

# Process Mining and Intelligence Project

## Emotion Based Music Selection

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January 27, 2025

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## 1 BPMN modeling

### 1.1 Process landscape

[Ettore Ricci, Paolo Palumbo, Francesco Boldrini, Zahra Omrani]

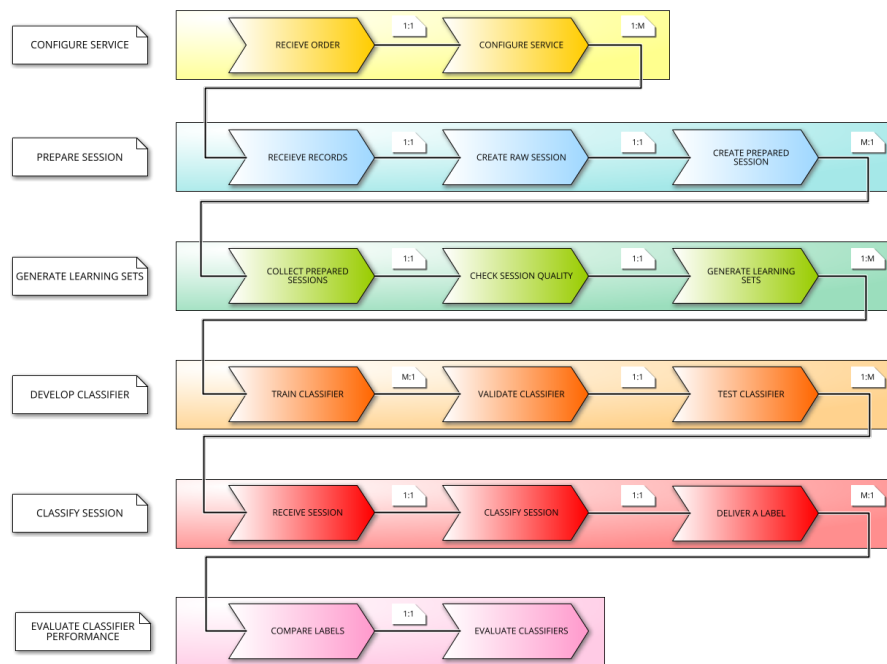
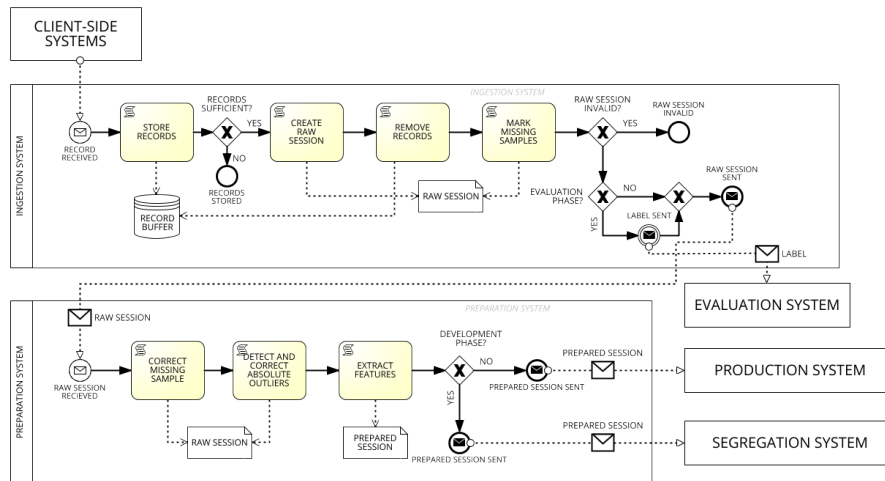


Figure 1: Process landscape

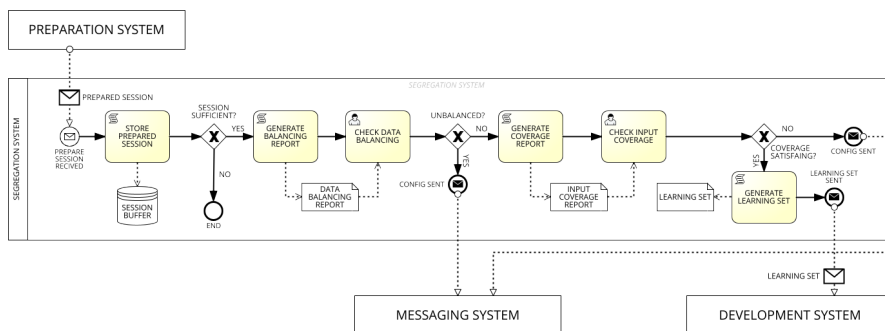
### 1.2 Process model

#### 1.2.1 Prepare session

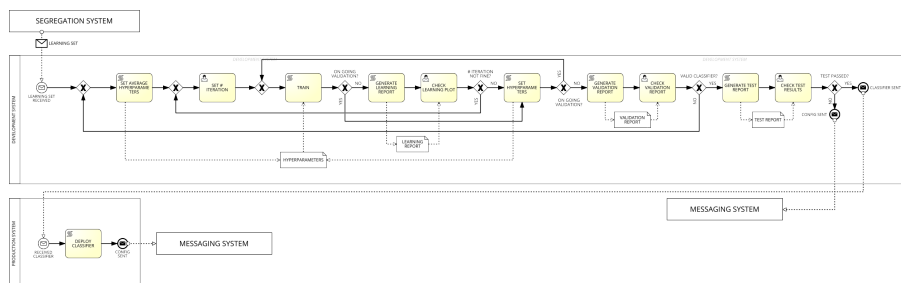
[Ettore Ricci, Paolo Palumbo]



### 1.2.2 Generate learning sets



### 1.2.3 Develop classifier



### 1.2.4 Classify session

[Ettore Ricci, Paolo Palumbo]

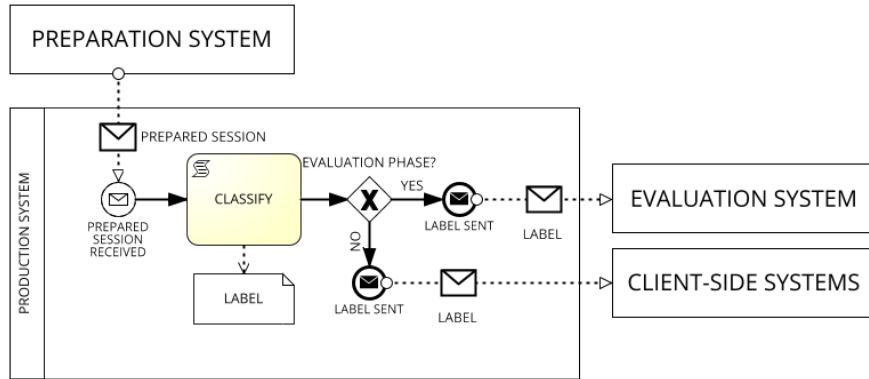


Figure 5: Business Diagram of the "Classify session" process

### 1.2.5 Evaluate classifier performance

[Ettore Ricci, Paolo Palumbo]

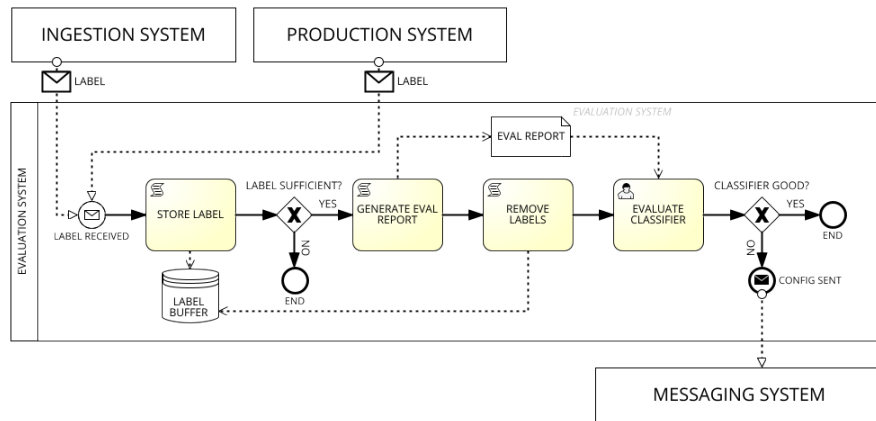


Figure 6: Business Diagram of the "Evaluate classifier performance" process

### 1.2.6 Configure systems

[Ettore Ricci, Paolo Palumbo]

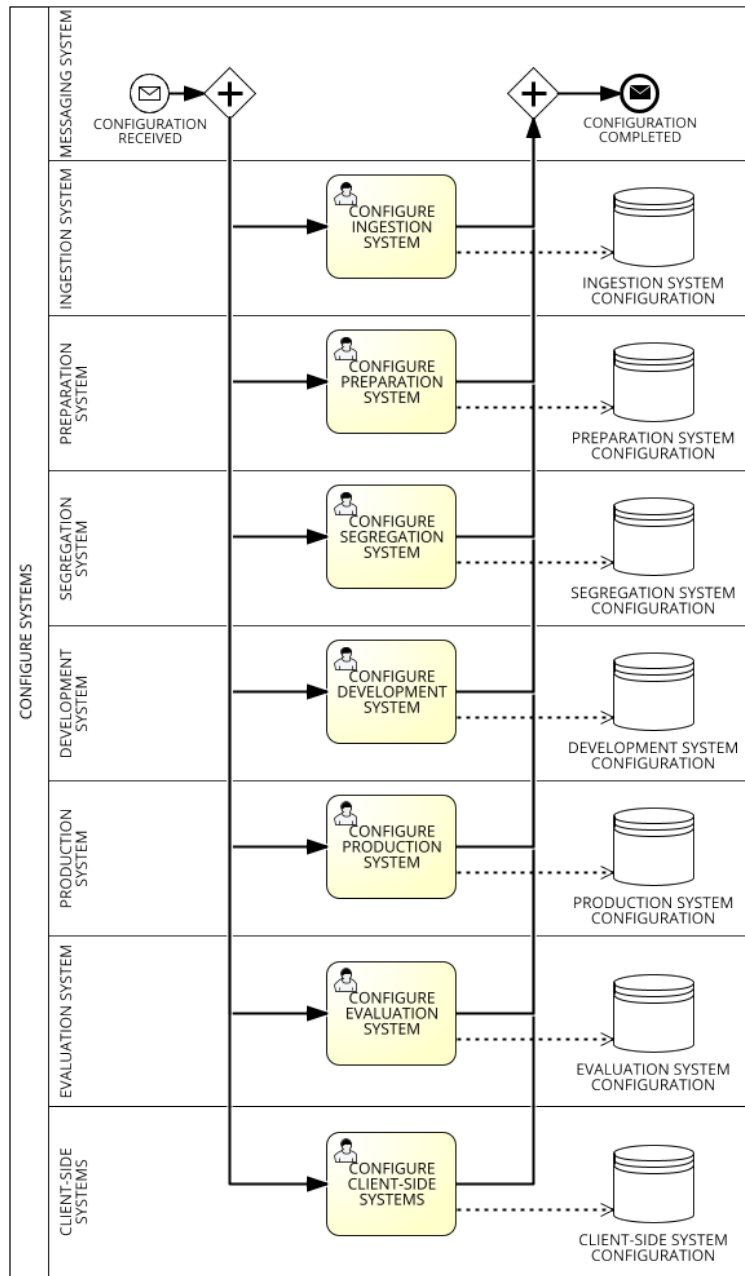


Figure 7: Business Diagram of the "Configure systems" process

## 2 Data modeling

### 2.1 Process model

#### 2.1.1 Prepare session

[*Ettore Ricci*]

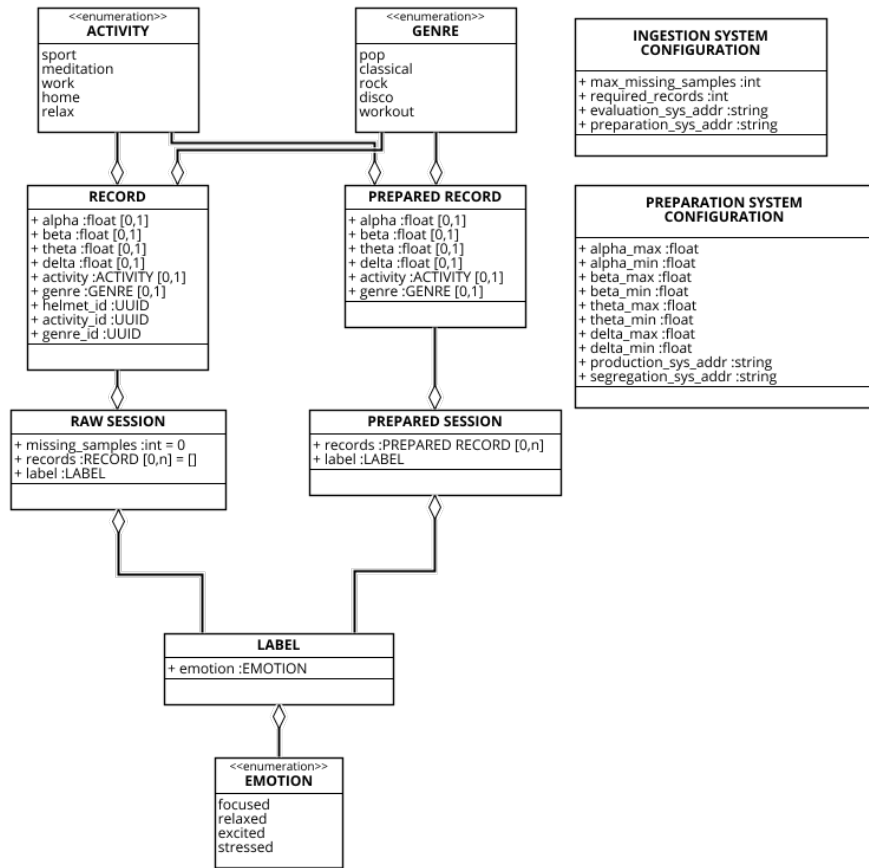


Figure 8: Data Model of the "Prepare session" process

### 2.1.2 Generate learning sets

[Paolo Palumbo]

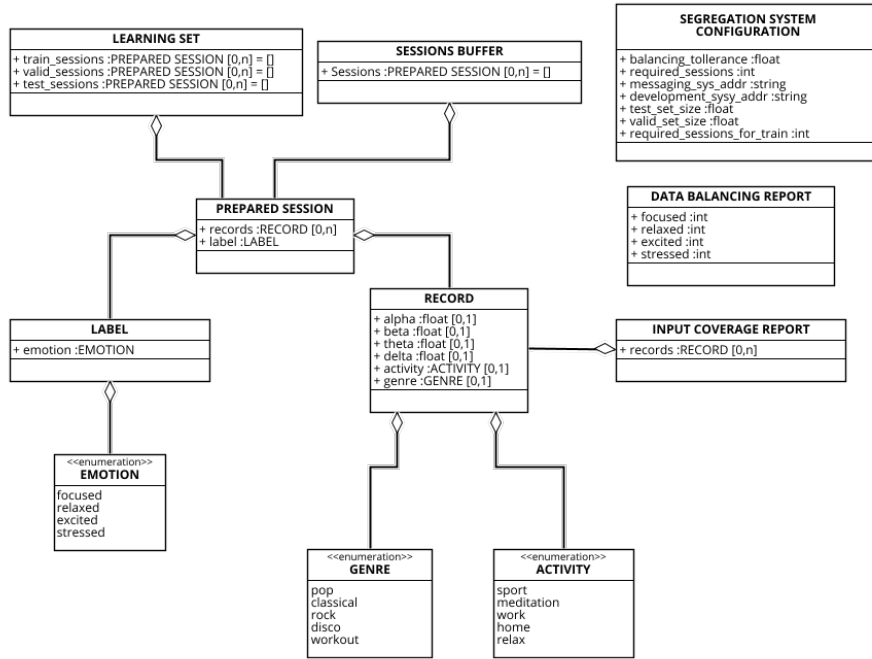


Figure 9: Data Model of the "Generate learning sets" process

### 2.1.3 Develop classifier

[Paolo Palumbo]

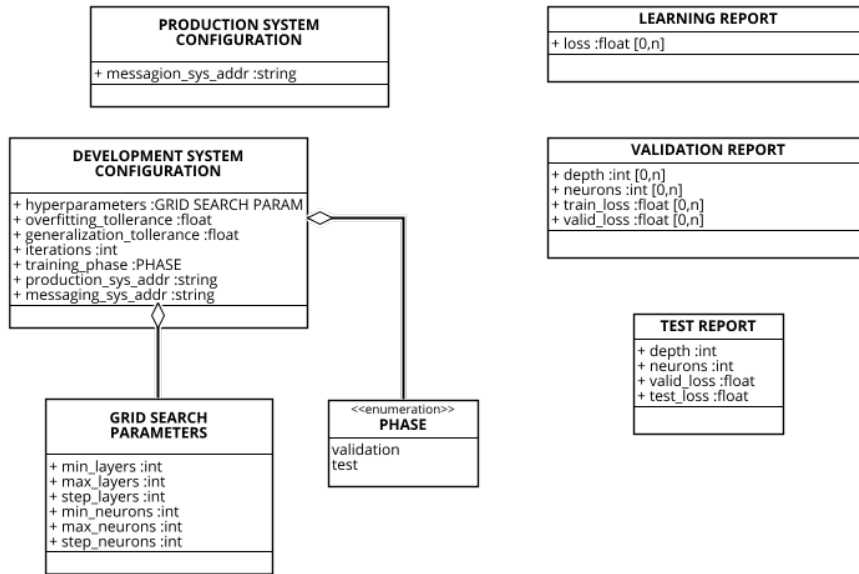


Figure 10: Data Model of the "Develop classifier" process

### 2.1.4 Classify session

[Francesco Boldrini]

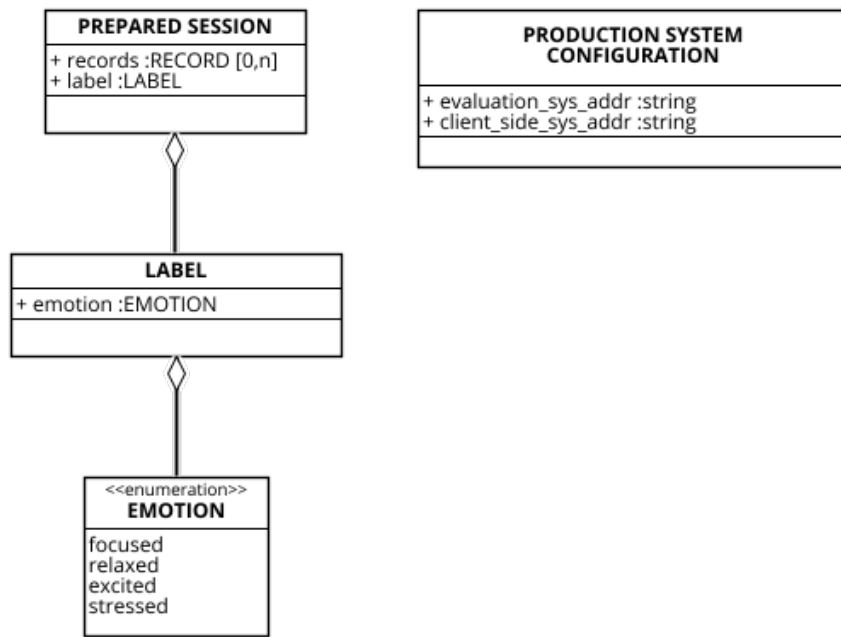


Figure 11: Data Model of the "Classify session" process

### 2.1.5 Evaluate classifier performance

[Zahra Omrani]



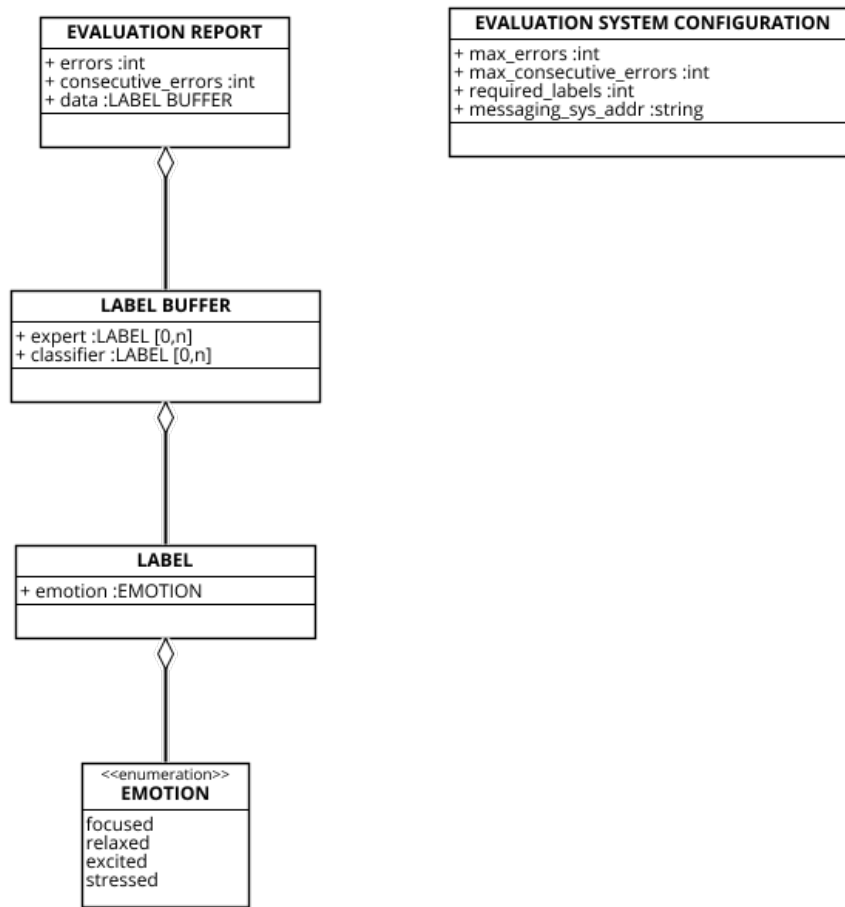


Figure 12: Data Model of the "Evaluate classifier performance" process

### 3 Task level modeling

#### 3.1 Roles and salaries

[Ettore Ricci, Paolo Palumbo]

Position	Description	Salary	Normalized Salary
Clerk	Handles administrative tasks, organizes documentation, and assists with data entry and labeling. Ensures smooth operations by coordinating communication and managing resources.	\$52,000.00	1.00
Data analyst	Prepares, analyzes, and visualizes data to extract insights. Collaborates on cleaning datasets, identifying trends, and supporting model validation.	\$60,000.00	1.15
ML engineer	Builds, tests, and deploys machine learning models, optimizing performance and scalability. Integrates AI solutions into production systems with a focus on efficiency.	\$130,000.00	2.50
Data scientist	Designs and experiments with AI models, applying advanced techniques to solve project challenges. Collaborates with experts to integrate domain knowledge and refine outputs.	\$123,000.00	2.37
Domain expert (Neurologist)	Provides medical expertise to guide AI development and validate results. Ensures solutions align with clinical standards and address neurological challenges.	\$267,000.00	5.13
<b>Minimum</b>		\$52,000.00	1.00

Table 1: Salary and normalized salary for each position

## 3.2 Segregation system

### 3.2.1 Check data balancing

[*Ettore Ricci, Paolo Palumbo*]

The task is performed by a Data Analyst.

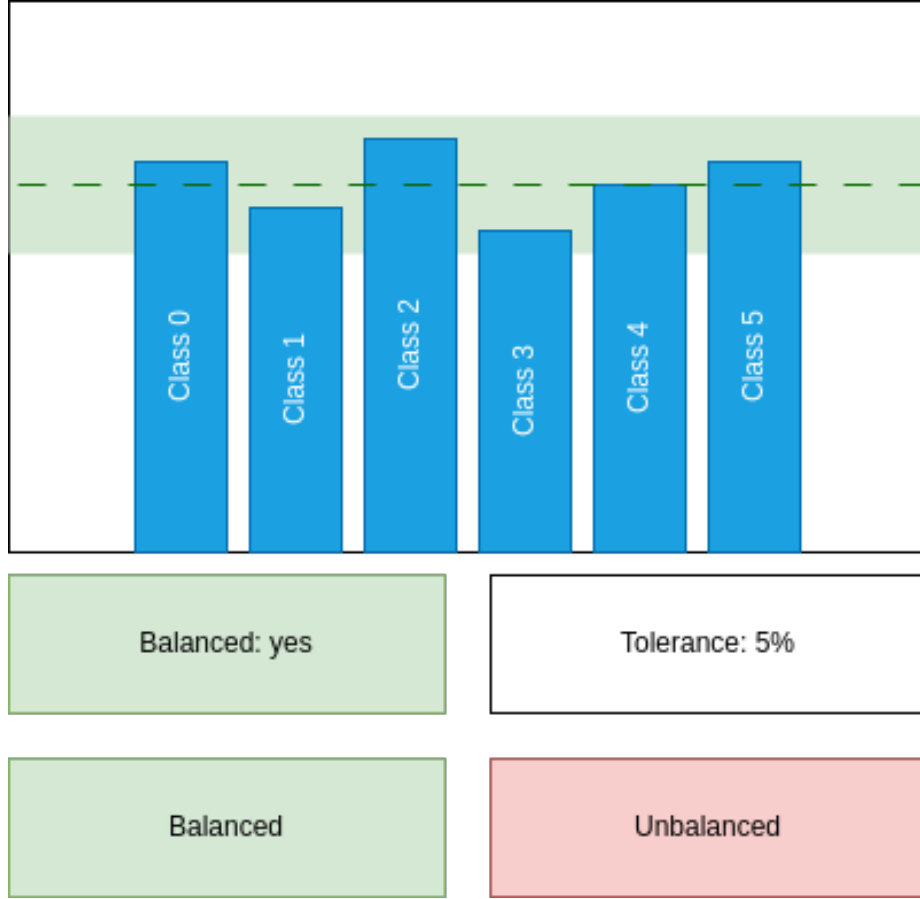


Figure 13: "Check data balancing" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Check data balancing" form.	1	1	1.15	1.15
2 <b>SYSTEM</b> shows the report.				
3 <b>SYSTEM</b> shows a hint whether the data is balanced or not.				
4 <b>ACTOR</b> checks the hint to see if the data is balanced or not.	1	2	1.15	2.30
5.1 <b>IF</b> the data is balanced.	0.2			
5.1.1 <b>ACTOR</b> clicks "Balanced" button.	0.2	1	1.15	0.23
5.2 <b>ELSE</b>	0.8			
5.2.1 <b>ACTOR</b> clicks "Unbalanced" button.	0.8	1	1.15	0.92
7 <b>SYSTEM</b> shows a confirmation dialog.				
8 <b>ACTOR</b> closes the form.	1	1	1.15	1.15
Human task cost				5.74

Table 2: Detailed use case for "Check data balancing" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.2.2 Check input coverage

[Ettore Ricci, Paolo Palumbo]

The task is performed by a Data Analyst.

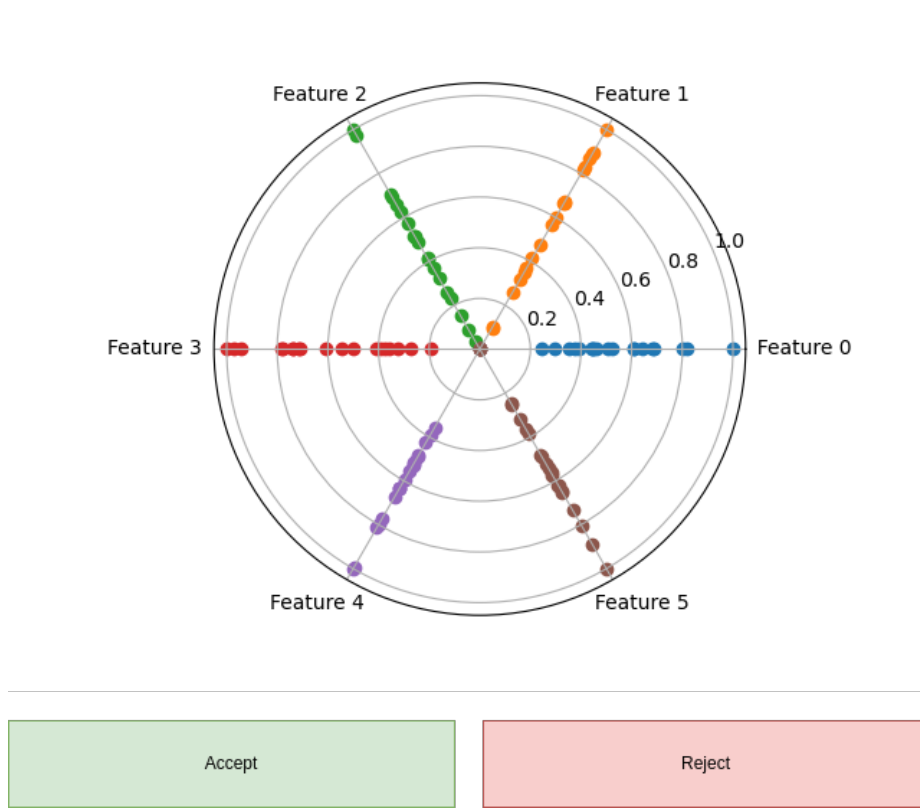


Figure 14: "Check input coverage" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Check input coverage" form.	1	1	1.15	1.15
2 <b>SYSTEM</b> shows a radar scatter plot of the input distribution.				
3 <b>FOR EACH</b> radius in the radar scatter plot:	6			
3.1 <b>ACTOR</b> checks if the distribution is uniform on the radius.	6	4	1.15	27.6
3.1.1 <b>IF</b> the distribution is not uniform as expected.	4			
3.1.1.1 <b>THEN</b> the input coverage is not satisfied.	4			
4.1 <b>IF</b> the input coverage is satisfied.	0.33			
4.1.1 <b>ACTOR</b> clicks "Accept" button.	0.33	1	1.15	0.38
4.2 <b>ELSE</b>	0.66			
4.2.1 <b>ACTOR</b> clicks "Reject" button.	0.66	1	1.15	0.76
5 <b>SYSTEM</b> shows a confirmation dialog.				
6 <b>ACTOR</b> closes the form.	1	1	1.15	1.15
Human task cost				31.04

Table 3: Detailed use case for "Check input coverage" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.2.3 Configure Segregation System

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

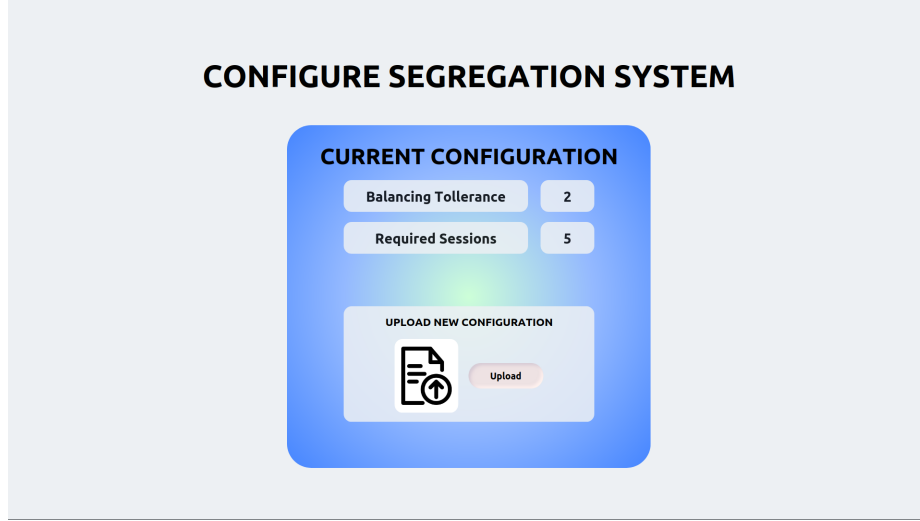


Figure 15: "Configure Segregation System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Segregation System" form.	1	1	2.50	2.50
2 <b>SYSTEM</b> displays current configuration and "Upload" button.				
3 <b>ACTOR</b> checks parameters against previous iterations on file	1	3	2.50	7.50
4 <b>ACTOR</b> adjusts file based on current parameters	1	3	2.50	7.50
5 <b>ACTOR</b> pushes "Upload" button and uploads configuration file	1	1	2.50	2.50
6.1 <b>SYSTEM</b> IF config is correct and correctly formatted				
6.1.1 <b>SYSTEM</b> shows a confirmation message.				
6.2 <b>ELSE</b>				
6.2.1 <b>SYSTEM</b> shows error message and aborts				
7 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				22.50

Table 4: Detailed use case for "Configure Segregation" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.3 Development system

#### 3.3.1 Set iteration number

[Zahra Omrani]

The task is performed by a ML engineer.

Set Iteration Number

Current Iteration Number 10

Enter New Iteration Number:

Submit

Iteration number updated successfully!

Figure 16: "Set iteration number" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Set Iteration Number" form.	1	1	2.5	2.5
2 <b>SYSTEM</b> displays the current iteration number.				
3 <b>ACTOR</b> inputs the desired number of iterations.	1	3	2.5	7.5
4 <b>ACTOR</b> clicks "Submit" button to confirm the iteration number.	1	1	2.5	2.5
5 <b>SYSTEM</b> shows a confirmation dialog.				
6 <b>ACTOR</b> closes the form.	1	1	2.5	2.5
Human task cost				15

Table 5: Detailed use case for "Set iteration number" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.3.2 Check learning report

[Paolo Palumbo]

The task is performed by a ML engineer.



Figure 17: "Check learning report" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Check training report" form.	1	1	2.50	2.50
2 <b>SYSTEM</b> shows the training loss curve.				
3 <b>ACTOR</b> checks the learning curve.	1	3	2.50	7.50
3.1 <b>IF</b> the loss is flat for at least half of the iterations:	0.4			
3.1.1 <b>THEN ACTOR</b> clicks "Overfit" button.	0.4	1	2.50	1.00
3.2 <b>IF</b> the loss is not flat at the end of the iterations:	0.4			
3.2.1 <b>THEN ACTOR</b> clicks "Underfit" button.	0.4	1	2.50	1.00
3.3 <b>ELSE</b>	0.2			
3.3.1 <b>ACTOR</b> clicks "Approved" button.	0.2	1	2.50	0.50
4 <b>SYSTEM</b> shows a confirmation dialog.				
5 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				15

Table 6: Detailed use case for "Check training report" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.3.3 Check validation report

[Ettore Ricci]

This task is performed by a ML engineer.

	ID	Depth	Neurons	Train MSE	Valid MSE	Delta MSE
1	954	3	4000	0.13	0.14	0.01
2	321	4	3000	0.23	0.24	0.01
3	5	3	1000	0.35	0.35	0.00
4	764	2	2000	0.24	0.45	0.21
5	202	3	2500	0.20	0.47	0.27
Reject						
Overfitting Tolerance:						0.10

Figure 18: "Check validation report" mock-up form



Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Check validation report" form.	1	1	2.5	2.5
2 <b>SYSTEM</b> shows the best 5 models sorted by increasing Validation Loss.				
3 <b>FOR EACH</b> model in the list:	5			
3.1 <b>IF</b> the model Validation Loss minus the Training Loss is less than the Overfitting Tolerance and the Best Model is not selected.	1	2	2.5	5
3.1.1 <b>THEN</b> select the model as the Best Model.	1	1	2.5	2.5
4 <b>FOR EACH</b> model in the list:	4			
4.1 <b>IF</b> the model is not the Best Model and the Validation Loss minus the Training Loss is less than the Overfitting Tolerance and the Second Best Model is not selected.	1	2	2.5	5
4.1.1 <b>THEN</b> select the model as the Second Best Model.	1	1	2.5	2.5
5.1 <b>IF</b> the Best Model is not selected.	0.05	1	2.5	0.125
5.1.1 <b>ACTOR</b> clicks "Reject" button.	0.05	1	2.5	0.125
5.2 <b>ELSE IF</b> the Second Best Model is not selected or the Validation Loss of the Second Best Model is one order of magnitude greater than the Validation Loss of the Best Model.	0.3	3	2.5	2.25
5.2.1 <b>ACTOR</b> clicks on the Best Model.	0.3	1	2.5	0.75
5.3 <b>ELSE</b>	0.65	3	2.5	4.875
5.3.1 <b>ACTOR</b> clicks on the least complex model among the Best Model and the Second Best Model.	0.65	3	2.5	4.875
6 <b>SYSTEM</b> shows a confirmation dialog.				
7 <b>ACTOR</b> closes the form.	1	1	2.5	2.5
Human task cost				32.91

Table 7: Detailed use case for "Check validation report" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.3.4 Check test results

[Ettore Ricci]

This task is performed by a ML engineer.

ID	Depth	Neurons	Valid MSE	Test MSE	Delta MSE
954	3	4000	0.14	0.15	0.01
Overfitting Tolerance:					0.10
Accept			Reject		

Figure 19: "Check test results" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens "Check test results" form.	1	1	2.5	2.5
2 <b>SYSTEM</b> shows the test results.				
3 <b>ACTOR</b> checks if the difference between the test results and the validation results is within overfitting tolerance.	1	2	2.5	5
4.1 <b>IF</b> the test results is not satisfactory.	0.01			
4.1.1 <b>ACTOR</b> clicks "Reject" button.	0.01	1	2.5	0.025
4.2 <b>ELSE</b>	0.99			
4.2.1 <b>ACTOR</b> clicks "Approve" button.	0.99	1	2.5	2.475
5 <b>SYSTEM</b> shows a confirmation dialog.				
6 <b>ACTOR</b> closes the form.	1	1	2.5	2.5
Human task cost				12.5

Table 8: Detailed use case for "Check test results" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.3.5 Configure Development System

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

**CONFIGURE DEVELOPMENT SYSTEM**

**CURRENT CONFIGURATION**

Overfitting Tolerance: 1

Generalization Tolerance: 1

Min Neurons: 1

Max Neurons: 200

Step Neurons: 1

Min layers: 10

Max Layers: 10

Step Layers: 1

**UPLOAD NEW CONFIGURATION**

Upload

Figure 20: "Configure Development System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Development System" form.	1	1	2.50	2.50
2 <b>SYSTEM</b> displays current configuration and "Upload" button.				
3 <b>ACTOR</b> checks parameters against previous iterations on file	1	3	2.50	7.50
4 <b>ACTOR</b> adjusts file based on current parameters	1	3	2.50	7.50
5 <b>ACTOR</b> pushes "Upload" button and uploads configuration file	1	1	2.50	2.50
6.1 <b>SYSTEM</b> IF config is correct and correctly formatted				
6.1.1 <b>SYSTEM</b> shows a confirmation message.				
6.2 <b>ELSE</b>				
6.2.1 <b>SYSTEM</b> shows error message and aborts				
7 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				22.50

Table 9: Detailed use case for "Configure Development" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.4 Evaluation system

#### 3.4.1 Evaluate classifier performance

[Zahra Omrani]

This task is performed by a Data Analyst.

×

Evaluate Classifier Performance

Session ID	Expert Label	Classifier Label	Error
0	1	2	Yes
1	1	3	Yes
2	2	1	Yes
3	3	3	No

Max number of errors tolerated (th1): 4  
Max number of consecutive error tolerated (th 2) :2

th1 satisfied  
 $3 < 4$

th2 exceeded  
 $3 > 2$

Pass

Fail

Figure 21: "Evaluate Classifier Performance" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Evaluate Classifier Performance" form.	1	1	1.15	1.15
2 <b>SYSTEM</b> displays a table of sessions with Expert Label (ground truth) and Classifier Label (predicted label). The difference between the labels (if any) represents an error.				
3.1 <b>ACTOR</b> checks the total errors threshold color.	1	2	1.15	2.30
3.2 <b>ACTOR</b> checks the consecutive errors threshold color	1	2	1.15	2.30
3.3 <b>IF</b> at least one threshold is red				
3.3.1 <b>ACTOR</b> clicks the "Fail" button.	0.4	1	1.15	0.46
3.4 <b>ELSE</b>				
3.4.1 <b>ACTOR</b> clicks the "Pass" button.	0.6	1	1.15	0.65
4 <b>SYSTEM</b> shows a confirmation dialog.				
5 <b>ACTOR</b> closes the form.	1	1	1.15	1.15
Human task cost				8.05

Table 10: Detailed use case for "Evaluate Classifier Performance" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.4.2 Configure Evaluation System

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

**CONFIGURE EVALUATION SYSTEM**

**CURRENT CONFIGURATION**

Max Errors	2
Max Consecutive Errors	5
Required Labels	5

**UPLOAD NEW CONFIGURATION**

Upload

Figure 22: "Configure Evaluation System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Evaluation System" form.	1	1	2.50	2.50
2 <b>SYSTEM</b> displays current configuration and "Upload" button.				
3 <b>ACTOR</b> checks parameters against previous iterations on file	1	3	2.50	7.50
4 <b>ACTOR</b> adjusts file based on current parameters	1	3	2.50	7.50
5 <b>ACTOR</b> pushes "Upload" button and uploads configuration file	1	1	2.50	2.50
6.1 <b>SYSTEM</b> IF config is correct and correctly formatted				
6.1.1 <b>SYSTEM</b> shows a confirmation message.				
6.2 <b>ELSE</b>				
6.2.1 <b>SYSTEM</b> shows error message and aborts				
7 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				22.50

Table 11: Detailed use case for "Configure Evaluation" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.5 Client-Side Systems

#### 3.5.1 Configure Client-Side Systems

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

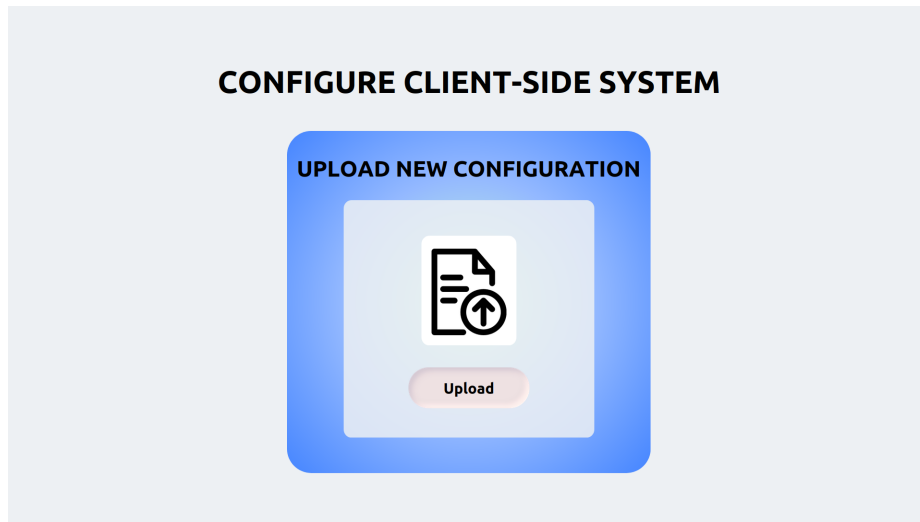


Figure 23: "Configure Client-Side Systems" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Client-Side System" form.	1	1	2.50	
2 <b>SYSTEM</b> displays the "Upload" button.				
3 <b>ACTOR</b> push the "Upload" button and upload the configuration file.	1	1	2.50	2.50
4 <b>SYSTEM</b> shows a confirmation message.				
5 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				7.50

Table 12: Detailed use case for "Configure Client-Side Systems" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

## 3.6 Production System

### 3.6.1 Configure Production Systems

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

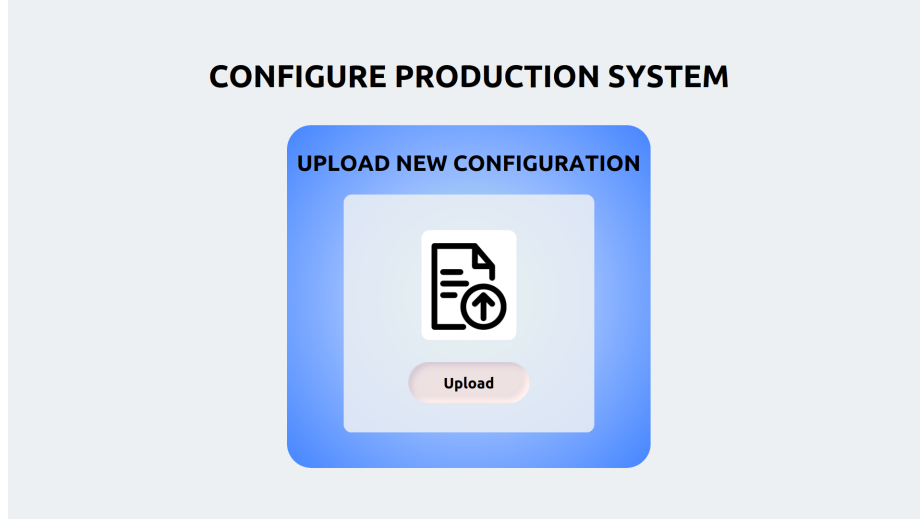


Figure 24: "Configure Production System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Production System" form.	1	1	2.50	2.50
2 <b>SYSTEM</b> displays the "Upload" button.				
3 <b>ACTOR</b> push the "Upload" button and upload the configuration file.	1	1	2.50	2.50
4 <b>SYSTEM</b> shows a confirmation message.				
5 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				7.50

Table 13: Detailed use case for "Configure Production" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

## 3.7 Ingestion System

### 3.7.1 Configure Ingestion System

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

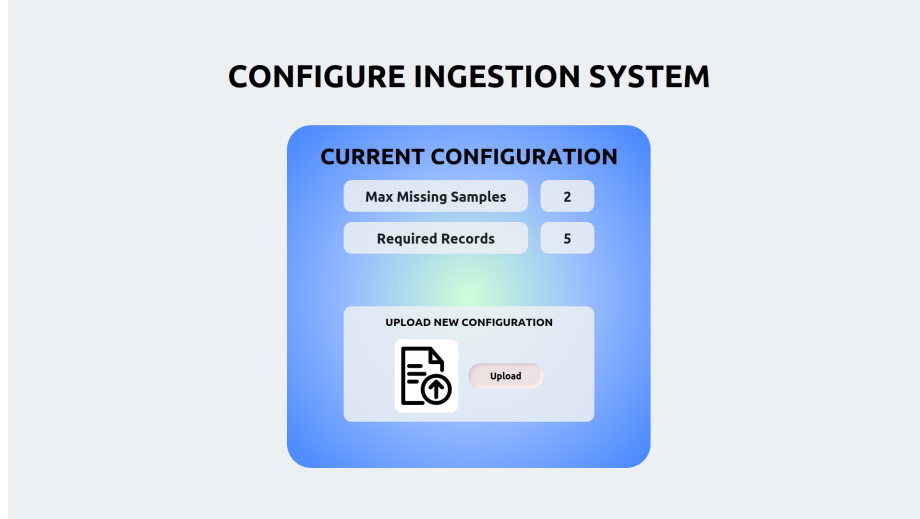


Figure 25: "Configure Ingestion System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Ingestion System" form.			2.50	
2 <b>SYSTEM</b> displays current configuration and "Upload" button.				
3 <b>ACTOR</b> checks parameters against previous iterations on file	1	3	2.50	7.50
4 <b>ACTOR</b> adjusts file based on current parameters	1	3	2.50	7.50
5 <b>ACTOR</b> pushes "Upload" button and uploads configuration file	1	1	2.50	2.50
6.1 <b>SYSTEM</b> IF config is correct and correctly formatted				
6.1.1 <b>SYSTEM</b> shows a confirmation message.				
6.2 <b>ELSE</b>				
6.2.1 <b>SYSTEM</b> shows error message and aborts				
7 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				22.50

Table 14: Detailed use case for "Configure Ingestion" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

### 3.8 Preparation System

#### 3.8.1 Configure Preparation System

[*Francesco Boldrini, Zahra Omrani*]

This task is performed by a ML Engineer.

Figure 26: "Configure Preparation System" mock-up form

Step	O	CL	S	SC
1 <b>ACTOR</b> opens the "Configure Preparation System" form.			2.50	
2 <b>SYSTEM</b> displays current configuration and "Upload" button.				
3 <b>ACTOR</b> checks parameters against previous iterations on file	1	3	2.50	7.50
4 <b>ACTOR</b> adjusts file based on current parameters	1	3	2.50	7.50
5 <b>ACTOR</b> pushes "Upload" button and uploads configuration file	1	1	2.50	2.50
6.1 <b>SYSTEM</b> IF config is correct and correctly formatted				
6.1.1 <b>SYSTEM</b> shows a confirmation message.				
6.2 <b>ELSE</b>				
6.2.1 <b>SYSTEM</b> shows error message and aborts				
7 <b>ACTOR</b> closes the form.	1	1	2.50	2.50
Human task cost				22.50

Table 15: Detailed use case for "Configure Preparation" task

O - Occurrence, CL - Cognitive Level, S - Normalized Salary, SC - Step Cost

## 4 Simulation

### 4.1 Collapsed workflow

[Ettore Ricci, Paolo Palumbo, Francesco Boldrini]





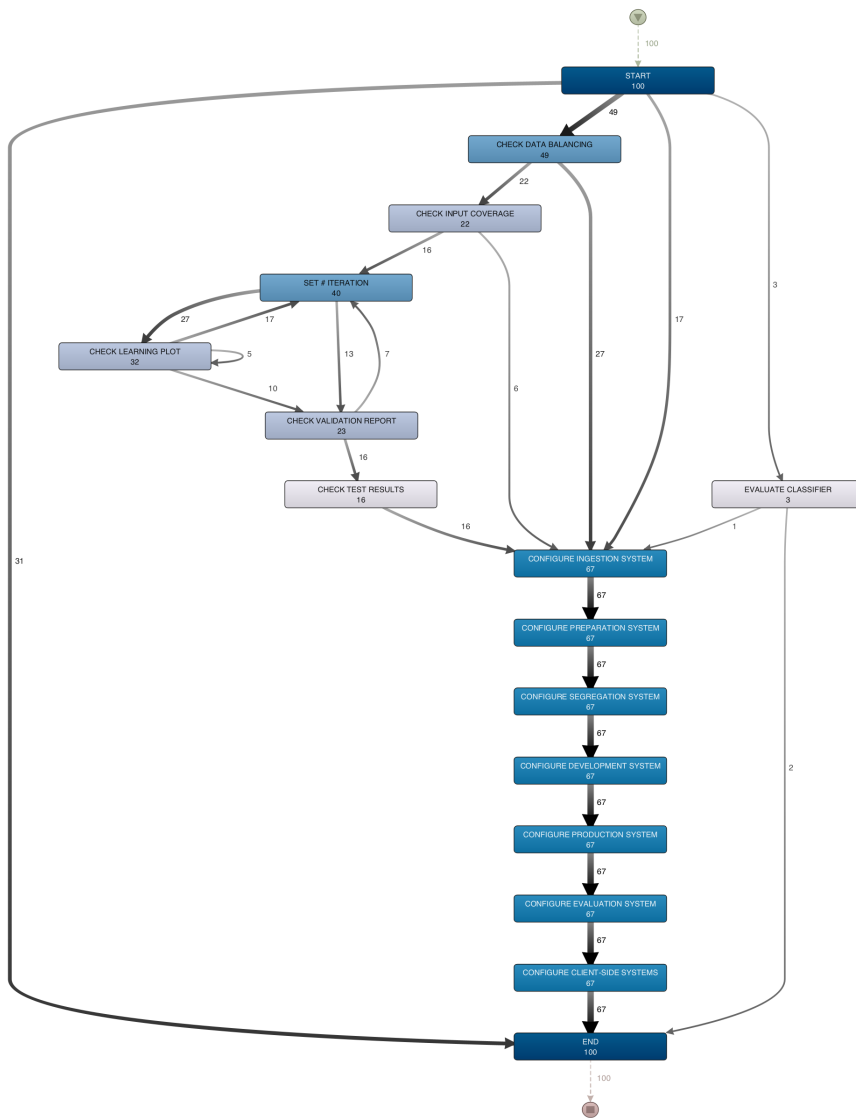


Figure 28: Disco analysis

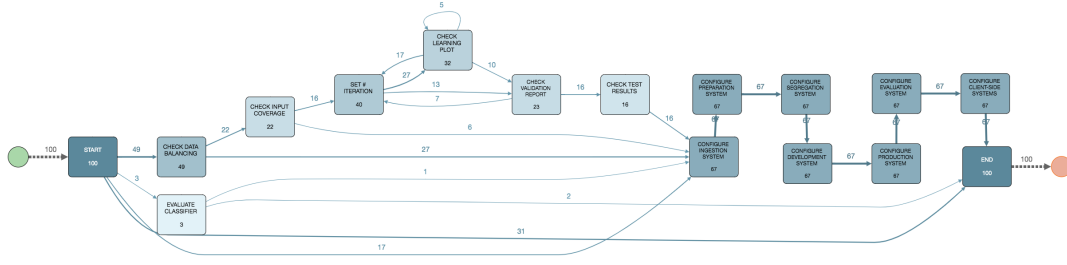


Figure 29: Apromore analysis

As we can see, the two transition maps mined from Disco and from Apromore are identical.

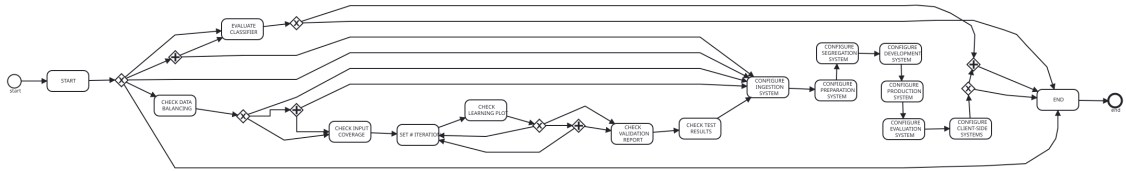


Figure 30: ProM mined BPMN model

The BPMN model mined from ProM is not compliant with the BPMN 2.0 specification (section 10.5). Furthermore, the model contains parallel gateways that are never present in the collapsed model.

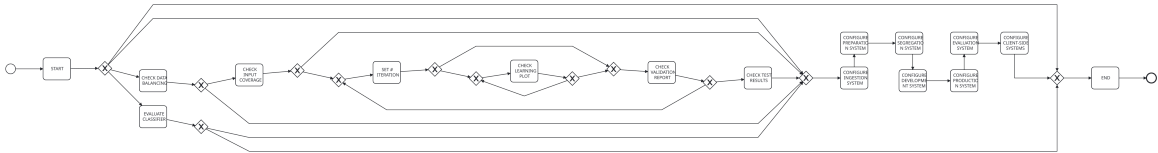


Figure 31: Apromore mined BPMN model

The BPMN model mined from Apromore is much more sensible compared to the one from ProM, also it is compliant with the BPMN 2.0 specification.

Tool	Trace	Generalization	Precision	Simplicity
Apromore	0.4203	0.9872	0.7566	
ProM	0.6666	0	0	

Table 16: Comparison of the process mining tools