AI·PROFICIENT

Artificial intelligence
for improved production efficiency,
quality and maintenance

Deliverable 3.5

D3.5: Future scenario-based decision making.

WP3: Platform AI analytics and decision-making support.

T3.5: Future scenario based decision-making and lifelong self-learning.

Version: 1.0

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Executive Summary

The Deliverable D3.5 is a public document of AI-PROFICIENT project delivered in the context of task 3.5: Future scenario based decision-making and lifelong self-learning as a part of WP3: Platform AI analytics and decision-making support, regarding the description of the AI-PROFICIENT service that aim providing life-long self/reinforcement-learning capabilities.

Task 3.5 has been viewed in the following of task 4.1 providing generic workflow and specific feedback mechanism while the later will gather the relevant feedback mechanisms and provide the HMI (see M18 Technical Periodic report – Part B for details). D3.5 incorporates in the introduction a reminder of the service description in the context of AI-PROFICIENT in relation to WP1 and its deliverables; the next sections describe the services developed for each use cases that incorporate reinforcement learning from human feedback.

D3.5 should be read as the next step of D4.5 and D4.1. D4.5 and D4.1 contain : the initial description of the end user's requirements related to the use cases in terms of the feedback management, the general overview of the different approaches about human feedback management in AI-PROFICIENT for reinforcement-learning, the initial specifications of the feedback-management solutions were described, the specific approaches for the use cases related to the different pilot sites where human feedback can contribute for AI-reinforcement, the updated requirements in feedback management related to the evolution of the AI models in each of the use cases during the dev elopement phase and the interfaces for managing feedback whenever they are relevant, considering ethical aspects to ensure user engagement and workload aspects.

However, due to the close relation to the AI models evolution, and the short delay suffered in some of them, some pending activities of T4.1 in specific use cases are to be finalized in the context of T3.5, where the reinforcement activities will be carried out supporting lifelong self-learning approach as agreed by the reviewers and the PO in M18 review and reported here in D3.5 leading to perform all the work described in the DoW.

1 Introduction

The goal of this deliverable is to gather the contributions that have been provided in task 3.5 in relation to life-long reinforcement-learning in the context of AI-PROFICIENT project. The objective of the task is to provide a reinforcement-learning mechanism of services thanks to human feedback (T4.1). This task will contribute to the development of Life-long self-learning service (S_LSL) already presented in D1.5 (see Table 1). It is worth mentioning that S_ LSL service is fed by S_HUM service whose purpose is to generate new data from the human knowledge and expertise dealing with the necessary interfaces to get the feedback but also with the conversion of the feedback to data that the AI-based models can take advantage of.

Table 1: S_LSL service description (from D1.5).

Service ID	**S_LSL**
Service input and dependency on other services:	This service relies heavily on the output of other services; hence, a clear definition of inputs/outputs is complex. However, the following are the minimum inputs required that have been identified so far: • Diagnostic and anomaly detection if the service is available. • Health state evaluation if the service is available. • Predictive Production quality assurance if the service is available. • Root-cause identification if the service is available. • Early anomaly detection if the service is available. • Generative holistic optimization if the service is available. • Feedback/improvements from the users when WP4 services are made available
Service output:	The purpose of the service is to provide a decision-making system that combines the optimization information coming from other AI-PROFICIENT services (developed at WP2 and WP3) with the human feedback mechanisms (developed at WP4).
High level service description:	This service integrates the AI information/data and the maintenance decisions by gathering the outputs of the modelling services developed at WP2 and WP3, then, it enriches that data with the feedback services developed in WP4 to produce a decision that also reflects the operators' feedback on the different AI models. This will enable taking prescriptive actions based on a close collaboration with the end-users. In addition, this service has the capability of being continuously improved over time, based on the feedback of the operators.

This service is intended to cover the _LSL requirements identified and detailed in the deliverable D1.4 as result of T1.4. as shown in the following Table 2.

Table 2: Functionalities to be provided by the AI-PROFICIENT project (from D1.4).

AI-PROFICIENT Functionalities	***ID***
Monitoring	_MON
Diagnostic and anomaly detection	_DIA
Health state evaluation	_HEA
Component prognostics	_PRO
Hybrid models of production processes and digital twins	_HYB
Predictive Production quality assurance	_PRE
Root-cause identification	_ROO
Early anomaly detection	_EAR
Opportunistic maintenance decision-making	_OPP
Generative holistic optimization	_GEN
Future scenario based Lifelong self-learning system	_LSL
Human feedback	_HUM
Explainable and transparent decision making	_ETD

Focusing on Life-long self-learning service, it is worth mentioning that most of the AI-PROFICIENT use cases identified the need to include re-learning mechanisms based on Human feedback. As described in D4.1 and D4.5, the final use cases including S_LSL service are shown in Table 3.

Table 3: Updated partners involvement in T4.1 for each use case from D4.5

WP/Task	**CONTI-2**	**CONTI-3**	**CONTI-5**	**CONTI-7**	**CONTI-10**	**INEOS-1**	**INEOS-2**	**INEOS-3**
WP4- HMI, explainable AI and shop-floor feedback								
4.1 Feedback/reinforc.	TEK		TEK CONTI INOS		IBE IMP ATC	IMP IBE	TF ATC TEK	IMP

In the following sections, a detailed description of the components dedicated to the above-mentioned use cases can be found.

2 Life-long reinforcement-learning: application use cases

2.1 CONTI2: Restart set

As described in D4.1, in the Restart set UC in Continental the AI-based model is expected to be “registering” the extrusion signals and using the known information about the recipe and compounds that will be used during the next extrusion, it should provide recommendations to the user in terms of readiness state and speed setpoint suggestions for each extruder.

The model will be trained upon the available information, but once it is deployed and in use in production, feedback is considered to be relevant and very valuable to reinforce and improve the model. Both implicit and explicit feedback will be used for such purposes following the approach described above.

The feedback architecture and developments for CONTI-2 was previously presented in D4.1 and further expanded upon in D4.5. As of the writing of this deliverable, no major architecture changes are anticipated. The deployment is currently underway, but there have been some delays related to the complexity of the data pipelines. The deployment is being carried out in an iterative way, starting with the deployment of just the recommendation models, which will be followed by the implicit feedback systems, and finally, the explicit feedback mechanism.

2.2 CONTI5: Tread blade wear

As described in D4.1, in CONTI5, AI-models aim to predict the optimal moment for changing the tread blade, while presenting the remaining life of the blade. However, due to the imperfection of the AI-models, the prediction will not always provide the best moment, and to correct these deviations, a human-feedback management will be applied.

Both implicit and explicit feedback will be used for this purpose following the approach described above.

2.2.1 Solution

2.2.1.1 Implicit feedback

As mentioned above, the aim of the AI models here is to predict the optimal moment to change the blade considering currently available information, such as material types and compositions, performed cuts, current signals information, and even the appearance of the blade. This diverse information will be processed by different AI approaches that are expected to be combined to make the most robust possible AI-based prediction solution, leading to a decision support system (DSS). But all of them give the same information, the optimal moment to change the blade.

Initially on D 4.1, the workflow was planned so that the maintenance craftsmen would collect later the information regarding the motivation for the blade change on the change report. However, until this report was updated (which could have a delay of up to 6 hours) the monitoring system would be providing wrong information, as there would not be any way of knowing that the blade was changed (for the algorithms side).

For that reason, and following CONTINENTAL’s internal digitalization effort to obtain more accurate information, the HMI created for information retrieval was placed instead on the Cutting System. This way, every time the cutting system lid is opened, a pop-up message appears and the operator/maintenance craftsmen that opened the lead chooses the best option. With this improved HMI and data-flow (see Figure 1 and Figure 2), the reinforcement of the operator is still gathered but, the accuracy of the implicit feedback is greatly improved. Taking advantage of this information and aligning the change moment with all the information registered within the system (current signal values, image of the blade) and comparing it to the prediction, information for reinforcement will be generated indicating the success of the recommendation.

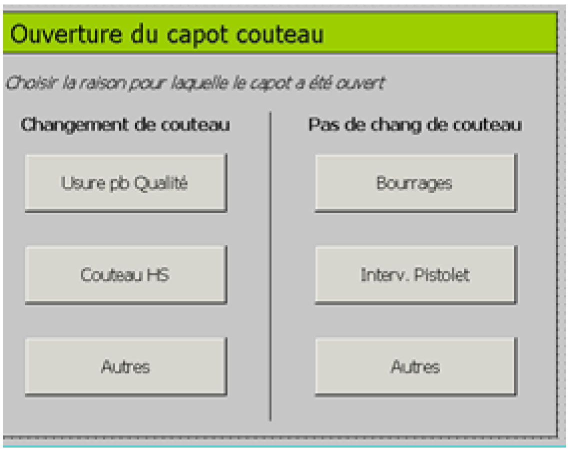

Figure 1: CONTI5 explicit feedback HMI.

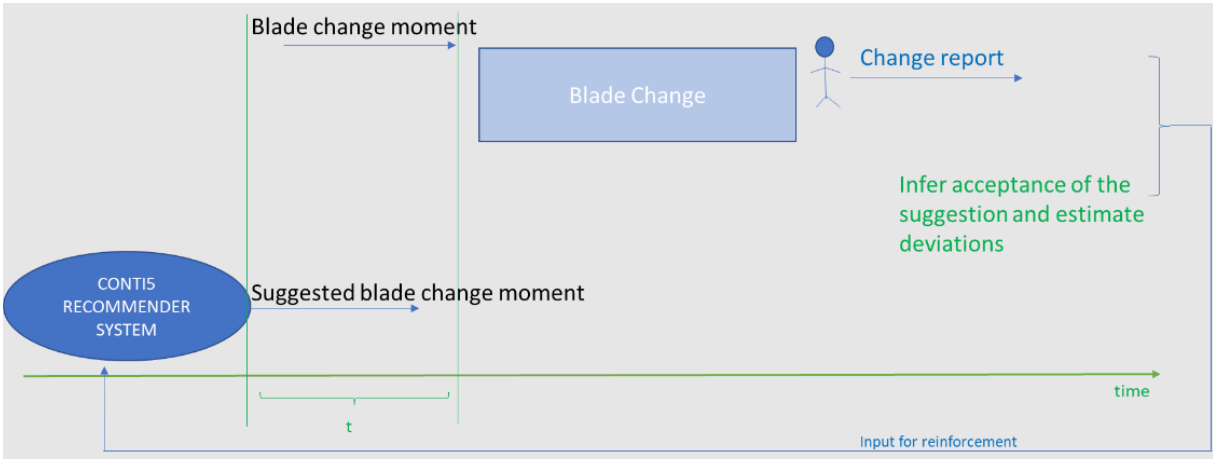

Figure 2: CONTI5 implicit feedback management approach

2.2.1.2 Explicit feedback

With the improvements previously explained, the explicit data retrieval itself is improved. In this way, by having a more accurate date-time for the blade change, the number of cuts counted for the blade are far more accurate, which will improve the goodness of the model.

At the same time, given the diagnosis/prognostics algorithm is not 100% accurate, the user's explicit feedback is very useful for reinforcement purposes since the blade change does not necessarily happen in its optimal end of life moment. The change could be performed due to planned maintenance, when the blade use could be extended for a longer time, or on the contrary it should be changed earlier. So, whenever the change process takes place, it is very useful to report the status of the blade at that specific moment. And it is also useful to record the main reason why the operator declines to follow a suggestion provided by the AI system.

In the case where the operator is “forced” to decline the suggestions of the algorithm (the blade brakes early but it is fine according to the algorithm) , the decision support system's HMI is used to collect the reason, again, displaying a set of options to the user to register the reason and then translate it to a classification interpretable by the AI-model, and be used as reinforcement information.

The explicit feedback reinforcement information will be combined with the implicit feedback and sent to the model with reinforcement purposes. Figure 3 presents the global workflow.

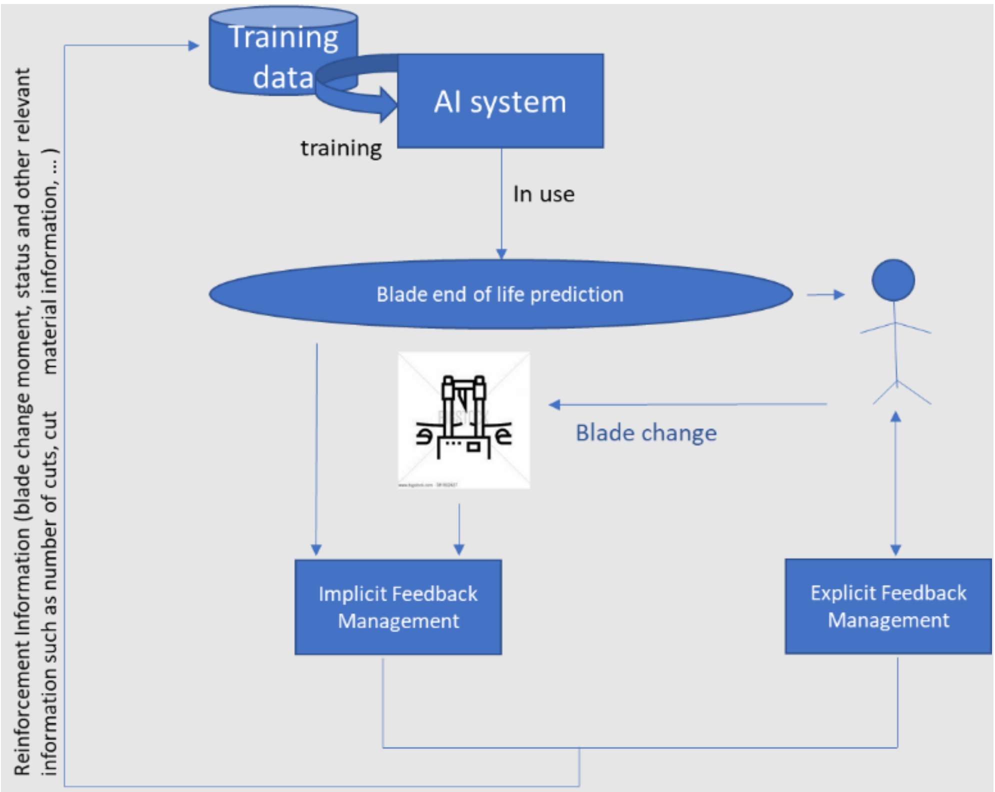

Figure 3: CONTI5 reinforcement-based flow

2.2.2 Ethical aspects – Ethics Team

Ethical issues related to CONTI5 for Human-Machine feedback management and the measures that are planned to address them are shown in the following table. Note that these recommendations were presented already in Deliverable 4.5, but we include them here again with an update of the ETHICS CODE designation, as well as of NA status in some cases due to development decision changes as described in the Ethics section below.

Table 4: Ethical issues for Human Feedback Management in CONTI5 use case.

ETHICS CODE	CODE ORIGIN[1]	Description	Measure	Responsible
ETH ID 4.1-7	CO report	Recommend that, as a best practice, the combined data results from explicit and implicit feedback be tagged, to indicate that active operator choices (explicit feedback) make up part of it	UPDATE: Implicit and explicit feedback information will be stored in separate fields of the internal DB to distinguish the source of the information. (explicit/implicit)	TEK CONTI INOS

[1] As ethic by design involve new requirement as the development are going on, the requirement table shows the deliverable or report and the requirement numbering following the ethic numbering rules there.

2.2.3 Implementation and Deployment in AI-PROFICIENT platform

The implementation and the deployment in the AI-PROFICIENT platform of the reinforcement mechanism based on the human-feedback in CONTI5 use case is shown below.

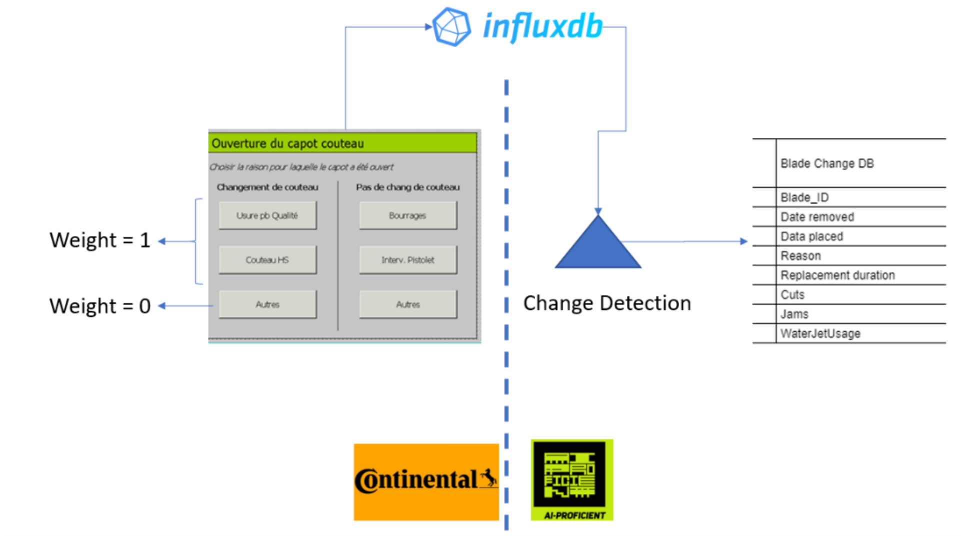

Figure 4: CONTI5 feedback management deployment for reinforcement

When the operators choose an option on the pop-up the signal is sent to InfluxDB. The Blade change detection algorithm keeps looking for blade changes and, one a blade change occurs, it updates the BladeChange DB with the Reason (the user explicit feedback) and records the cuts that the blade carried out (which is used for the explicit feedback).

2.3 CONTI10: Quality analysis tool

2.3.1 Solution

The Quality analysis tool aims to monitor relevant process signals and to alert the user when the deviation in certain product characteristics is predicted, with the decision support provided in order to prevent further deterioration. This shop floor assistance will comprise the information about the potential cause of the deviation and (sub)optimal sets of recommended readjustments that could be taken by the user. However, the quality of described direction of the user-tool communication can be highly improved through proper integration of the users' feedback regarding the tool's outcomes. The current approach in collecting feedback envisions both explicit and implicit feedback, among which the implicit ones can be used in any phase of tool deployment (both testing and later active use in production).

The initial architecture of the CONTI10 tool includes following services:

- Post-hoc Explainable Anomaly Analysis (PEAA),
- Short-term Post-hoc Anomaly Analysis (SPAA),
- Surrogate Explainable Data Driven Model (SEDDM),
- Generative Holistic Optimization (GHO), and
- Natural Voice interaction module (NVI),

where SPAA, NVI and GHO implement the concept of reinforcement learning pipeline, based on the user feedback. The purpose of the collected feedbacks differs from service to service, meaning that SPAA collects the feedback and engages it in improvement of root cause identification submodule, GHO does that to improve quality of the process optimizer suggestions and, finally, NVI performs acquiring of the feedback for the GHO, by interpreting voice commands.

The final deployed version of the Quality analysis tool will not involve NVI, due to a noisy environment in the production line and difficulty to use it in those conditions. This decision led to creation of the alternative way of displaying GHO results and feedback gathering. For that purpose, joint CONTI dashboard (human machine interface) will be used, where all the interfaces are integrated and organized in several frames, each of them dedicated to specific service.

More detail on the reinforcement learning concept and the deployment behind each of the services, is available in the following, while detail on services final visualization can be found in the deliverable 4.3.

2.3.1.1 Implicit feedback

Generally speaking, under implicit feedback are meant the control actions (changes of some reference values) made by the operator after the event of interest (some disturbance in the process occurred that has been considered as a potential cause, or the deviation, in product characteristics, is already present). GHO is an example of CONTI10 service, that will benefit from this kind of feedback. The implicit feedback processing is realized as an internal module within the service and will allow for retraining of the service in absence of the explicit feedback.

2.3.1.2 Explicit feedback

Concerning provided suggestions of relevant process variables set-points values, the explicit feedback can be extracted from users' actions made through the human machine interface (HMI), while the following scenarios are possible:

- User selected one of the suboptimal set of parameters as an indicator of his/her agreement,
- User selected the "none of the above" option, indicating that that there is no appropriate suggestion, derived from expert knowledge,
- User declined to make a choice.

Regarding anomaly detection, root cause identification and feedback of the user in that term, an explicit approach is considered, in at least the testing phase, using the HMI. Similarly, to the previous scenario distinction, there are the following options:

- "Recommendation does not correct; the cause is an improper setting of (a drop-down menu will appear with listed potential causes)",
- "Recommendation does not correct; but the cause is still unknown to the operator and/or to the quality manager",
- "Recommendation correct".

Concrete wording is given for the sake of illustration and, such that it is prone to modifications. Anyhow, those scenarios are the general descriptions of two existing systems of collecting the explicit feedback within CONTI10 use case:

- Natural Voice Interaction module, accompanied to Generative Holistic Optimization, and
- Short-term Post hoc Anomaly Analysis (SPAA) feedback collection system.

Both systems are supposed to display results created by certain services within the Quality Analysis Tool, while allowing for interaction with the operator and the acquisition of his/her feedback on the provided outputs. Details of the developed feedback collection system prototypes are described, even though, in the final version of the tool, they are combined in unique HMI, in order to allow for a more comfortable user experience.

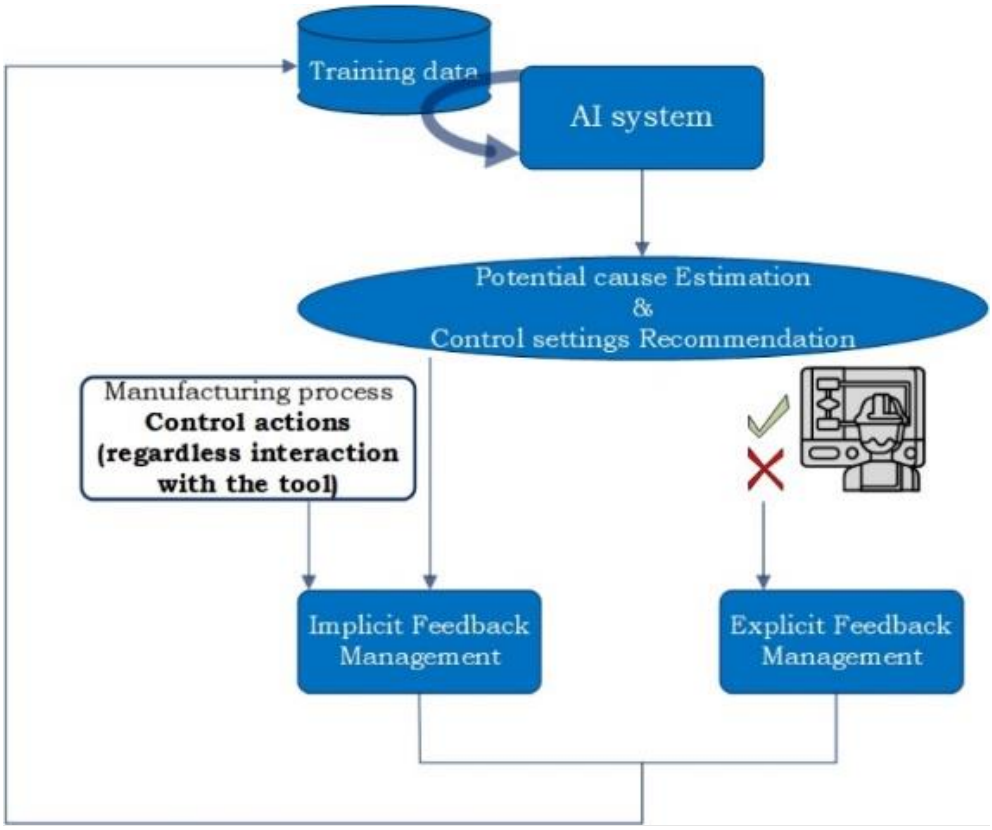

Figure 5: CONTI10 reinforcement-based flow

2.3.2 Ethical aspects – Ethics Team

Ethical issues related to CONTI10 for Human-Machine feedback management and the measures that are planned to address them are shown in the following table. Note that these recommendations were presented already in Deliverable 4.5, but we include them here again with an update of the ETHICS CODE designation, as well as of NA status in some cases due to development decision changes as described in the Ethics section below.

Table 5: Ethical issues for Human Feedback Management in CONTI10 use case.

ETHICS CODE	CODE ORIGIN[2]	Description	Measure	Responsible
ETH ID 4.1-7	CO Report	Recommend that, as a best practice, the combined data results from explicit and implicit feedback be tagged, to indicate that active operator choices (explicit feedback) make up part of it	An additional parameter will be included representing the origin of the data (explicit/implicit)	IBE IMP ATC
ETH ID 4.1-8	CO Report	Given that voice data is inherently sensitive data, recommended that best practices on ethics side similar to measures of Article 5(b) GDPR be implemented regardless of legal compliance requirements	~~Elaborate for voice: purpose; amount; deletion measures; use and deletion timeline; encryption approach; data region and storage~~.	IBE IMP ATC

[2] As ethic by design involve new requirement as the development are going on, the requirement table shows the deliverable or report and the requirement numbering following the ethic numbering rules there.

			** Now NA	
ETH ID 4.1-9	CO Report	Recommend formulate a data minimization plan, to be used in further deliverables as needed and as promoting best practices in future projects	Outline a data minimization plan	Continental; IMP; IBE; ATC
ETH ID 4.1-10	CO Report	Recommend that as an ethics best practice in spirit of GDPR, demonstrable consent for natural voice feedback be asked of operators and quality managers, regardless of legal compliance	~~Written consent for natural voice feedback data~~ ** Now NA	Continental; IMP; IBE; ATC;
ETH ID 4.1-11	CO Report	Apps are not being developed in the native language of the operators. Recommend that industrial and technical partners develop a clear, detailed, and practical plan for how they will bridge the language gap or difficulties related to operator language and HMI use	Consider solutions such as bringing in outside (French speaking) resources to help develop the app in French rather than translate after development.	Continental; IBE

2.3.3 Implementation and Deployment in AI-PROFICIENT platform

2.3.3.1 Natural Voice Interaction module

Since D4.5, the decision of not using natural voice interaction has been taken. Nevertheless, as work has been done on this topic, we decided to present it below in D3.5. Indeed, the results could be used as a service for the next development of AI-PROFICENT where NCI is needed. NVI should have been utilized to gather explicit feedback associated with the outputs of optimization service within the Quality Analysis Tool. For that purpose, a web application, based on the cognitive services offered by Microsoft Azure, has been developed. See D4.5 for further explanations.

This service aims to be a tool for operators to provide explicit feedback on the decision support system.

The system is built on a MySQL database as a central component, where information from both the AI-Proficient platform's recommendation models and user interaction is stored. Interaction with this information takes place through specific visual and voice interfaces.

The NVI interface will interpret the voice commands from the operator with the information pre-trained from the models stored in the MySQL database. Those pre-trained suggestions of different actions will be shown to the operator to complete the pending action.

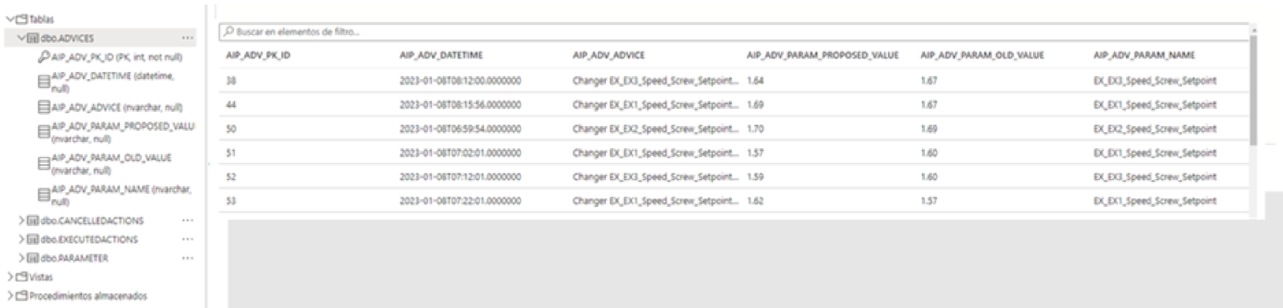

Figure 6: NVI Interaction BD

The general schema of the interaction is shown in Figure 7.

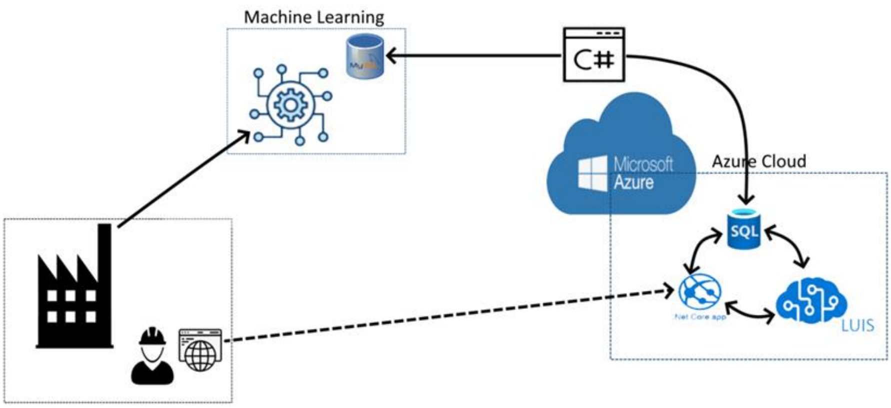

Figure 7: CONTI10 explicit feedback management approach

The suggestions provided by the decision making are displayed in a web interface, and operators and managers will interact with them through a series of intentions available with voice commands. The operator can access the ASP.NET application deployed in Azure using a browser (Chrome, Firefox, Edge) on a computer with an Internet connection through the following URL: https://aiproficientsite.azurewebsites.net/.

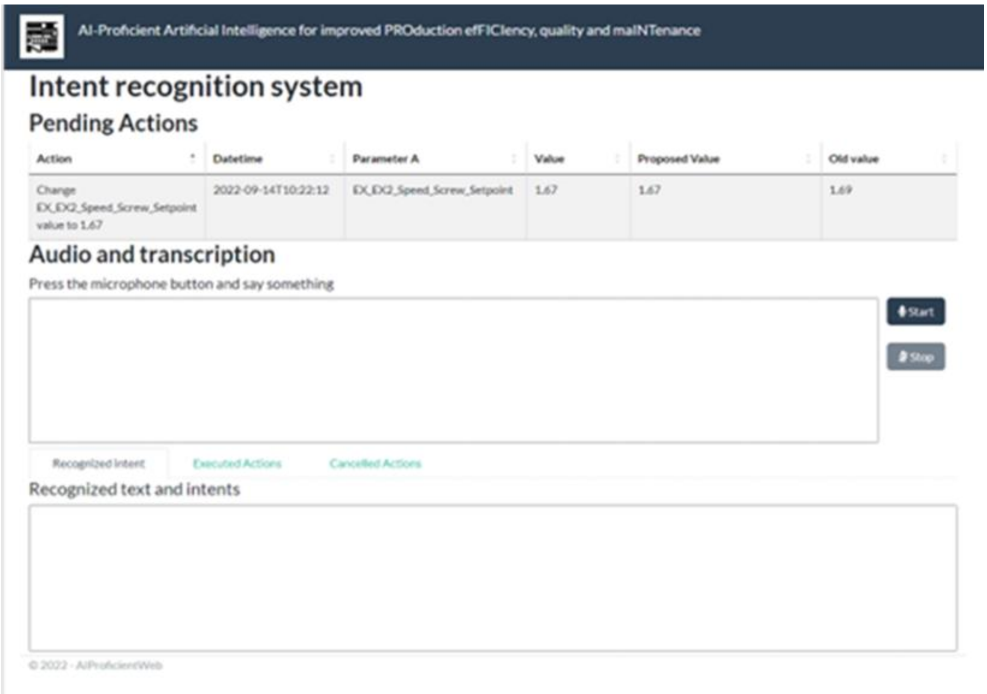

Figure 8: CONTI10 explicit feedback interface (original from D4.5)

Following the recommendations of the ethics team (ETHIC 4.1-1), the web interface has also been translated into French. For this purpose, the translation of intentions and actions has been worked out with Conti staff for the NVI. The corresponding French terms have been reported in a table to ensure the completeness of the translation (see Figure 9). The original English interface (see Figure 8) has been translated into French and is presented in Figure 10. The French interface is also available at URL: https://aiproficientsitefr.azurewebsites.net/

			Proposed Value	Other possibility	Other possibility
Intent	Accept	confirm	confirmer		
		alright	bien	Ok	
		change value	modifier la valeur		
		it's ok	c'est bon	C'est ok	
		ok	d'accord	C'est ok	
		execute action	exécuter une action	Exécuter l'action	Exécuter cette action
		execute	exécuter		
		accept action	accepter l'action	Accepter cette action	
	Cancel	decline	~~déclin~~	Refuser	
		cancel	annuler	Abandonner	
		delete	effacer		
	Next advice	next tip	Prochain conseil		
		next step	L'étape suivante	Etape suivante	
		optimize the process	optimiser le processus	Optimiser	Optimisation du processus
		how can I optimize the process?	comment puis-je optimiser le processus ?		
		what's the next tip?	quel est le prochain conseil ?	Conseil suivant	Prochain conseil
		what is the next tip?	quel est le prochain conseil ?	Conseil suivant	Prochain conseil
	Change parameter value	set parameterA to {value}	définir le paramètreA sur {valeur}	Définir A sur {valeur}	Mettre A à {valeur}
		set parameterB to {value}	définir le paramètre B sur {valeur}	Définir B sur {valeur}	Mettre B à {valeur}
		set parameterC to {value}	définir le paramètreC sur {valeur}	Définir C sur {valeur}	Mettre C à {valeur}
		set parameter1 to {value}	définir le paramètre1 sur {valeur}	Définir 1 sur {valeur}	Mettre 1 à {valeur}
		set parameter2 to {value}	définir le paramètre2 sur {valeur}	Définir 2 sur {valeur}	Mettre 2 à {valeur}
		set parameter3 to {value}	définir le paramètre 3 sur {valeur}	Définir 3 sur {valeur}	Mettre 3 à {valeur}
		~~set A parameter to {value}~~	~~définir un paramètre sur {valeur}~~		
		~~set B parameter to {value}~~	~~définir le paramètre B sur {valeur}~~		
		~~set C parameter to {value}~~	~~définir le paramètre C sur {valeur}~~		
		set A parameter value to {value}	définir la valeur du paramètre A sur {valeur}		
		set B parameter value to {value}	définir la valeur du paramètre B sur {valeur}		
		set C parameter value to {value}	définir la valeur du paramètre C sur {valeur}		

Figure 9: Intents translated to French.

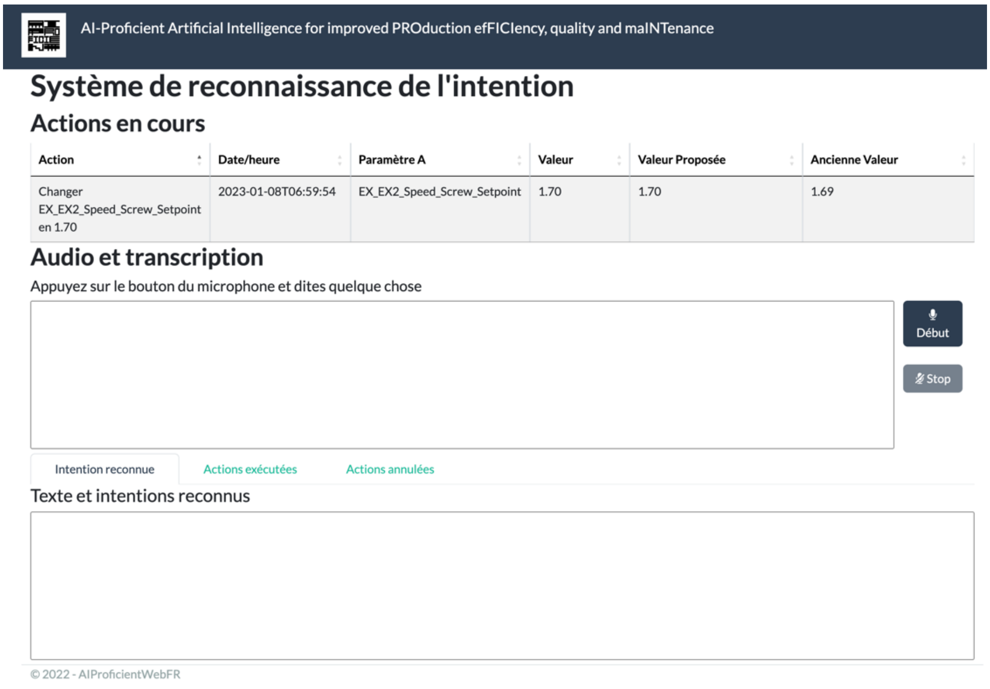

Figure 10: CONTI10 explicit feedback interface translated in French.

The full description of the interface is available in D4.5. The interface is divided into three sections:

- Pending Actions: Display the pending actions for decision making.
- Audio and transcription: In this section, the voice commands of the operator are transcribed.
- Recognized text and intents: In this section, three different tabs are envisioned: Recognized Intent, Executed Actions, Canceled Actions.

The collected status of users' actions (both operators' and quality managers') is recorded in the database in a compliant manner (as suitable datatype) and further available to the services within the tool, where the optimization service is the one that primarily will benefit from them. Following the recommendations of the ethics team (ETHIC 4.1-7) the voice interaction is collected as implicit feedback. Following the recommendations of the ethics team (ETHIC 4.1-8) the system does not permanently collect the voice of the interacting user so that the GPDR is preserved. Additionally, the system was prepared to be moved to specific company Azure hosting.

The system has been tested in the Continental plant, but due to the noise within the plant near the combiline, and the difficulty of deploying a microphone system that minimizes this problem, the system will not be deployed in permanent model.

2.3.3.2 Short-term Post hoc Anomaly Analysis (SPAA) feedback collection system

The Short-term Post hoc Anomaly Analysis (SPAA) implements a mechanism to monitor process related signals and alert the user in case an anomaly. SPAA is monitoring real-time width, weight, length, and thickness measurements, and if a deviation is found then an analysis of 60-second data begins. This analysis aims to find out what caused the deviation. The alerts towards the end user consist of notifications of anomalies detected as well as potential factors of the process responsible for this deviation. The tool has also an underlying mechanism of collecting human feedback from the users and subsequently updating and optimizing the backbone service components of the tool which are the Anomaly Detection and the Root Cause Analysis module. The Short-term Post hoc Anomaly Analysis (SPAA) implements a mechanism named Short-term Post hoc Anomaly Analysis feedback collection system (SPAAFCS). The SPAAFCS is responsible of collecting human feedback from the users and subsequently updating and optimizing the backbone service components of the tool which are the Anomaly Detection and the Root Cause Analysis module. The main objective of the explicit feedback provided through the Short-term Post-hock Anomaly Analysis feedback collection system is to optimize the performance of the whole tool. The feedback is used to populate the Anomaly Detection knowledge base, whereas in the case of the Root Cause Analysis, in future work a side model will be trained and redeployed, and thus leveraging the reinforcement learning mechanism, to provide more accurate predictions towards the user. Data from the feedback that are needed to improve the model are stored on a mysql database. The SPAAFCS is interconnected with a User Interface provided by Tenforce. The user interface aims to give the user a clear picture of what is happening in production and an easy way to report incorrect model results. For the integration with the UI the following functions has been implemented on SPAA

- Status Endpoint: Returns the current or last outcome of the analysis.
- Report Anomaly Detection outcome Endpoint: Marks Anomaly Detection’s outcome as erroneous and stores the frame with correct outcome to use it for future training.
- Report Root Cause Analysis outcome Endpoint: Marks Root Cause Analysis outcome as erroneous and stores the frame with correct outcome to use it for future training. UI must provide the root causes.

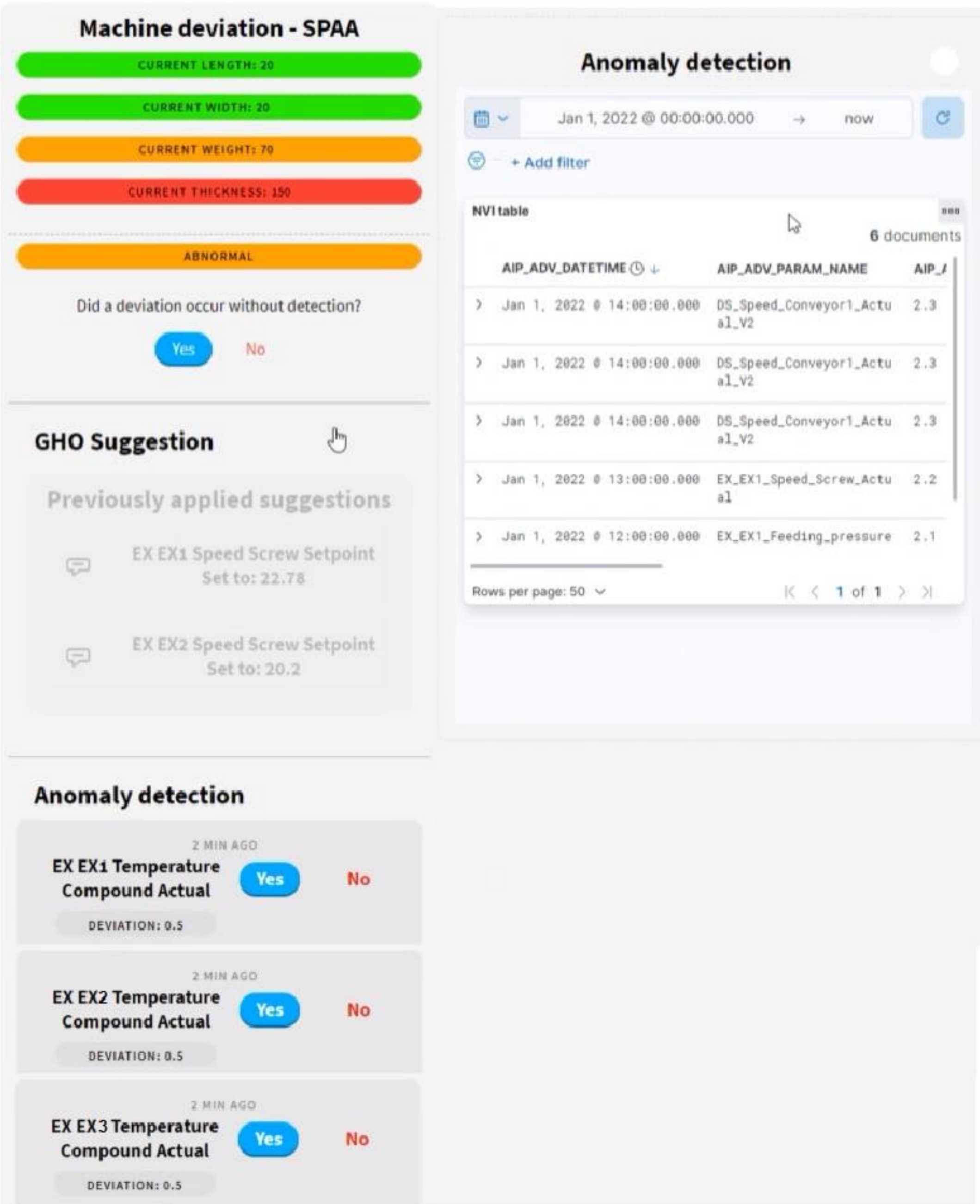

Figure 11: SPAA User Interface

In addition, we have implemented other functions which can be used in future works or secondary user interfaces.

- Historical data endpoint: Returns all or within a date range outcomes.
- Report Anomaly Detection outcome on past data: Return all or within a date range Anomaly Detection outcomes that have been reported by a user.
- Report Root Cause Analysis outcome on past data: Return all or within a date range Root Cause Analysis outcomes that have been reported by a user.
- Revert a "report" on an outcome: If an outcome has been reported as erroneous by accident then using that endpoint the action can be reverted.

Finally, Short-term Post-hock Anomaly Analysis implements a mechanism named Short-term Post-hock Anomaly Analysis Improvement System (SPAAIS). SPAAIS is responsible for the optimization of the model. Every 24-hours the mechanism is checking the database if there are available data stored that can be used for improvement in case there are enough data then a model training starts. When model training is over it performs a soft restart on the service with the newest and improved model.

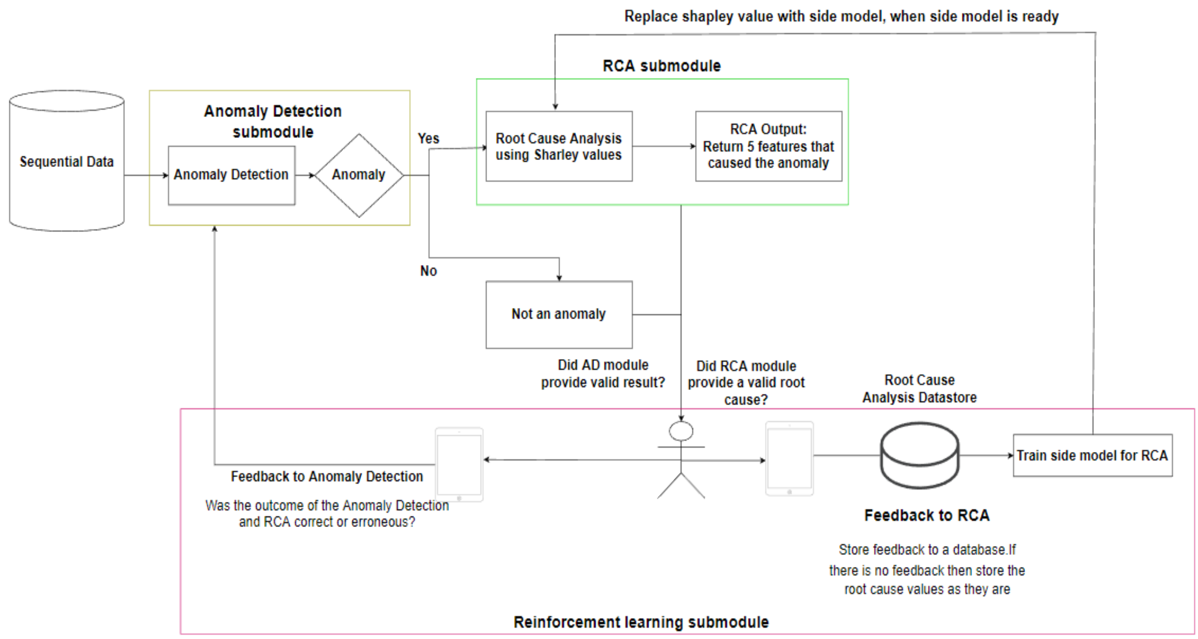

Figure 12: CONTI10 SPAAFCS Tool Architecture

In the figure above, a high-level modular blueprint of the Short-term Post hoc Anomaly Analysis feedback collection system is provided. The HMI layer resides on the bottom of the blueprint where a Native Application is provided to the user.

For the purposes of improving both the content presented through the Short-term Post hoc Anomaly Analysis feedback collection system, and demonstration of the whole User Experience, an application has been developed. The app has been developed using react native framework and is also compatible with smartphone devices. Through the app, specific user actions can be aggregated and analyzed to provide explicit feedback. Some indicative applicable scenarios, already reported in D4.5, are:

- The user reports manually a possible anomaly event in case the Analysis Tool has not identified it.
- The user provides correction on an erroneous anomaly alarm indicated by the SPAAFCS
- The user has selected a root cause belonging to the possible options suggested by the tool.
- The user has selected a root cause belonging to the possible options belonging to a lower position in ranking of potential root causes.
- The user has selected to provide a different root cause, not belonging in the possible causes identified by the tool.
- The user has failed to provide the requested information on every level of the application.
- The user can access older metrics and provide correction on an erroneous anomaly alarm indicated by the Analysis Tool
- The user can access older metrics and provide correction on an erroneous root cause analysis, indicated by the SPAAFCS.
- The user can see which frames have already reported.

In the first prototype of the Native App the user has the option to:

- Initiate live monitoring of the process.
- Access historical data collected.
- Accept alerts about Anomalies Detected and correct them in case they are erroneous.
- Select potential root causes predicted by the tool or suggest alternative ones.

- Report an Anomaly
- Report a Root Cause

The prototype native application consists of two main features:

a) Live Monitoring

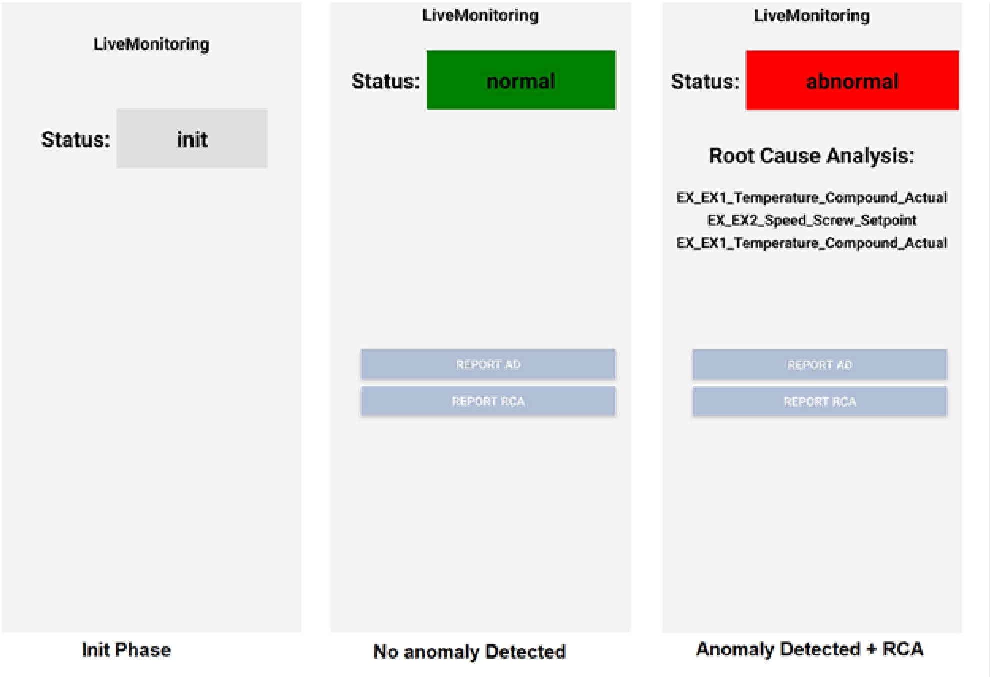

Figure 13: Live Monitoring screen

Through live monitoring the user can see live if there is an anomaly or not on the production line. The “Status” indicates the machine’s state based on the live metrics and in case there is an anomaly the root causes will be shown to the user. The user has the option to report the outcome if the outcome is erroneous by pressing the “Report AD” button or “Report RCA” in case he wants to report Root Cause Analysis. User’s feedback is stored on a separate database and the data will be used to optimize the models.

b) History Monitoring

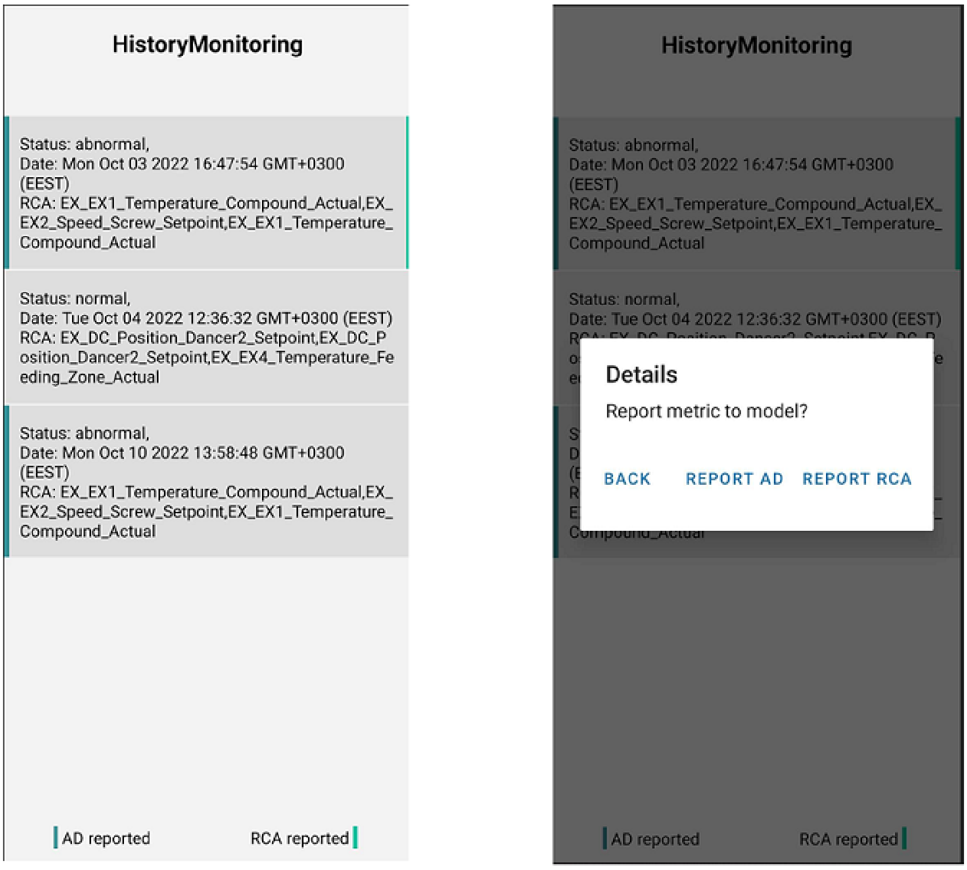

Figure *14*: History Monitoring screen

Through historical monitoring, the user can see past metrics and outcomes. The user can report an erroneous outcome that happened in the past or check the incidents that already have been reported. The “zomp” color on the left indicates that the user has already reported the metric to the anomaly detection module and the “caribbean green” color on the right indicates that the user has already reported the metric to the Root Cause Analysis module.

The application is currently used for demo purposes. With further development, it can add the capability of having monitoring "on the go" in the future.

2.3.3.3 Generative Holistic Optimizer (GHO) feedback collection

The modular structure of Generative Holistic Optimizer (GHO) envisions the existence of time-series clustering, multi-objective evolutionary algorithm and reinforcement learning modules. The service works on demand, being triggered by detected or predicted deviation in production quality, that could be performed by two other services (Short-term Post-hoc Anomaly Analysis and Surrogate Data-Driven Models), see Figure 15, or by the inner triggering system, which is not the case in CONTI10 use case service instance.

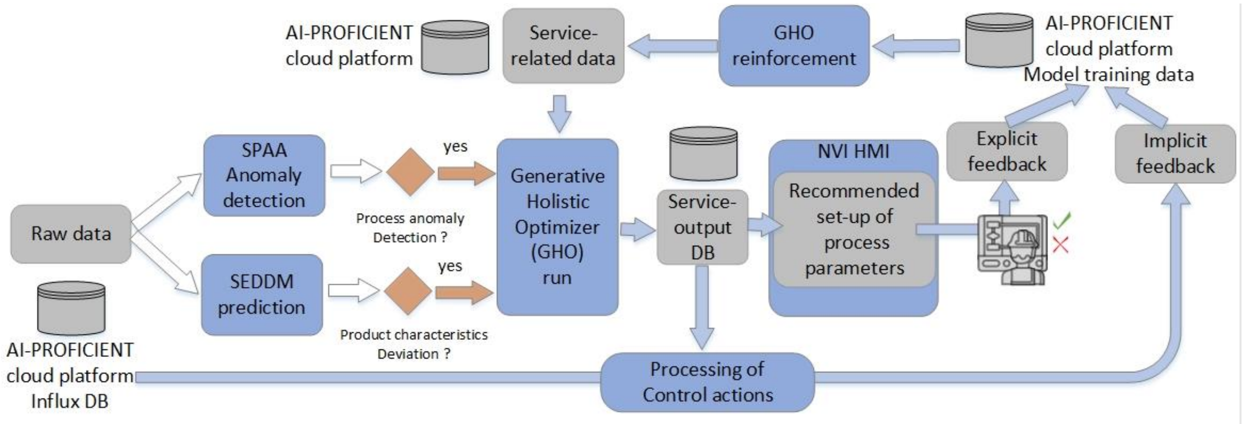

Figure 15: GHO reinforcement pipeline schema

At the moment of triggering, the service performs initialization of optimization algorithm, by identifying the cluster to which the current working point in production belongs to. To be able to perform so, the service connects to the auxiliary time-series model repository (service-related data, in figure below) and identifies the auxiliary model that encapsulates distribution of data around the working point under consideration.

Those auxiliary models are created in the offline training phase and their purpose is to steer the optimization algorithm. Essentially, they are the objects of retraining in the reinforcement part of service pipeline and retraining is performed using the collected end-user feedbacks, stored in feedback collection tables (see Figure 16). This table is populated with data coming from the user-machine interaction and with data generated by service. The first one is so-called explicit feedback, that is an optional and desirable way of evaluating the GHO outputs/suggestions.

The second one is implicit feedback, which is automatically created by the service and does not require intervention of the user. Namely, after the service run execution and output display on the dashboard, the pulling of the Influx DB with the production real-time data starts and lasts for a certain period. If it is identified that process parameter, which has been suggested for readjustment, is changed and depending on whether it is changed to the suggested value or another value, the feedback will be created, labelled accordingly and stored in the MySQL database, in the convenient format.

Finally, in the sleep time of the service, the reinforcement module is run and carries out the auxiliary models retraining, that are further stored in the aforementioned model repository and used in the first next optimizer run.

Figure 16: Feedback data management within CONTI10 GHO service

2.4 INEOS1: Reactor stability at Geel plant

As the GHO service, including feedback, means of the integration for this use case, highly rely on the digital twin final realization, the development activity is still ongoing and more tangible results will be provided in the final technical progress report. Indeed, the final Digital Twin for INEOS-1 use case will be delivered at end of M30 at the same time as the present deliverable. As such the development of the GHO, which required the DT, will take place after and the feedback will follow.

Hence, this system is like the one described as a part of the section related to CONTI10 use case, with details including both explicit and implicit feedback. The explicit one will be present through the HMI developed as a part of tasks 4.2 and 4.3 where operators will be able to accept, reject and not respond to the suggested action. On the other hand, by analyzing the actions taken by the operator after the recommendation, additional feedback regarding the recommendation quality could be extracted.

Hence, the implementation of the GHO reinforcement pipeline will look like the one in CONTI10 tool, Figure 16, with the adaption needed to meet specific INEOS-1 requirements. Namely, the subject of process optimization, and therefore feedbacks provided, will be reactor-related control parameters, while the auxiliary suffix-trees models will model the distribution of the INEOS1 reactor data.

2.4.1 Ethical aspects – Ethics Team

Ethical issues related to INEOS1 for Human-Machine feedback management and the measures that are planned to address them are shown in the following table. Note that these recommendations were presented already in Deliverable 4.5, but we include them here again with an update of the ETHICS CODE designation, as well as of NA status in some cases due to development decision changes as described in the Ethics section below.

Table 6: Ethical issues for Human Feedback Management in INEOS1 use case.

ETHICS CODE	CODE ORIGIN	Description	Measure	Responsible
ETH ID 4.1-7	CO Report	Recommend that, as a best practice, the combined data results from explicit and implicit feedback be tagged, to indicate that active operator choices (explicit feedback) make up part of it	An additional parameter will be included representing the origin of the data (explicit/implicit)	IBE IMP
ETH ID 4.1-8	CO Report	Given that voice data is inherently sensitive data, recommended that best practices on ethics side similar to measures of Article 5(b) GDPR be implemented regardless of legal compliance requirements	~~Elaborate for voice: purpose; amount; deletion measures; use and deletion timeline; encryption approach; data region and storage.~~ ** Now NA	Ineos; IMP; IBE
ETH ID 4.1-10	CO Report	Recommend that as an ethics best practice in spirit of GDPR, demonstrable consent for natural voice feedback be asked of operators and quality managers, regardless of legal compliance	~~Written consent for natural voice feedback data~~ ** Now NA	Ineos; IMP; IBE
ETH ID 4.1-11	CO Report	Apps are not being developed in the native language of the operators. Recommend that industrial and technical partners develop a clear, detailed, and practical plan for how they will bridge the language gap or difficulties related to operator language and HMI use	Appropriate solution for language issues and developing that solution directly with the operator cooperation to see what works best for them.	Ineos; IMP; IBE

2.4.2 Implementation and Deployment in AI-PROFICIENT platform

The implementation and the deployment in the AI-PROFICIENT platform of the reinforcement mechanism based on the human-feedback will be reported in the WP5 and the periodic technical report.

2.5 INEOS2: Image recognition at Geel plant

In this use case, Optical Character Recognition (OCR) is employed to read labels on the additives packaging at the INEOS Geel plant with a mobile device. The labels are scanned for text which is matched against known product names and lot numbers, so INEOS's quality control system can verify whether the right additive bag is used at the right feeder.

The operator is kept in the loop to verify the AI's match on the mobile device before sending it to the quality control system, correcting text recognition mistakes and completing missing product data.

The main additions with respect to D4.5 are in section 2.5.3.

2.5.1 Solution

2.5.1.1 Explicit feedback

The data matching AI is continuously trained as new data comes in. This data comes from two sources.

- The first source is an automatic daily copy of INEOS's product database, which gets updated as new shipments of additive bags come in.
- The second source is explicit feedback from the operator during the label scanning procedure. If an additive bag is not known to INEOS's product database, the matching AI cannot extract the relevant information from the label. The operator is the only actor who can provide the correct information at this point of the additive loading process. The updated product data is fed back to the AI system and INEOS's product database to avoid further issues.

2.5.1.2 Implicit feedback

The label pictures with their approved or corrected text are saved on TenForce servers to allow us to make informed, data-based decisions when improving parts of the system. We anticipate two opportunities to use this data.

- Using Google's cloud OCR service gives very good recognition results, but it might not be the fastest or securest option. When deciding on a replacement for the OCR module, this data will be invaluable for evaluating the performance of each system. With enough images it might even be possible to train a custom OCR model for the use case.
- The bar is set very low for signaling an uncertain recognition. In most cases, no correction will be needed. With more training data it will be possible to make the AI system more confident, thus minimizing the number of times we ask for explicit feedback from the operator.

No automatic reinforcement happens using implicit feedback.

2.5.2 Ethical aspects – Ethics Team

Ethical issues related to INEOS2 for Human-Machine feedback management and the measures that are planned to address them are shown in the following table. Note that these recommendations were presented already in Deliverable 4.5, but we include them here again with an update of the ETHICS CODE designation, as well as of NA status in some cases due to development decision changes as described in the Ethics section below.

Table 7: Ethical issues for Human Feedback Management in INEOS2 use case.

ETHICS CODE	CODE ORIGIN[3]	Description	Measure	Responsible
ETH I-G UC 2 ID 6	CO Report	AI Errors handling	The responsible partners will develop a protocol to address the 1% of cases where the AI itself will make an error, or where the operator	INEOS

[3] As ethic by design involve new requirement as the development are going on, the requirement table shows the deliverable or report and the requirement numbering following the ethic numbering rules there.

			(or Control room Quality manager) will make an error relative to the AI suggestion, i.e., a clear set of instructions about what to do in this or this case	
ETH ID 4.1-2	CO Report	Definition of tasks after AI suggestions arrives	The responsible partners will create processes to clarify to the Control room Quality manager exactly what he is supposed to do once AI suggestions start coming for the DCS.	INEOS
ETH ID 4.1-3	CO Report	AI errors propagation handling	The responsible partners will undertake a conceptual analysis of the hypothetical situation in which an AI error may occur and, try to identify the propagation points at which it could be caught before causing a product problem, leading to strengthen and thus, contributing to minimize even eliminate the AI error.	TF TEK ATC INEOS
ETH ID 4.1-7	CO Report	Recommend that, as a best practice, the combined data results from explicit and implicit feedback be tagged, to indicate that active operator choices (explicit feedback) make up part of it	An additional parameter will be included representing the origin of the data (explicit/implicit)	TF TEK ATC INEOS
ETH ID 4.1-8	CO Report	Given that voice data is inherently sensitive data, recommended that best practices on ethics side like measures of Article 5(b) GDPR be implemented regardless of legal compliance requirements	~~Elaborate for voice: purpose; amount; deletion measures; use and deletion timeline; encryption approach; data region and storage.~~ ** Now NA	Ineos; TF; ATC
ETH ID 4.1-9	CO Report	Recommend formulate a data minimization plan, to be used in further deliverables as needed and as promoting ethical best practices in future projects	Outline a data minimization plan	INEOS; TF; ATC
ETH ID 4.1-10	CO Report	Recommend that as an ethics best practice in spirit of GDPR, demonstrable consent for natural voice feedback be asked of operators and quality managers, regardless of legal compliance	~~Written consent for natural voice feedback data~~ ** Now NA	Ineos; TF; ATC
ETH ID 4.1-11	CO Report	Apps are not being developed in the native language of the operators. Recommend that industrial and technical partners develop a clear, detailed, and practical plan for how they will bridge the	ensuring that the app has simple and clear non or minimalist voice option/framework which operators can switch to completely at need and developing that option/framework directly with the operator cooperation to see what works best for them.	INEOS; TF; ATC

		language gap or difficulties related to operator language and HMI use		

2.5.3 Implementation and Deployment in AI-PROFICIENT platform

The system is composed of three main parts: the HMI device, TenForce's AI system, and INEOS's DCS systems. The HMI is a mobile app with a dedicated user experience flow to guide an operator through the process of checking in an additive big bag at a feeder with the DCS. Before checking in, the operator can verify and correct the values recognized by the AI system and by doing so, give explicit feedback to improve the system.

The AI system is deployed on the TenForce backend which has a direct HTTPS connection with the mobile application. It consists of an OCR system and a data matching module. The OCR system uses Google's cloud OCR service and does some text post-processing to improve results. The matching module is developed inhouse using FuzzySharp. It requires an up-to-date copy of INEOS's product database to give relevant matches.

The TenForce backend communicates with INEOS's DCS system (i.e., the product database and the check-in system) using Azure Service Bus. No direct connection is made, to avoid any security issues on INEOS's network.

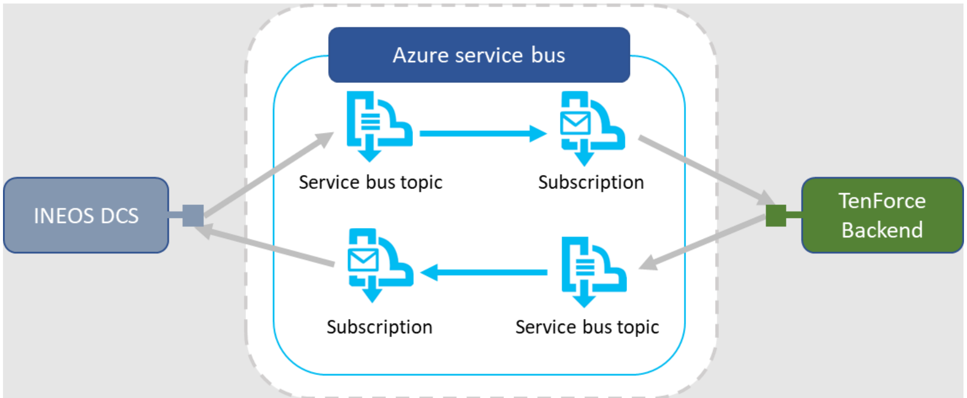

Figure 17: INEOS2 Azure Service Bus

The user flow and system interactions are illustrated in the diagram below. The user's actions are denoted in the orange column, while the system's actions are described in the green columns. The blue columns are the INEOS system which the system interacts with.

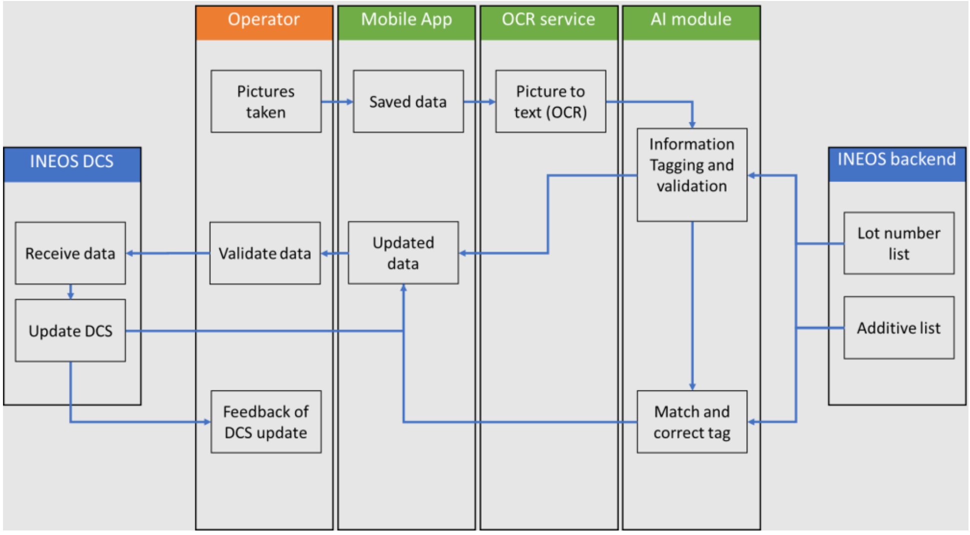

Figure 18: INEOS2 user flow and system interactions

The system was developed with continuous feedback from INEOS to find bugs, clear up the specifications, and improve the user experience flow and AI accuracy. The final version has been accepted by operators who will be using the app onsite, and it is currently in use for real life testing.

2.6 INEOS3: Rheology drift at Cologne plant

The implementation and deployment of the reinforcement mechanism based on human feedback within this use case has been stopped due to a final decision made by the pilot after the use case validation process. Namely, the problem under consideration in the INEOS3 use case had to undergo validation process, as at the beginning it was unclear whether the real reason of product quality degradation lies in the extrusion part of the process or not.

Two iterations of data analysis were carried out using datasets collected with different methodologies. The first one contained recordings of the rheology parameters measured on small samples taken from the storage charged for long period (approximately 10 hours) of production, making it difficult to correlate those rheology labels with the anomaly patterns in extrusion process data. However, causal discovery had been performed with the available process data, and cause-effect relations were created with regard to the intermediate calculated variable, which has been considered as correlated with rheology parameters, but archived with higher frequency than rheology, and till now, used by the pilot as some kind of indication of future rheology degradation.

The second iteration of analysis has been carried out on a dataset created with a different methodology. Essentially, samples were taken immediately after leaving the production line, allowing for proper labeling of the process dataset. The results obtained were in accordance with the first iteration of analysis, with the added value of stronger cause-effect relations between extrusion process data points and rheology data (that new data collection methodology allowed). These causal relations will further be used as heuristics in decision making.

The pilot owners see the value of offline data analysis and find it sufficient on the project and the use case level. Therefore, they decided not to proceed with the AI platform setup and online services engagement, which consequently led to the absence of the reinforcement mechanism implementation and application in this use case.

3 Ethical Issues

This section report the exchange in the task 3.5 about ethical considerations. A first part report the exchanges that took place during the meeting and a second part gives the several ethical recommendations specific to Task 3.5.

3.1 Cologne meeting - (Feb 13/2023)

At recent meetings during the Cologne Ineos plant visit, the issue of the implementation of GDPR related recommendations given for Task 4.1 was raised. In discussion, several partners indicated that natural voice interaction for feedback would no longer be considered as part of various services because it was not feasible due to the noise levels at the plants. If the latter is so, then the ethics team indicated that they would update several of the related recommendations to NA (no longer applicable), as has been their practice so far when proposed solutions have changed; but they requested definite confirmation of natural voice interaction not being used, in the context of Deliverable 3.5, which was envisioned in part as taking up unresolved issues from Deliverable 4.1.

The use of red/green ‘traffic’ light combinations in the visual interface proposals for several of the services also raised the issue of potential color blindness in the operators, particularly given that about 50% of people who are colorblind are unaware that they are. The ethics team thus suggested a simple colorblindness test for the users.

3.2 Recommendations, Task 3.5 Specific.

#	Description	Mitigation Measure
ETH ID 3.5-1	(Continental, Ineos, UL) Recommend that you confirm in Deliverable 3.5 that natural voice interaction will no longer be used at shop floor level for operator feedback or operator interface control, i.e., that no user voice data will be gathered directly by partners or processed indirectly through third parties such as Microsoft Azure Luis or Google	Both INEOS and Continental confirmed that NVI will no longer be used.
ETH ID 3.5-2	(Continental and Ineos) Recommend that you carry out a colour-blindness test for all operators and engineers who will potentially use the user interfaces	Both Continental and Ineos committed to such a test, either as a specific response to the recommendation (Continental) or as a part of annual in-house employee examination (Ineos)

4 Conclusions

In continuity of D4.1 and 4.5, the deliverable presents the different mechanisms for human feedback management for reinforcement learning explored in AI-PROFICIENT, distinguishing the 2 main types of feedback: ***implicit feedback***, and ***explicit feedback***.

Modifying the data workflow to include a "comparison" step that looks at both the AI-models' outputs and the real data can almost solve the development for implicit feedback. However, explicit feedback requires specific solutions development, which includes at least an interface for human interaction and interpreting the feedback. The feedback gathering channel will determine whether simple tag interpretations or more advanced technologies such as natural language processing should be considered.

The different approaches foreseen at the beginning of the T4.1 and continued in the T3.5 have been tested, at the time of delivering D3.5, through 4 different AI-PROFICIENT use cases (1 has been stopped by the pilot leader, INEOS, one being in standby). The following table presents a summary of the different feedback management approaches implemented (or in progress) in the different use cases.

Table 8: Human Feedback management components summary.

UC	Human Feedback Component	Responsible
CONTI2	Implicit & Shopfloor explicit feedback management	TEK
CONTI5	Implicit & Shopfloor interface based explicit feedback management	TEK, CONTI, INOS
CONTI10	Implicit & Web-based explicit feedback management	IBE, IMP, ATC
INEOS1	To be implemented like CONTI10	IMP, IBE
INEOS2	Explicit feedback management	TF
INEOS3	INEOS decided to stop	IMP

Apart from technical challenges, the implementation of explicit human feedback management mechanisms raises ethical issues that require careful analysis to ensure GDPR compliance and protect human well-being. The AI-PROFICIENT project has considered ethical aspects in the 4 already-developed use cases that involve human feedback management by analyzing the explicit feedback gathering mechanisms with ethics experts on a case-by-case basis. Each use case was examined to identify a set of ethical considerations, and the technical team, in collaboration with the use case leader, defined measures to mitigate or resolve them.

Finally. As detailed throughout the document, the use cases involved in T4.1 have been further developed, in T3.5, regarding the human feedback as much as the technical implementation of the services allowed it. To that end, it must be noticed that 2 uses cases are in standby mode CONTI2 and INEOS1 since service implementation suffer some delay and INOES3 has been discarded by the pilot leader INEOS.

Acknowledgements

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