Assessing the impact of process awareness in Industry 4.0

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Abstract. The historical (and market) value of classic cars' depends on their authenticity, which can be ruined by careless restoration processes. This paper reports on our ongoing research on monitoring the progress of such processes.
We developed a process monitoring platform that combines data gathered from IoT sensors with input provided by a plant shop manager, using a process-aware GUI. The underlying process complies with the best practices expressed in FIVA's Charter of Turin. Evidence (e.g. photos, documents, and short movies) can be attached to each task during process instantiation. Furthermore, car owners can remotely control cameras and car rotisserie to monitor critical steps of the restoration process.
The benefits are manifold for all involved stakeholders. Restoration workshops increase their transparency and credibility while getting a better grasp on work assignments. Car owners can better assure the authenticity of their cars to third parties (potential buyers and certification bodies) while reducing their financial and scheduling overhead and carbon footprint.

Keywords: Classic Cars Restoration · Charter of Turin · Business Process · BPMN · DMN · Internet of Things · Industry 4.0 · Process Monitoring · GUI · Process Awareness · Process Mining.

1 Introduction

Classic cars are collectible items, sometimes worth millions of euros [1], closer to pieces of art than to regular vehicles. To recognize their historic status required to reach these price-tag levels, classic cars should go through a rigorous certification process. This means that, during preservation or restoration procedures, strict guidelines should be followed to preserve their status, otherwise authenticity can be jeopardized, hindering the chances for certification. Such guidelines are published in FIVA's [4] "Charter of Turin Handbook" [3]. Since the

[4] Fédération Internationale des Véhicules Anciens (FIVA), https://fiva.org

expertise required for matching those guidelines is scarce and very expensive, car owners often choose restoration workshops far away from their residences, sometimes even overseas. This means that to follow the work done, long-range travels are required, with corresponding cost and time overheads and an increase in carbon footprint.

We are tackling this issue by creating a platform that allows classic car owners to follow the work being done while reducing the need for manual input by workshop workers. This is accomplished by creating a digital twin that mirrors the work done at the workshop.

In this paper, we describe a process-aware platform with a model-based GUI that is used by both workshop workers and car owners. We use a BPMN+DMN model described in [7] that is inspired by the "Charter of Turin's Handbook" guidelines. This is the first attempt we are aware, of modeling this charter and was a great starting point for this research. Other sources, including local experts, provided the information required to fill the blanks during the modeling process because the charter is vague in certain procedures or of subjective interpretation due to being written in natural language.

During execution, process instances (cars under preservation or restoration) progress from task to task, either due to automatic detection with ML algorithms that take as input IoT sensors' data collected by an edge computer attached to each car or due to manual intervention by the workshop manager. During the preservation or restoration process, the latter can attach evidence (photos, scanned documents, and short videos) to each task instance (task performed upon a given car). That evidence is used to automatically generate, using a LaTeX template, a report for car owners, for them to warrant the authenticity of the restoration and/or preservation their classic cars went through, to certification bodies and/or potential buyers. Our platform also allows holding meetings remotely with car owners, granting them complete control of a set of pan, tilt, and zoom operations upon a set of IP cameras at the workshop pointed at their car in a specific showroom. This feature reduces car owners' financial and scheduling overhead and their carbon footprint. Both features (evidence collection and online interaction) increase the transparency of the restoration and preservation processes.

We adopted an Action Research methodology, as interpreted by Susman and Evered in [12], where five stages of work are continuously iterated: Diagnosing, Action Planning, Action Taking, Evaluating, and Specifying Learning. By choosing this methodology, we aim to constantly receive feedback from platform users on the features being implemented, allowing an agile and quality-in-use development roadmap [4].

We claim two major contributions of this ongoing applied research work: (i) the positive impact of the proposed digital transformation in this Industry 4.0 context, and (ii) the assessment of the feasibility of process-aware / model-based GUIs, a topic we could not find addressed in the literature.

This paper is organized as follows: section 2 presents related work along three axes that intersect our work; section 3 describes the proposed platform and section 4 presents the corresponding validation efforts; finally, in section 5, we draw our conclusions and prospects for future work.

2 Related Work

2.1 Car Workshop Systems

Several commercial systems can be found under the general designation of "Auto Repair Shop Software". Besides documenting the history of ongoing repairs exist, they usually are concerned with financial management (invoicing), scheduling, workforce management, inventory, and management of interactions with customers (with some features found in CRM systems) and suppliers (e.g. paints and spare parts). An example that covers these aspects is (Shopmonkey) [5], advertised as a "Smart & simple repair shop management software that does it all".

Software systems specially designed for classic cars are scarce. One example of such is (Collector Car Companion [6]. It is a platform targeting classic car owners and restoration shops that allows documenting cars and their restoration processes, including photographic evidence. Additionally, it can be used to catalog parts and track costs and suppliers.

We could not find any model-based solution for managing classic car restoration and preservation processes. For examples of such systems, we had to look at other industries.

2.2 Business Process Models in Industry 4.0

Kady et al. [5] created a platform aimed at beekeepers to help them manage their beehives. This was achieved by using sensors to continuously measure the weight of beehives and other discrete measurements at regular intervals. Additionally, they built BPMN models with the help of beekeepers, based on apicultural business rules. The patterns of the measurements collected are identified for data labeling and BPMN events association. These events trigger automated business rules on the workflow model. The process monitoring realized in this work is executed in a very similar way to ours. The differences occur in the way it is presented in the GUI. Instead of offering the visualization directly on the BPMN model itself, they added trigger events to the model that send notifications to the beekeeper's mobile phone.

Schinle et al. [10] proposed a solution to monitor processes within a chaincode by translating them into BPMN 2.0 models using process mining techniques. These models could then be used as graphical representations of the business processes. The authors claim to use process monitoring and process mining techniques, but it is unclear how the model-based GUI includes the monitoring aspects, as the only representation of a model shown is the one obtained after process mining, without process monitoring elements.

[5] https://www.shopmonkey.io
[6] https://collectorcarcompanion.com/

Makke and Gusikhin [8] developed an adaptive parking information system that used cameras and sensors to track parking space occupancy, by implementing Petri Nets as digital twins for the parking space. In their representation, tokens were used to represent vehicles, places to represent areas or parking spots, and transitions to represent entrances and exits of the parking areas. Petri nets were also used as a way to represent the routes that individual vehicles took while in the parking space. The authors used a model-based GUI monitoring approach, but the models are hidden from the final users. This differs from our solution, as we present BPMN models in the GUI used by final users.

Pinna et al. [9] developed a graphical run-time visualization interface to monitor Smart-Documents scenarios. Their solution consisted of an interface with a workflow abstraction of the BPEL models that highlighted the services already performed and the ones being performed. The decision to use BPEL abstraction models over the BPEL models themselves was because the BPEL workflow contained too many components, which made the scenario unreadable for human users, such as control activities and variables updating. Their abstraction used an icon-based GUI, instead of the usual text-based, for representing activities. It is unclear why this decision was made, as it seems that this annotation makes it harder to follow the process for an unaccustomed user. To mitigate this problem, by mousing over the icons, some additional information about the activity can be obtained. This publication does not describe the validation of the proposed approach.

Most of the articles that use BPMs in Industry 4.0 contexts adopted BPMN, as confirmed by the secondary study titled "IoT-aware Business Process: a comprehensive survey, discussion and challenges" [2]. Our choice of using BPMN is then aligned with current practice. However, the main conclusion we draw from our literature review is that using a process-aware model-based GUI in Industry 4.0 is still an unexplored niche. The closest example we found of using this untapped combination of technologies is [8], but still, it seemed to only be used as an intermediary analysis tool.

3 Proposed Platform

3.1 Requirements

Our platform can be divided into two separate subsystems, each with its own set of use cases. The first is the *Plant Shop Floor Subsystem*. This is the main part of our system where the Charter of Turin-based models can be viewed and interacted with. The operations that the different users can do in this subsystem are identified in the use case diagram in Figure 1.

The *Experimental Hub Subsystem* manages the live camera feeds to be used during scheduled meetings with car owners. The possible operations done in this subsystem are identified in the use case diagram in Figure 2.

In the diagrams, the *Plant Shop Manager* actor represents the workshop staff members that will control the day-to-day updates done to each vehicle and update the system accordingly. The *Administrative Manager* actor represents the workshop staff members who will have the control to create and delete restoration and preservation processes, as well as some administrative tasks, like registering new users to the system and sending credentials to be used to access the *Experimental Hub Subsystem*. Lastly, the *Classic Car Owner* actor stands for the owners themselves.

3.2 Architecture

In the original architecture proposed in [7], the Camunda's Workflow Engine was used (and still is) to execute the Charter of Turin-based process, i.e. allowing its instances to be created, progress through existing activities, and deleted. The data stored in this platform were obtained through REST calls by a component designated as *Connector*. This component used *BPMN.io* to display the BPMN models on a web page to be interacted with by the workshop manager, indicating the path taken during the restoration process. This component also included a REST API that allows the retrieval of information about each instance. This API was used by a component developed with the *ERPNext platform* to allow owners to see the progress applied to their car as a list of completed tasks, while also providing some CRM functionalities for the workshop manager. We decided to discard the use of the *ERPNext platform* because, albeit it is open-source, implementing new features within this platform was laborious and inefficient, due to scarce documentation and lack of feedback from its development team.

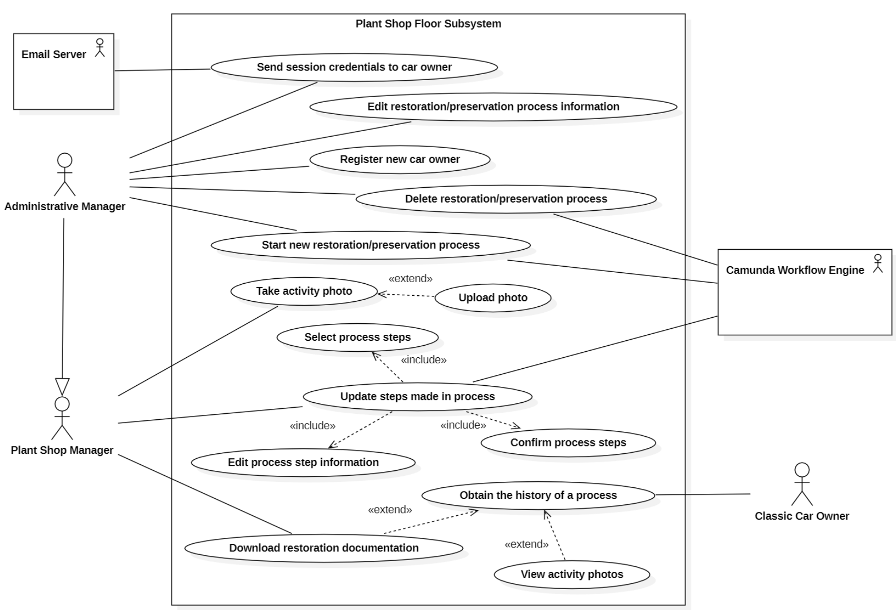

Fig. 1: Use Case Diagram of the Plant Shop subsystem

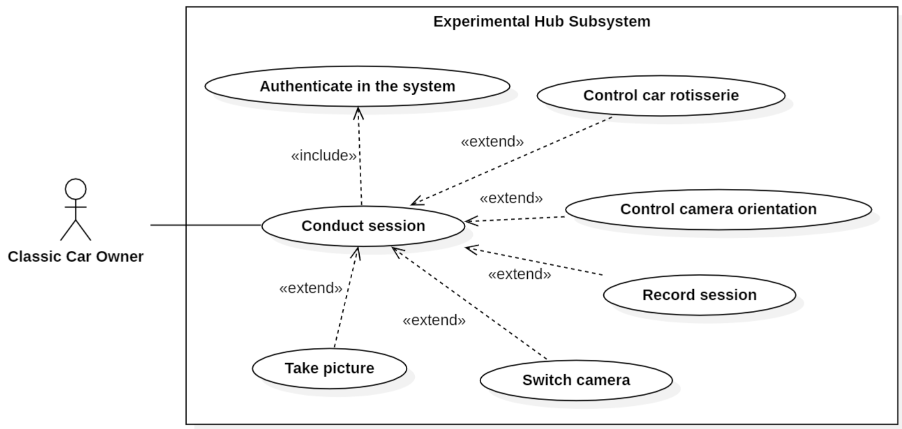

Fig. 2: Use Case Diagram of the Experimental Hub subsystem

An overview of the current system's architecture is depicted in the component diagram in Figure 3.

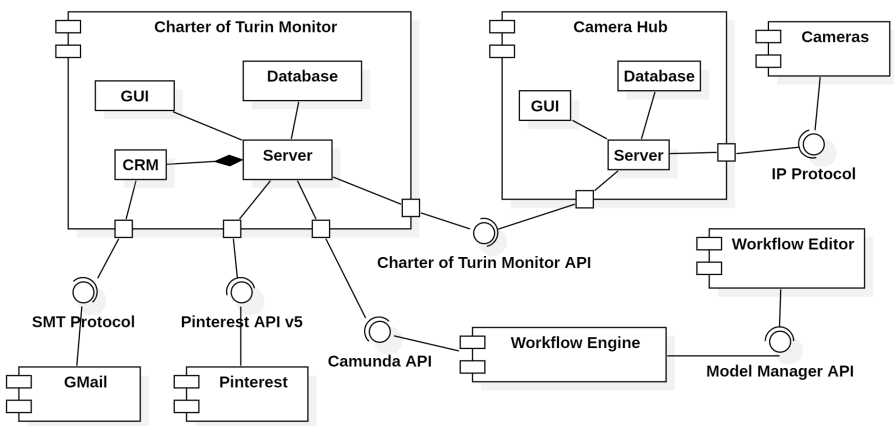

Fig. 3: Component Diagram of the system

The *Workflow Editor* component is used to design the BPMN and DMN diagrams, while the *Workflow Engine* component stores the latter and allows for the execution of their workflows.

The *Charter of Turin Monitor* is the component that integrates the features formerly existing in the *Connector* component with some CRM features equivalent to those reused from *ERPNext*. It serves as the GUI that workshop employees use to interact with the BPMN process instances and use the CRM features to convey information to the owners. It also serves as the GUI used by classic car owners to check the progress and details of the restoration/preservation processes. One of these details is a direct link to the secret *Pinterest* board that holds the photographic evidence taken by the workshop staff members. These boards are divided into sections, each representing an activity with photos attached.

Lastly, there are several IP cameras mounted in what we called the *Experimental Hub*, a dedicated room on the workshop premises. Classic car owners can remotely access and control these cameras through their web browsers, using the *Camera Hub* component. During their meeting, this access will only be available for a limited time, assigned by the workshop manager within the *Charter of Turin Monitor* component. The *Camera Hub* component also calls an API implemented in the *Charter of Turin Monitor* component to upload photos and videos taken during the meetings directly to the corresponding *Pinterest* board.

3.3 Technologies

To model and deploy the BPMN and DMN models, we chose two *Camunda* products: *Camunda's Modeler* for process modeling and *Camunda's Workflow Engine* for process execution. Camunda software is widely used by household name companies, which stands for its reliability. The choice was also due to the two products being freeware, offering good tutorials and manuals.

For our back-end, we chose *ASP.NET* framework, primarily due to the offered plethora of integration alternatives, matching our envisaged current and future needs. The back-end was deployed on a Docker container in a Linux server running in a virtual machine hosted by an *OpenStack* platform operated by INCD (see the acknowledgment section). The database software we chose was MongoDB, as there is plenty of documentation on integrating it with .NET applications and deploying it with Docker.

For our front-end, we decided not to use the default .NET framework *Razor*, but instead use *Angular*. Even though this framework does not offer integration as simple as *Razor*, *.NET* provides a template that integrates the two, while providing highly dynamic and functional pages with many libraries and extensions. Within our front-end, we integrated *BPMN.io*'s viewer *bpmn-js*. This viewer was developed with the exact purpose of working with *Camunda* and offers a simple way to embed a BPMN viewer within any web page.

Finally, we chose *Pinterest* to store the photographic evidence collected. The option of storing these directly in the database or another platform was considered, but *Pinterest* was ultimately chosen by offering an API that allows all needed functionalities to be done automatically, without the need for manual effort. Also, it provides good support, in the form of widgets and add-ons, for integrating its GUI within other web pages, in case there is a later need for this feature.

All the code and models used in this project can be found on GitHub [7].

[7] https://github.com/PedroMMoura

4 Validation

This work has two main parts requiring validation, the DMN and BPMN models based on the process described in the "Charter of Turin Handbook" and the GUI used to represent them.

4.1 Model Validation

To validate the models, we asked for feedback from the classic car workshop experts before deployment. This allowed for the more abstract parts of the "Charter of Turin Handbook", which is fully described in natural language, to be complemented with the actual process followed in the workshop. A continuous improvement is now in place since the platform was already deployed in the workshop. Whenever any inconsistencies are found, the appropriate changes are swiftly made to allow for a fast redeployment.

4.2 GUI Validation

For GUI validation, we required analysis from the viewpoint of both the workshop workers that directly interact with the Chart of Turin-inspired model and the car owners, who use the platform to follow the process.

To validate the workshop workers' interaction, we resorted to using an expert panel [6]. The selected members for this panel needed prior knowledge of the models, or at least the general process, being used. This meant that we were limited to people that work directly for workshop companies that do restoration and preservation on classic cars and to certification companies engineers. Once the experts had been chosen (see table 1), we conducted meetings with them, showing the platform and requesting feedback with a small interview. In the interim between interviews, we kept updating the platform based on the feedback received, checking how the satisfaction with it evolves. Upon completion of all the interviews, all data is aggregated and used to evaluate the results. This is still an ongoing task. From the interviews done so far, the feedback received has been mostly positive, with a great interest in the project being developed. Among the suggested features that were already implemented are coloring the tasks that require evidence gathering according to FIVA requirements, a text field for each task that allows for any additional information to be added when necessary, and a few other usability improvements.

Table 1: Expert panel characterization

Profession	Expertise	Field of Work	Years of Experience
Manager	Plant shop floor works	Car body restore shop	20
Secretary	CRM	Car body restore shop	15
Manager	HR management	Car body restore shop	15
Engineer	Classic cars certification	Certification body	25
Researcher	BPM modeling	R&D	25

To validate the owners' interaction with the system, we decided to use an interview approach [11]. These interviews will be performed with any classic car owner willing to participate, not requiring prior knowledge. As a result, we should get a good idea of new users' overall satisfaction levels while using our platform. After being informed of our work, several classic car owners and long-time customers of the workshop showed great interest in working with us to test the platform. As of the writing of this document, these interviews have not yet been conducted, because priority was given to finishing the validation of the workshop workers' interaction before starting the validation of the owner's interaction. This choice was made because, while the worker's interaction directly affects the owner's GUI, the owner's interaction barely affects the worker's experience.

5 Conclusions and Future Work

In this paper we described our ongoing effort to develop and validate a platform for monitoring the progress of classic cars' restoration process and recording evidences to allow documenting it in future certification initiatives.

We took FIVA's Charter of Turin's guidelines as inspiration for producing a BPMN process model that is used as backbone of our process-aware graphical user interface. The validation feedback received until now has been very positive. This work has gathered interest from several players in the classic car restoration industry, from classic car owners to workshops and certification bodies, which will be very helpful in improving the developed platform and in future validation steps.

As future work, we plan to use process mining techniques to validate the models, based on data that is already being collected. Since each classic vehicle is just a process instance, we will have to wait until a considerable number of them complete the restoration process, since process mining ideally requires a large amount of data to produce adequate results.

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