we decided to split this Trainer class in three classes: DataSetManager handles the database queries, the Trainer class has all the algorithms implemented and the TrainingManager handles the training pipeline.

#### 4.4.6 Prediction

- Prediction is handled by a new process

**Reason:** This has the same motivation with handling the training with a new process: Being able to handle other requests while a prediction is under way.

- Added DataSetManager and PredictionManager classes

**Reason:** This also has the same reasoning with the training: The Predictor class we had was a typical God object. The DataSetManager handles the database queries, the Predictor class implements all the algorithms and the PredictionManager handles the prediction pipeline.

## 5 Functional Requirements Coverage

### 5.1 Mandatory Requirements

Number	Requirement Name	Implemented?	Notes
F010	Show a welcome page with a login panel when the website is accessed	YES	
F020	Show registration panel when clicked on register in the welcome page	YES	
F030	Show a workspaces overview where the available workspaces are listed after logged in	YES	
F040	Allow creating workspaces with the given name, sensors to be used and their sampling rate	YES	
F050	List the available sensors (accelerometer and gyroscope) for the recordings on the workspace creation window	YES	
F060	Show the workspace panel when a workspace is selected	YES	
F070	Allow renaming workspaces on the workspace panel by double clicking on the workspace name	YES	
F080	List labels with their sample count on the labels overview window	YES	
F090	Allow creating labels for the actions to be recorded in the workspace	YES	
F100	Allow renaming labels on the labels overview	YES	
F110	Allow deleting labels which in turn deletes the data samples with the selected label	YES	
F120	Display a link to be used for recording data to the workspace when collect data is clicked	YES	
F130	Display a button to copy the link to the clipboard	YES	
F140	Display QR code with the same link in the previous function embedded to be used for recording data	YES	
F150	Display the collected data samples chronologically on the workspace panel	YES	
F160	Visualize the selected data sample as a graph when the data sample is clicked on the workspace panel	YES	
F170	Allow changing the graph type	NO	(0)
F180	Display the metadata of the selected data sample (identifier of the recording device and recording date/time)	YES	
F190	Allow setting the start/end time of the labeled actions on the graph view of the selected data sample	YES	
F200	Allow relabeling the selected data sample	YES	
F210	Allow deletion of the selected data sample	YES	
F220	Allow selecting data imputation options on the workspace panel	PARTIALLY	(1)
F230	Allow selecting feature extraction options on the workspace panel	YES	
F240	Allow selecting normalization options on the workspace panel	YES	
F250	Allow selecting machine learning model on the workspace panel with hyperparameters	YES	
F260	Request training of the model according to the selected options and automatically deploy it	YES	
F270	List trained and deployed models on the models overview	YES	
F280	Show the overview of the selected model when clicked on a model on the models overview	YES	
F281	Display the used parameters of the selected model	YES	
F282	Display the performance metrics of the selected model	PARTIALLY	(2)
F290	Display a mini QR code symbol for each model on the models overview	YES	
F300	Display a link to use the deployed model on mobile devices when the mini QR code symbol is clicked	YES	
F310	Display a button to copy the link to the clipboard	YES	
F320	Display QR code with the same link in the previous function embedded to be used for classifying data	YES	
F330	Display a logout button on all pages Mobile Web Client	YES	
F340	Show a list of available labels that will label the recorded data when the data collection is initiated	YES	
F350	Show an error if not all the required sensors are available in the device	YES	
F360	Allow configuring the countdown duration until the recording starts	YES	
F370	Allow configuring the recording duration	YES	
F380	Show a button to initiate the recording	YES	
F390	Show a countdown page with the current configuration on display (label, sensors used and their sampling rates)	YES	
F400	Display the sensor data in real-time as curves for each sensor on a single graph	YES	
F410	Show a recording completed page when the recording duration times out	YES	
F420	Allow discarding the last recording	YES	
F430	Allow another recording with the same configuration	YES	
F440	Allow editing configurations for the next recording	YES	
F450	Show a page for classification when the link of a model is opened	YES	
F460	Start listening to the sensor data of the mobile device right after the page is loaded	YES	
F470	Display the sensor data in real-time as curves for each sensor on a single graph	YES	
F480	Display the classified actions on the webpage in real time	YES	
F490	Allow stopping the recording	YES	
F500	Display the classified actions as a chronological list when the recording is stopped	YES	
F510	Allow restarting the recording 5.1.2 Server API	YES	
F520	Serve authentication services	YES	
F530	Handle workspace information	YES	
F540	Handle workspace data set.	YES	
F550	Handle label information for a workspace	YES	
F560	Store data coming from a mobile client	YES	
F570	Initiate the configured model training	YES	
F580	Handle model information for the workspace	YES	

(0): one graph type only

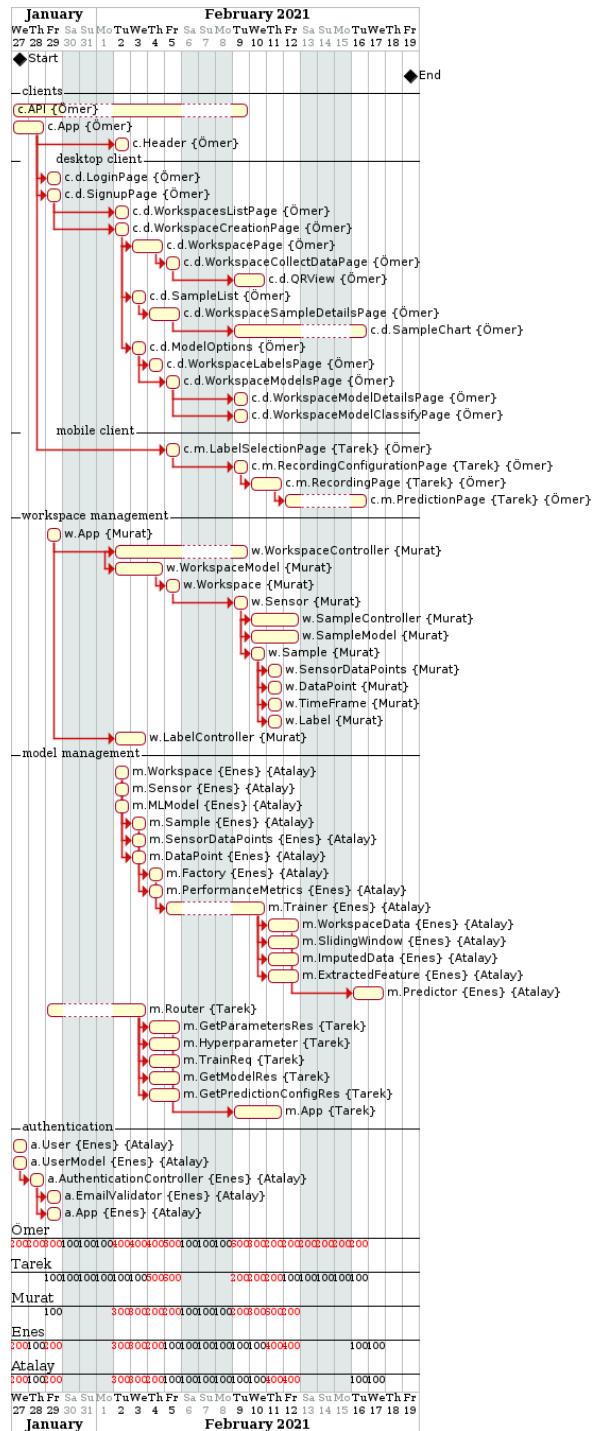
(1): Not all imputers implemented

(2): Not all metrics implemented

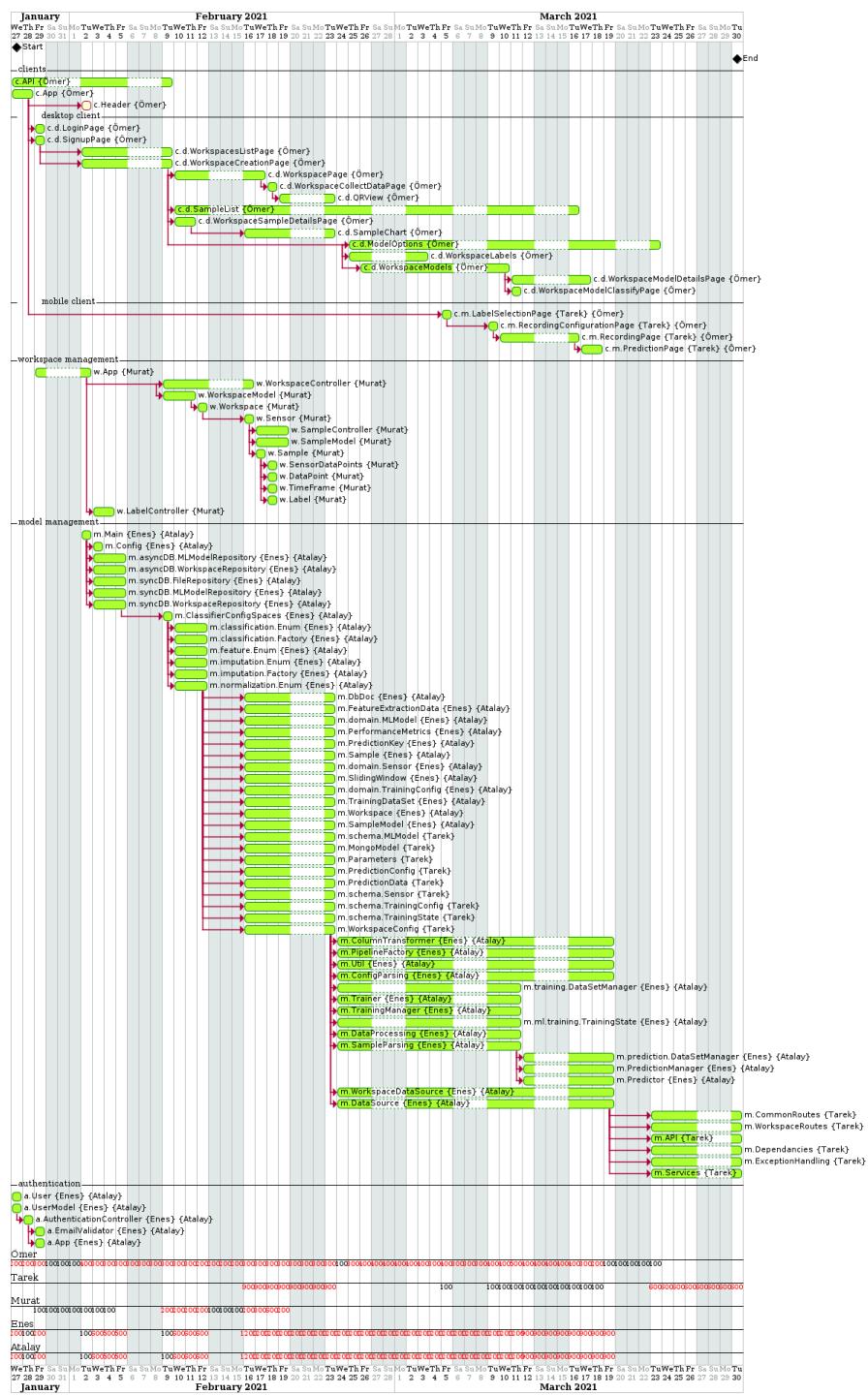
## 5.2 Optional Requirements

Number	Requirement Name	Implemented?
F590	Serve a "Stay Signed In" functionality on the desktop web client	NO
F600	Add CAPTCHA to login after 5 consecutive failed login attempts	NO
F610	Show a sign if a data collecting device is currently active	NO
F620	Allow listing samples by label on the workspace panel	NO
F630	Allow adding descriptions to the labels to assist data collection	YES
F640	Give the user non-visual feedback if an action is identified	NO
F650	Set a sound feedback to play when an action is identified	NO
F660	Serve a list of languages for the user interface	NO
F670	Support magnetometer sensor	NO
F680	Serve a "Forgot password" option that allows users to recover credentials	NO

## 6 Planned Schedule



## 7 Actual Schedule



## 8 Appendix

### 8.1 Client Diagram

