Computers in Industry 138 (2022) 103615

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

Hybridizing humans and robots: An RPA horizon envisaged from the trenches

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A R T I C L E I N F O

Article history:
Received 5 December 2020
Received in revised form 10 December 2021
Accepted 23 January 2022
Available online 11 February 2022

Keywords:
Robotic process automation
Process mining
Computer-human interaction

A B S T R A C T

After the initial hype on RPA, companies have more realistic expectations of this technology. Its current mature vision relegates the end-to-end robotic automation to a less suitable place and considers the human-robot collaboration as the most natural way for automating robotic processes in real-world settings. This hybrid RPA implies a vertical segmentation of process activities, i.e., some activities are conducted by humans while robots do others. The literature lacks a general method that considers the technical aspect of the solution, the psychological impact of the automation, and the governance mechanisms that a running hybrid process requires. In this sense, this paper proposes an iterative method dealing with all these aspects and results from a series of industrial experiences. Additionally, the paper deeply discusses the role of process mining in this kind of method and how it can continuously boost its iterations. The initial validation of the method in real-world processes reports substantial benefits in terms of efficiency.

1. Introduction

Robotic Process Automation (RPA) has received increasing attention in many different sectors in the last few years. It has prominently grown in the enterprise software market (Biscotti, 2018) where RPA has focused mainly on efficiently and automatically solving extensive administrative and back-office processes (Madakam et al., 2019). RPA is seen as another tool in the automation tool-set of an organization that enables mimicking the human actions that are performed on the user interfaces and, therefore, allowing for a higher level of automation. Although the initial hype and the existing predictions of billionaire investments for the following years (Fersht and Snowdon, 2018), nowadays, companies have more realistic expectations of RPA keeping a significant traction (Taulli, 2020a). These expectations go beyond high savings and fast returning of the inversion with fully automated processes (Penttinen et al., 2018). In turn, the mature vision of RPA starts by acknowledging that humans are the keystone in the RPA horizon (Kirchmer and Franz, 2019).

1.1. Problem statement

In the early days of RPA, the main focus was on automating the highly repetitive branches of a business process that were executed by the employees (e.g., because the API of the system is not accessible) (Penttinen et al., 2018). Those frequent branches that (1) included a low level of exceptions, (2) involved an enclosed cognitive scope, and (3) were susceptible to human error were suitable candidates to automate with RPA (Fung, 2014). However, this *horizontal* segmentation of processes ended up having minimal applicability since these ideal branches —which should be fully automated— seldom occur (cf. left side of Fig. 1). On the contrary, a *vertical* segmentation of activities results to be a more natural approach. Here, part of the activities is identified as convenient to automate while other activities keep being executed by humans (Mendling et al., 2018) (cf. right side of Fig. 1). The automation of these processes implies the collaboration between robots and humans, leading to a hybrid approach which is the one that has been deployed most in recent years.

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https://doi.org/10.1016/j.compind.2022.103615
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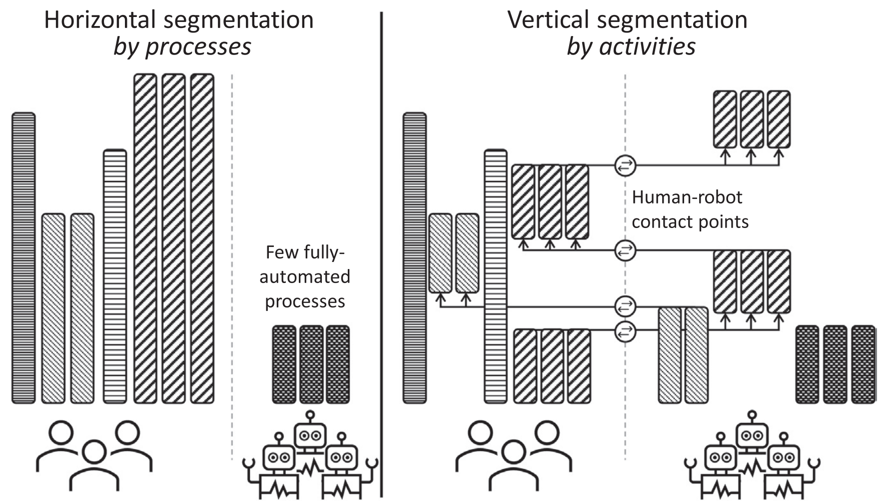

Fig. 1. Workload assignment to humans and robots in both horizontal and vertical segmentation approaches.

This collaboration implies incorporating the "human-in-the-loop" instead of end-to-end automation. Regardless it is understood as a human process with robotic activities, or a robotic process with human activities, its challenges can be tackled with different approaches (Jiménez-Ramírez et al., 2020; Axmann and Harmoko, 2020):

1. Asynchronous collaboration. Here, robots and humans keep their task queues which they process independently to each other. In this orientation, human workers may send activities to the robot queue and, hereinafter, continue with the following human task.
2. Synchronous collaboration. Here, the robot's duties consist of "on-demand" activities that need to be started as soon as they are requested. In this orientation, the human keeps waiting for the robot to complete its task since the robot outcome is needed to complete the human task.

The most common orientation is the first one, where the collaboration is done in an unattended way. Scenarios that are faced by this approach include, for example, processes where a robot gathers data from several information systems before a human comes into action. Here, the robot groups and presents the information in a structured way so that the humans may perform their cognitive actions in an agile way. The benefits which can be obtained are beyond the efficiency of humans. On the one hand, the human-robot contact points have complete control of the data, time, and activities needed in the decision-making. That is, the cognitive work of humans can be "McDonaldized". On the other, this "McDonaldization" would pave the way to make these activities more efficient with Machine Learning approaches or if-then rules.

Previous approaches have already identified and addressed the presence of humans within the RPA lifecycle. Some of them (Herm et al., 2020; Jimenez-Ramirez et al., 2019; Sigurðardóttir, 2018) enclose the human activity in the early stages of the identification of activities and processes to robotized, but they miss the later presence of humans during the process execution. In contrast, others (Ravindranath and Bhaskar, 2020; Mohanty and Vyas, 2018) acknowledge the collaboration between robots and humans mainly in data validation activities related to artificial intelligent contexts. All these approaches lack a general method to be applied in an RPA context with robot-human collaboration.

1.2. Contribution

The current paper explores the aforementioned challenge of the asynchronous human-robot collaboration and proposes a method derived from industrial experiences in the RPA field. Besides the methodological support for RPA implementation, the method is addressed considering the socio-technical implications and pointing out the critical factors to conduct such implementations successfully, which are key contemporary challenges in the RPA field (Syed et al., 2020).

The proposed method starts by structuring the contact points between robots and humans. This activity implies the design of a "landing area" which is the single point where the switching of the responsibility happens, thus avoiding the "cases in limbo", i.e., where neither humans nor robots have the knowledge that they must treat within an activity. On the one hand, the design of this landing area must guarantee that all the required information is passed from the robot to the human in a structured way, with enough details about the conducted activities so that the human is confident in the robot's results. On the other hand, humans should be able to pass their results in an agile and structured way so that the robot may continue the execution autonomously. Besides transferring the responsibility between the process actors, these designs should consider (1) the psychological perspective of the humans to prevent a negative feeling or rejection stances of the automation initiative and (2) a data-aware approach that centralizes all the interactions with this transfer point for being able to learn and improve its performance in subsequent versions.

In addition, the proposed method leverages the strong benefits that *process mining* (van der Aalst, 2016) may bring to RPA —as already recognized by Geyer-Klingeberg et al. (2018)— in this specific context of robot-human collaboration. Specifically, process mining deploys the necessary mechanisms to visually and quantitatively analyze the metrics to divide activities between robots and humans potentially. In addition, it supports the continuous monitoring of human activities to make the "landing area" more efficient progressively, i.e., identifying "McDonaldized" activities that can be automated. Besides that, it may identify the friction points existing in the "landing area" due to incomplete transfers of knowledge between robots and humans that may lead to process redesigns. In general, process mining provides a comprehensive and automated analysis of the processes, which typically requires a high effort. Moreover, this analysis typically starts with inaccurate or incorrect information since there is a natural and historical resistance from humans to automation (Pouget, 1913). However, process mining diminishes this threat by obtaining an accurate analysis of the processes that are being continuously monitored.

Moreover, the proposed method has been applied in industrial settings in the domain of business process outsourcing (BPO). The results evidence a clear benefit in terms of time savings and, more importantly, in controlling the evolution of automation. Nonetheless, the early results of the method also reveal several limitations and lessons learned that disclose future lines for research.

In a previous work (Cabello et al., 2020), an abstract overview of the method was presented. However, this paper significantly extends it by:

- Materializing the method to be applicable to real RPA contexts.
- Elaborating over a running example to demonstrate the applicability of the method.
- Including a comprehensive study of the related works and an extensive discussion of the advantages and limitations of the proposal.

The rest of the paper is structured as follows. Section 2 provides an introduction to the human-in-the-loop context within RPA. Section 3 describes a running example for such a context. Section 4 details the proposal. Section 5 reports the experiences in industrial settings conducting the proposed method. Section 6 provides a discussion of the method and its limitations. Section 7 summarizes the main related works within the scope of human-robot collaborations. Section 8 concludes the paper and elaborate on the open research lines.

2. Human-in-the-loop and RPA

This section aims to describe the different application areas and scopes of RPA (cf. Section 2.1) and how the industry has pushed to acquire a strong maturity level (cf. Section 2.2), thus envisaging a natural human-robot collaboration (cf. Section 2.3).

2.1. RPA scope. Back and front office

Medium and large-sized organizations have been increasingly adopting RPA in the last years for automating. They use the "Robotic FTEs" to set a "Virtual Back-office" which can perform manual activities without a direct human participation and with high efficiency and speed (Willcocks et al., 2017; Fung, 2014; Slaby, 2012). The main application has been done in the so-called "back-office" activities of Administration and Finance business scopes (Ortiz and Costa, 2020; Gotthardt et al., 2020). Activities in this area are, for example, analysis and report of finances, management of sales, payments, receipts, taxes, and accounting in general. All these activities share that they are systematic, have a significant volume of cases, require an enclosed cognitive effort, and are executed on existing information systems through their user interface, thus being good candidates for RPA (Penttinen et al., 2018; Fung, 2014). These early adopters of RPA were motivated by the high expectations on efficiency, cost savings, and capacity for adapting to potential fluctuations of the workload in the short term.

Later on, the previous back-office approach was extended to incorporate the "front" activities too. Herein, a human tries to respond quickly to a request, for example, processing phone or online queries and claims in a Customer Service Center where clients might expect an answer at the moment. Front activities tend to be simpler —if compared with the back-office activities—, require an immediate response, and include a relatively wide variety of actions, although they are short in time. Traditionally, macros have been broadly used to automate these kinds of short but repetitive actions in spreadsheets or legacy systems. Moreover, sometimes, macros have been responsible for carrying out highly critical activities. Nonetheless, it implies a significant operational risk since macros are usually developed using "informal programming", and the code remains on the employee side. Thus, they are associated with governance and maintenance problems. Here, a view of "RPA steroids" is applied to the traditional concept of macros. An "on-demand" approach of RPA has recently been applied to solve these deficiencies by substituting old macros with attended robots (Axmann and Harmoko, 2020). However, the "reaction time" factor is critical to consider RPA applicable in this scenario.

For all these reasons, RPA has a strong presence in the back-office scope, which offers a faster return of investment (Geyer-Klingeberg et al., 2018). Nowadays, it is also present at the front-office scope since the separation of both is generally fuzzy or even there is no separation, so trying to separate them artificially would produce inefficient processes.

2.2. Industry stances for RPA maturity

The advances of RPA have been mainly led by industry in the last years. The strongest leaders have delivered RPA solutions posing the focus on the back-office activities. Here the solutions of UiPath (2019), Prism (2019) and Automation Anywhere (2019) are highlighted. With the scope of the front-office, other vendors like PegaSystemPEGA (2019) are also highlighted. All of them have contributed to the maturity of RPA through the following actions:

- Moving from the script-based robot programming to a comprehensive low-code or no-code robot construction environment. That is, business users are enabled to contribute to the robot constructions where deep technical skills are not required. These frameworks enable a continuously increasing plethora of components designed to address each specific administrative need that the robot should do.
- Providing advanced tools for the governance, control, and management of *farms* of robots. They enable the required business capabilities to administrate the virtual back-office, e.g., controlling in real-time the state of the robots or reporting online performance indicators of the robotic processes.
- Creating and maintaining RPA knowledge databases and RPA MOOC[4] environments allows an increasing number of people trained in RPA topics. This enables a new generation of workers qualified in RPA tools to be ready for companies.
- Developing and providing advanced RPA components for solving cognitive activities. The use of *Machine Learning* within RPA has broadened its application to tasks that were not initially considered as candidates for robotic automation.

Nonetheless, the current market landscape is divided into two different approaches regarding the inclusion of RPA tools and philosophy within the companies and their processes:

1. **The BPM-centric approach**: The Business Process Management (BPM) discipline has been helping organizations to control their processes efficiently (Weske, 2007; Dumas et al., 2018). It is about the analysis, design, development, deployment, and operation of the processes and integrating them with the company's information systems. In this market approach, RPA elements are considered as other information systems to integrate into the

[4] MOOC: Massive Open Online Course.

BPM tool. One of the most prominent industrial examples in this orientation is Appian[5], a benchmark in the BPM sector. Besides enabling the integration with different external RPA vendors, Appian has recently acquired an RPA company to offer their RPA elements within their own platform. [6]

This approach presents several advantages. The BPM paradigm counts with a contrasted maturity in developing process vision, strategy, and objectives. This explains why there are numerous integration elements out-of-the-box in the majority of BPM tools. In addition, this integrated process environment enables putting the focus on the end-user experience. Nonetheless, the BPM-centric approach is mainly applied to heavy and complex processes with a centralized IT infrastructure. Moreover, BPM solutions typically require a business transformation and large economic investments, which might be non-affordable or cost-effective if human FTE reduction is the only dimension to consider.

2. **The RPA-centric approach**: This market approach concerns those standalone RPA solutions which provide robot-human interaction for the specific situation of the designed processes. In contrast to BPM, these solutions mainly focus on organizing fine-grain tasks on the robot side. In this orientation, UiPath[7] stands as one of the major leaders. Along with a comprehensive toolbox of robotic components, it allows data entry forms for the inclusion of humans in the robot workflows through its control and governance tool called “Orchestrator”.[8]

   One of the major advantages of these approaches is the detailed control of the human and robot activities that they provide, which, consequently, it enables precise management of the workload that both robots and humans generate to each other. In turn, the RPA-centric approaches lack a general overview of the company processes and, thus, the required exploitation mechanism to work on general process optimization.

   Beyond the standard batch-processing behavior of RPA, this approach includes the RDA (Robotic Desktop Automation) vision of the robotization/hybridization, i.e., robots that respond quickly to the humans’ on-demand request, the so-called “attended robots”. This entails a robotic process with fewer steps, which spends less execution time to produce immediate responses. In the case of UiPath, the RDA view is offered by the “Assistant tool” [9] which is an end-user solution to command the robots. RDA offers a simple mechanism to the user for interacting with the robots. However, since these solutions are conceived for an agile interchange of information, it lacks (1) support for complex or sophisticated interactions, and (2) comprehensive feedback from the robot in case of a KO occurs, i.e., the human would hardly know what has happened to the robot if it fails.

2.3. The human-in-the-loop scenario

In the early times of RPA, companies tried to robotize 100% of the manual activities within their processes. That is, performing end-to-end automation, including as many complete process branches as possible. After the many cases of failures, mainly because of unrealistic expectations (Hindle et al., 2018), a more mature view of RPA left apart from this monolithic approach. In turn, the current view separates the fractions of the processes that are too complex and would produce the whole automation to be non-profitable. Discovering such non-automatable activities in the early RPA stages has been recognized as a key factor for the success of the RPA development that may, eventually, run stably (Jimenez-Ramirez et al., 2019). In that way, part of the process keeps being executed by humans instead of robots.

Even with the incorporation of Machine Learning techniques in RPA, the number of suitable processes for end-to-end automation is fairly lower than the processes where only some parts of it are suitable. Therefore, including both robots and humans in the robotic automation brings more efficiency and effectiveness to RPA. This hybrid scenario, also called “human-in-the-loop”, is a more realistic and common scenario where:

- Some of the activities are identified as suitable for execution by RPA due to their high frequency and systematic nature.
- The rest are kept to continue being executed by humans due to their low frequency, cognitive nature, or because there is no simple identification of execution criteria.

3. Running example

This section describes a motivating scenario and a running example that includes the main drawbacks that are addressed in the current paper. Fig. 2 depicts the process of one of the scenarios proposed for the validation of this study (cf. Section 5) [10]. Some of these process activities are designed to be executed by a human, i.e., “Validate Invoice & Copy to SAP”.

This human activity can be seen as a subprocess that is decomposed in the following activities (i.e., the human must perform all these actions):

1. Look for the client’s invoice, which is associated with the running instance given the invoice number. The required invoice might be in different information systems, e.g., external ERPs, CRMs, shared folders, or even, in the email. Therefore, all these systems have to be visited until the invoice is found.
2. Validate the content of the invoice and that it is properly signed. The name, VAT number, and amount must match those recorded in the own SAP system. The invoice layout of each company might be different from other companies, thus, a variety of layouts exist.
3. In case that there is some missing information or errors (e.g., not found, unreadable, not associated with the given client), the client must be contacted to amend the errors. Then, the human activity ends, and the client has to start the overall process again.
4. In case that everything is correct, some invoice data must be inserted into the SAP system to evidence the validation. Then the human activity ends, and the overall process continues.

This simple flow of steps is affected by several exceptional situations. Sometimes, the human finds none or more than one invoice within the different information systems. For some others, the client is not found in SAP.

4. A method to hybridize processes

This section describes the industrial method that has come up from research experiences in the business environment (cf. Section 4.1Fig. 3 (a)). Furthermore, some key factors are presented to help the teams to measure the success of the application of the method (cf. Section 4.2, Fig. 3 (b)) which can be later enriched from a process mining approach (cf. Section 4.3, Fig. 3 (c)).

[5] https://www.appian.com/hyperautomation/
[6] https://www.appian.com/news/news-item/appian-acquires-robotic-process-automation-rpa-company/
[7] https://www.uipath.com
[8] https://www.uipath.com/product/orchestrator
[9] https://docs.uipath.com/robot/docs/uipath-assistant

[10] Due to confidentiality issues, all the activities that do not directly concern the running example are shown blurred.

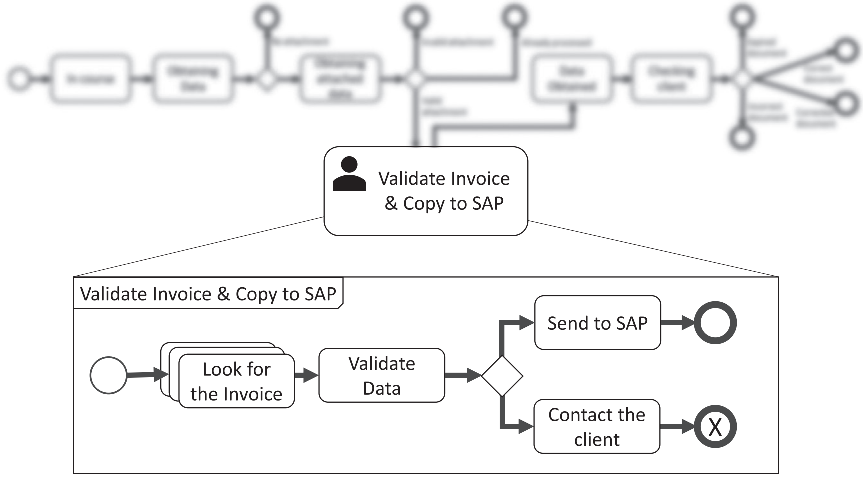

Fig. 2. Human-in-the-loop example.

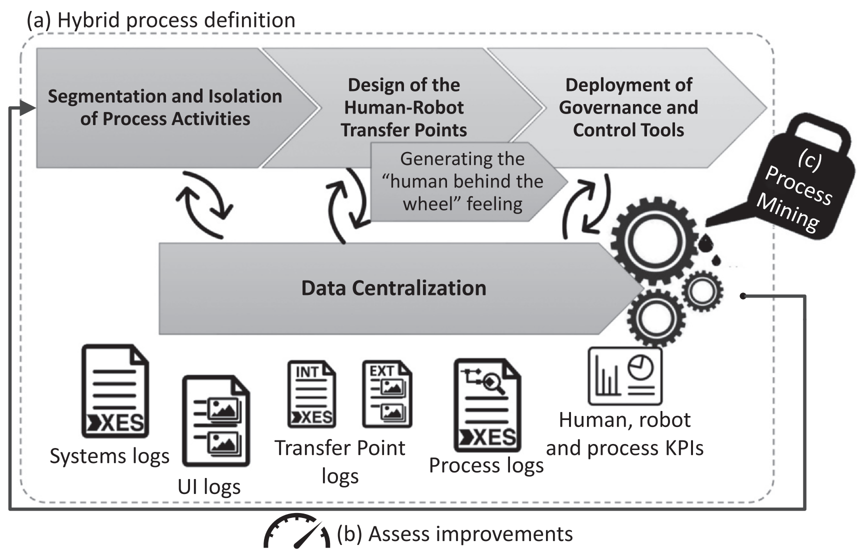

Fig. 3. The defined process.

4.1. *Defining the hybrid process*

The proposed method aims to help development teams to create a hybrid process and consist of the five key activities which are depicted in Fig. 3. From a technical perspective, the method starts with the segmentation of the process (i.e., identifying which parts of the process should be on the robot or on the human side) and the isolation of each segmented part. Then, an information system needs to be designed for each point where the ownership of the process moves between robot and human. Herein, it is important to highlight that such a design should pay special attention to the psychological perspective: the humans must feel that they are the ones "behind the wheel". Lastly, the resulting hybrid process requires a supervision system that enables governance and control mechanisms. Additionally, from an analytical perspective, the previous activities tend to be data-intensive and, thus, require a data centralization activity that leverages all the generated data.

4.1.1. *Segmentation and isolation of process activities*

It is essential to identify which parts of the process are the robots' responsibility and which ones of the humans. Simultaneously, it is crucial to enable the required mechanisms to avoid humans bypassing or disrupting the robot activities. This prevention can be done by designing the execution method to "poka-yoke" task or by restricting the access to concrete systems designed just for the robots.

The input of this step is a process design where part of its activities are manual ones executed by humans. This step aims to return (1) the best candidate portion (i.e., activities) that can be delegated to the robots (i.e., segmentation) and (2) the context of the information systems required to conduct such portions (e.g., system credentials or access level to shared folders).

Example 1. Regarding the process of Fig. 2, the activity "Look for the invoice" might be identified as a candidate for the robot while the others may remain on the humans' side. One simple mechanism to avoid that humans performing the robot activity is to grant access to the invoice systems only to the robots.

As another industrial revolution, people involved in these processes might negatively perceive the impact of hybridization. Experience shows that, although these isolation mechanisms can be seen as "anti-Luditte"[11], it is required to maximize the probability of success.

[11] The Luddites were the radical faction in the UK that destroyed textile machinery in the 19th century.

The segmentation of activities is a relevant topic in RPA (Leno et al., 2020). Although it has not yet been extensively studied, some proposals address this problem by using Machine Learning techniques (Agostinelli et al., 2021; Geyer-Klingeberg et al., 2018), rule mining and discovering data transformation techniques Bosco et al. (2019) or probabilistic methods (Fazzinga et al., 2018), among others. In general, these methods pursue identifying parts of the process with a high volume of cases, prone to human failure, or which require limited cognitive effort (Fung, 2014).

4.1.2. Design of the robot-human transfer points

Since the same process may include parts that are to be conducted by robots and parts conducted by humans, it is necessary to identify and design how to transfer the ownership of the process between robot and human and vice-versa, i.e., the checkpoints at the *Border Control*. Therefore, this step takes as input each isolated portion of the process identified in the previous step. The objective of this step is, for each isolated portion, to design a transfer point (i.e., a graphical information system which serves to the human) which, first, transfers the ownership of the process from the robot to the human and, second, transfers it back to the robot when the human activity is finished. Some important rules should be considered:

1. Its position within the process must be defined unambiguously.
2. Each transfer point has a unique direction for the information flow between the two kinds of workers.
3. The transfer of information of the process must be done completely and in a single step.

Following these three rules, it can be ensured that the human has all the necessary information to continue with the process without *looking back* to what the robot has been doing.

More precisely, when a human picks up a task –which was preceded by a robot activity in the process flow– from the queue, four different elements should be presented in the transfer point. First, the concise information needed to conduct their task, i.e., the outcome of the robot task, is necessary as input for this concrete task. Second, a series of potentially empty views related to the performance of the robot when creating such an outcome, i.e., meta-information related to the input:

- Confidence view: comprehensive information about how the robot has conducted its task so that the human may check if the main information is reliable. This view aims to generate trust in automation.
- Uncertainty view: the degree of uncertainty related to the processing/interpretation steps done by the robot. In contrast to the confidence view, here the aim is to call the attention to the human who must check if the robot has interpreted its task properly.
- Missing data view: list of elements that the robot could not retrieve or generate so that the human will have to do it. Similarly to the uncertainty view, human attention is called again but, this time, the human has to do something from the scratch, e.g., due to a robot malfunction.
- Raw view: non-processed information that the robot has used to complete its previous task. This view aims to serve as a basis to check or repair those items pointed in the uncertainty and missing views, respectively.

Third, in case that after the human task there is a transfer back to the robot (i.e., the next robot's activity expects an output by the human activity), a custom output view is shown where the human introduces the required information in a structured form. While the human requires extensive information to complete the task appropriately, the output form should be concise and easy to entry. Otherwise, the human may suffer an increase of workload leading to a "clumsy" automation (Parasuraman et al., 2000). Nonetheless, this custom view should be designed to avoid misinterpretations to diminish the transfer errors, i.e., if the human expects a date, this input field should be validated before letting the human finish the task. And lastly, a special output view is presented to enable the human to break the flow in case some errors have been detected either on the input or meta-input information or in the proper human task that prevents passing the ownership to the robot. The tasks that go to this special output branch are tagged as KO (i.e., malfunctioning) and will wait into the queues of the managers or operators to be processed.

In several situations, it is the human the one who starts or ends the process flow, i.e., the human activity is the first or the last of a process. In those cases, the design of the transfer point may lack input or output views, respectively.

This design of the transfer points has implications in the workflow design of the robot too. Besides its specific functionality, the robot design must guarantee two main things:

- When a robot continues after the human task, its input information must be aligned with the output of the transfer point.
- When a robot precedes a human task, its output information must be sent together with the four meta information, i.e., confidence, uncertainty, missing, and raw.

This step generates trust and robustness in the hybrid process. Without that, the human efficiency —and thus the process efficiency— decreases since it produces the effect of *"I have to review the robot task because I do not trust."* Although both humans and robots may perform perfectly individually, experiences in the development of RPA acknowledge that this trust and robustness is necessary to avoid the "cold welding" effect that eventually produces the process to break.

Generating the "man-behind-the-wheel" feeling.

Reducing the employees' awareness of the system is identified as one of the primary vulnerabilities in the automation projects (Parasuraman et al., 2000). It has implications on human and system performance and, ultimately, in a low trust in automation (Parasuraman, 1987). Therefore, in addition to the former rules, the design of these transfer points should aim to generate the capacity and the feeling that the human may know and control the global state and evolution of the process during its execution, i.e., avoiding reducing the situation awareness due to the automation. That is of utmost importance since, as indicated by the French Luddite, anarcho-syndicalist, and activist Émile Pouget (1860–1931), *"the worker will only respect the machine the day it becomes his friend, reducing his work, and not like today, which is his enemy, takes jobs and kills workers"* (Pouget, 1913). Furthermore, this feeling may have effects, first, in the early stages of the adoption of the new —hybrid— way of working and, second, to ensure the efficient execution of the process.

Several elements help in acquiring this process knowledge. On the one hand, the robot's OK/KO resulting state, i.e., if it has completed its activity with success or failure, respectively. The later information is accompanied by the operational details of the collaboration between the robots and the humans, e.g., its trace log.

Example 2. Fig. 4 shows an example mock-up of a user interface designed to transfer the ownership to a human when activity "Looking for the invoice" (cf. Fig. 2) is finished. It can be seen how the robot identified by "RR101 (Rick)" transfers the ownership with the relevant data. Before the human task, "Validate Data", is

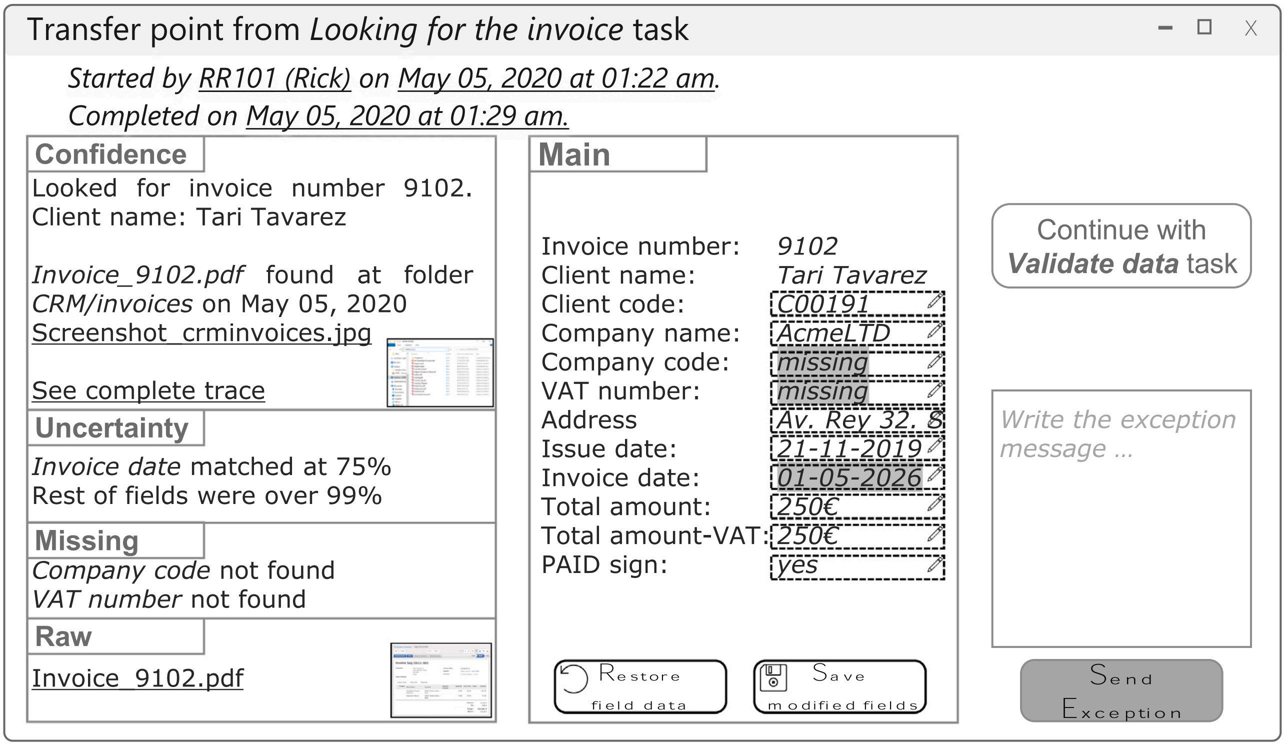

Fig. 4. Transfer point mock-up for the running example.

open, the human must see this interface showing the data extracted from the invoice in an editable way, being able to modify it if errors or missing information is found.

Moreover, extended meta-information is depicted related to these data, that is:

- A confidence view showing (1) the invoice which has been found along with the name of the information system where the robot found the invoice, (2) a screen capture of the invoice file in the mentioned information system, (3) the client and invoice numbers that were used by the robot to look for the invoice, and (4) a direct access to the complete trace of the robot execution.
- An uncertainty view that guides the attention to such pieces of information in the invoice where the robot presents low fidelity.
- A missing view that clearly point to those parts of the invoice that the robot could not extract.
- A raw view showing the invoice in its original format before the extraction was performed.

The human has both the option to continue with the associated task or the option to raise an exception if the normal flow of the process can not be followed due to some detected problems. Fig. 4 does not show the *output view* since the ownership is not transferred back to a robot in the process.

On the other hand, the aggregated information related to the volume of work assigned to the robots and the execution state of each assigned case (i.e., pending, running, or completed) are also valuable to acquire this feeling. Although this information may result of interest mainly for managers or supervisors (see, for example, the next activity in the method), it needs to be accessible by the humans who execute the activity. Experiences show us that these workers rarely access this information, just mainly when errors occur. Nonetheless, it is important to create the feeling that this information is available to avoid perceiving that the *virtual* workmates operate in a *black-box* manner.

4.1.3. Deployment of governance and control tools

This step addresses one of the most critical needs of a process supervisor: the integrated control of the whole process. For this, it takes as input the hybrid process design where transfer points act as glue between humans and robots. This step aims to return a system that follows the philosophy of a Business Activity Monitoring tool for real-time analysis (Kang and Han, 2008) which combines the human and the robot supervision under the same view. There are numerous use cases in the supervisor scope, e.g., balancing the workload, identifying bottlenecks and the occupancy and productivity of the workforce, managing the task queues of the different workers, managing alarms to control the values of specific KPIs like the number of pending cases, etc. In the context of RPA, these use cases are extended with the ones that involve the participation of robots, e.g., balancing work between robots and humans, taking the control of cases for manual execution, scaling, or descaling the digital workforce to fit some existing service level agreements, among others. To help the supervisor in making these decisions, specific KPIs are designed for the RPA context. The following ones are examples of KPIs taken from the industrial practice:

- The number of KOs. That is, the robot operations that fail. They can be distinguished into two types: *operative* KO (i.e., the robot is unable to continue its work, e.g., due to a system malfunctioning) and *business* KO (i.e., the robot is able to complete its work but it deals with some kind of exception, e.g., the client does not exist in the CRM) that can be considered as a partial OK. The ratio of the number of KOs against the OKs and the number of subsequent KOs in a row are meaningful indicators to detect issues in the processes.
- The number of retries. As a common strategy, robots are programmed to go back and retry in case that a step fails. Only when a retries limit is reached, the step is considered as failed (i.e., KO), and human intervention is required. Although this helps reducing the number of KOs, the operation time of the robot soars, thus, this number must be supervised.

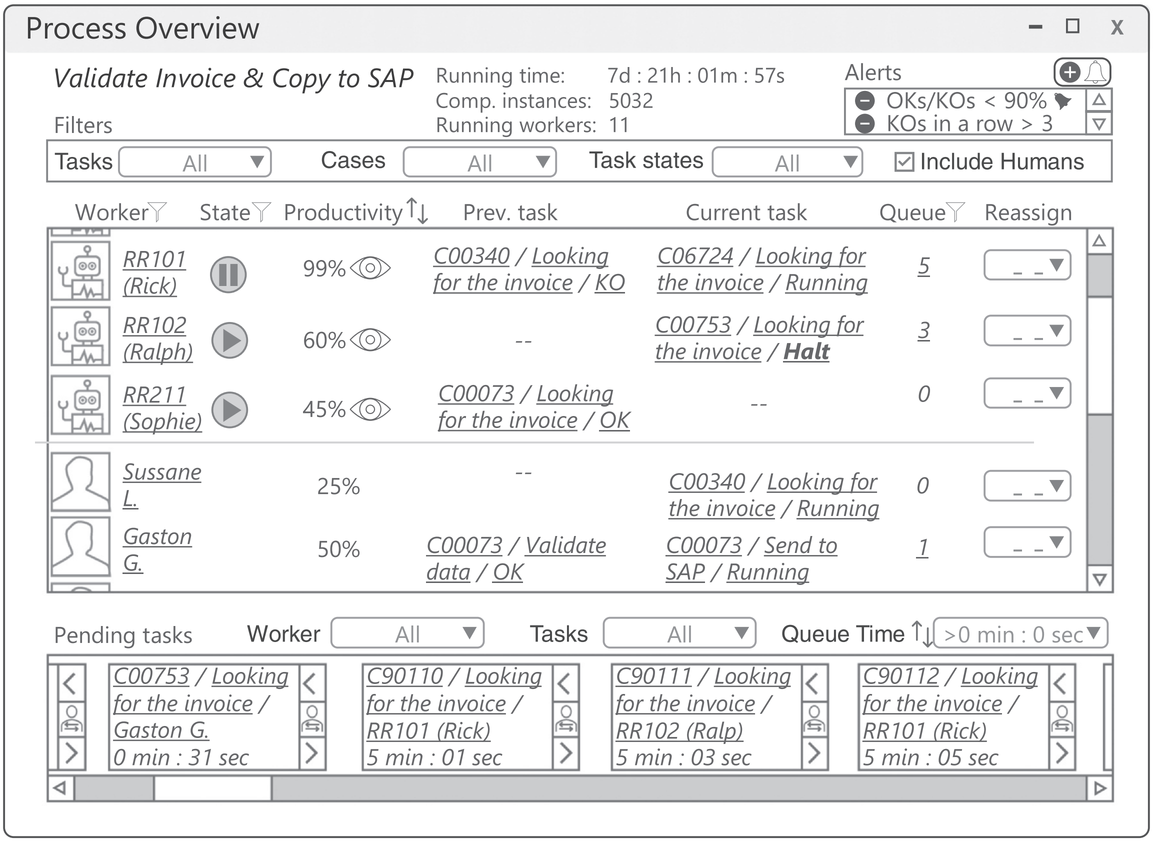

Fig. 5. Process overview mock-up for the running example.

- The occupation time of a robot. That is, the amount of time the robot is working on cases. It is interesting to distinguish between the different processes and subprocesses to identify bottlenecks. The ratio of the occupation time against the total uptime of a robot is relevant as well.

To support this challenging scenario, the deployed system must allow the supervisor to control the processes, i.e., to complete the previous use cases, e.g., start/stop the robots, move a task between a robot and human, etc. What is more, these tools may also be designed to guide towards a process of governance that diminishes the human decision-making intervention. This can be achieved by programming rules —deterministic ones or based on Machine Learning— that automate the supervisor's actions.

Example 3. Example 2 describes the flow from the perspective of a human that works within a process instance. In turn, Fig. 5 shows an example mock-up designed for a process supervisor with a general view of the workforce involved in the process similar to Business Activity Monitoring tool. It includes, among other things, (1) a general view of the robots, (2) the queue of tasks that are pending for the robots, and (3) the individual state of each robot. Between other data, the process supervisor can check which robots are executing the activity "Look for Invoice", the productivity of each of them (i.e., the working time/uptime), and all those robots which are halted due to any circumstance.

The same supervisor is enabled with action buttons to govern the process. For instance, tasks in the robot queue (i.e., assigned and pending) can be reassigned to a human, thus automatically granting this human the access level required to perform such a task. Besides that, this governance can be ruled by alerts defined by the supervisor or the organization itself. Therefore, when an alarm is fired, the supervisor is notified and other actions can be triggered automatically.

Although the previous step was focused on creating the perception that the human worker knows and controls the process, the current step is oriented to achieve that the cadence of tasks is ruled by the robot actions, which push tasks in the human queues. Experience shows that a faster adoption and greater process efficiency is generated with this kind of model where the human workers keep in charge of a reduced set of manual, relatively long, and cognitive activities which *help the robots* to accomplish the processes.

4.1.4. Data centralization

In the current era, where data is one of the most valuable assets of an organization, it is not surprising that the success of the hybridization of the process depends on both data and its quality. On the one hand, having a centralized repository where the process traces are stored to analyze the process and workforce performance, which enables the aforementioned control and governance mechanisms more accurately, is essential. This repository may keep data related to each of the three previous activities of the method for both robots and humans. First, related to the information systems accessed in the hybrid process, their systems logs must be identified since they yield relevant information for the segmentation activities. As identified in existing literature (Agostinelli et al., 2020; Leno et al., 2020; Jimenez-Ramirez et al., 2019), the UI logs (i.e., logs acquired by monitoring the user interface of the humans while interacting with the information systems) may serve as an additional resource to help in the segmentation along with the systems logs. Second, the transfer points may generate useful traces to understand how humans interact with the new system. In addition, the systems and UI logs that are gathered within the transfer point (i.e., regarding isolate activities) enable performing local analysis, which tends to be more affordable than holistic process analysis. Such a holistic analysis can be done, nonetheless, with the hybrid process logs, which

Proc.	Woker	Task	Instance	Environment	State	Start	End
⊟ P021	RR101 (Rick)	Looking for the invoice	C00340	VM-101	KO - business	2020/05/5 -01:22:35	2020/05/5 -01:25:02

Action	State	Message	Screenshot	Start
Open folder *~/invoices*	OK	Invoice not found	sc101_aes0.jpg	2020/05/5-01:22:35
Open folder *CRM/invoices*	OK	Found *invoice_0340.pdf*	sc101_21so.jpg	2020/05/5-01:22:39
Extract data	OK	Extracted 354 words	sc101_2aa1.jpg	2020/05/5-01:24:31
Check *Invoice Number*	KO	Should be *"0340"* but is *"ooo0340"*	Sc101_7t32.jpg	2020/05/5-01:25:02

Proc.	Woker	Task	Instance	Environment	State	Start	End
⊞ P021	Sussane L.	Looking for the invoice	C00340	Dsk-SUSPC	OK	2020/05/5 -08:05:10	2020/05/5-08:35:00
⊞ P021	Sussane L.	Validate Data	C00340	Dsk-SUSPC	Running	2020/05/5 -08:36:18	2020/05/5-08:39:40

Fig. 6. Log example of a robot and human interaction.

contain the traces of the hybrid process from a BPM perspective (cf. Fig. 6). Lastly, the calculated KPIs from the previous logs serve as a basis for analyzing the overall behavior of the hybrid process. This repository may keep these data related to both humans and robots in such a way that they are of similar quality, detail level, and structure so that they can be analyzed in an aggregate manner and as a whole. On the other hand, the continuous collection of data in a centralized repository enables the comparison of the real performance regarding the evolution from the manual process to the different versions of the hybrid process deployed over the time. Moreover, detecting hidden inefficiencies, errors, optimizations, or automation opportunities can be systematized based on this data. In that way, the improvements in the hybrid process can be pulled and motivated by the data pieces of evidence found.

Example 4. Fig. 6 shows an example of a simplified centralized data store containing some process log events. These events are related to the actions which were performed on an instance of the process of Fig. 2. This log is useful to do a "post-mortem" analysis of the instance since, as can be seen, it showed an unforeseen KO in a robot task. Note that this log keeps low-level information regarding each individual action of the robots and activity-level information that aggregates them. The design of the custom columns for this process includes the state of the task, e.g., OK in case of successful completion, KO-operation in case the worker cannot execute the task, and KO-business in case that some business rule is not fulfilled. In addition, it includes the state of each individual robot's action along with a description message. As shown in the last action of the robot —RR101 (Rick)—, an unexpected failure occurred when it checked some data of the invoice. It seems that some "o's" are captured and, although it can be seen that another worker has eventually conducted the task, its screenshots and other related data can be used to improve the "Extract data" action of the robot to avoid similar errors in the future.

The knowledge that can be gathered from this centralized data is later used as feedback for the next iteration of the method. For instance, the log related to the activity "Sent to SAP" might point to it as a candidate activity to be performed by the robots instead of the human workers. Experience shows that hybridizing a process is a continuous effort where each cycle of the method aims to (1) shift workload from the human side to the robot side, or (2) adapt the already-automated parts to address new requirements or detected errors.

4.2. Assessing the process improvements

The previous steps aim to design a hybrid process that leverages the best of both humans and robots. Applying this process successfully would generate the necessary fluidity and robustness in the overall process, producing quality and performance improvements. These improvements are pursued in each cycle of the method. For evaluating that each cycle improves the previous process version, the development teams require a set of guiding metrics. In addition, these metrics would serve for pointing out what the next versions have to improve. The following ones are considered key metrics in the current proposal:

- POK (Percentage of OK collaborations): This metric shows the balance between (1) the cases that have been conducted end to end as designed and (2) the total number of cases. Here, only those cases that involve the collaboration between robots and humans are considered.
- PRC (Percentage of Rescued Cases): This metric represents the percentage of cases where a human has to take the manual control of a robot task. It aims to measure the degree of fluidity of the hybrid process. As described in the method, every time that a robot task fails, such a task remains in a *dirty* state that a human has to finish after seeing what the robot has done, e.g., looking at the trace log. Moreover, sometimes it involves reprocessing the task from the beginning. These manual interventions break the process flow, change the worker queues, and invalidate the process estimations. Therefore, keeping this metric as lower as possible should be a must.

Example 5. Fig. 6 shows a *rescued case* in the task "Looking for the invoice" (cf. Fig. 2) from case "C00340". As can be seen, it is performed by two workers, first, by the robot "RR1010 (Rick)" and then, after it produces a KO, by "Sussane L." who rescues the case.

- OMT (Operation Medium Time): It measures, on the one hand, the required "pure" time for executing the human tasks and, on the other, the required "around" time for managing them. The latter includes managing work queues, monitoring the process activities, and other non-productive time invested around the tasks themselves. Although OMT of humans always exists, the design of the new process must pursue to reduce the human time required in both effective executions and management.

Table 1
Summary and formalization of metrics for process improvements.

Metric	Summary	Formula
POK	Ratio of cases which involved a successful –OK– human-robot collaboration.	$\lvert\{c \in CollabCases \mid state(c) = OK\}\rvert / \lvert CollabCases\rvert$ where $CollabCases = \{c \in Cases \mid \{human, robot\} \subset tasks(c).\ worker.\ type\}$
PRC	Ratio of cases which involved that a human had to take the control –rescue– of a robot task.	$\lvert RescuedCases\rvert / \lvert Cases\rvert$ where $RescuedCases = \{c \in Cases \mid t \in tasks(c) \wedge \{human, robot\} \subset t.\ worker.\ type\}$
OMT *pure*	Time per case that a human invested in working on the process tasks.	$\sum_{t \in HumanTasks} t.\ time / \lvert Cases\rvert$ where $HumanTasks = \{t \in Cases.\ tasks \mid t.\ worker.\ type = human\}$
OMT *around*	Time per case that a human invested in managing and operate the process, its tasks and its resources.	$\sum_{t \in AdminTasks} t.\ time / \lvert Cases\rvert$ where *AdminTasks* are those tasks not logged in the process log, but logged by the governance and control tools.
RHT	Time per case that human workers invested in robot activities.	$\sum_{t \in RescuedTasks} t.\ time / \lvert Cases\rvert$ where $RescuedTasks = \{t \in Cases.\ tasks \mid t.\ worker.\ type = human\}$

- RHT (Robot to Human Time): This metric brings to light the total time humans invest in performing tasks that were initially designed for the robots. This may happen due to the robot's unavailability, KOs, or any other human interventions, e.g., when some deadline is given, and robots can not cope with it on their own. In general, as it happens with the PRC metric, the time that the human expends on these unforeseen tasks is a key indicator of the underperformance of the process.

Table 1 summarizes the previous metrics and provides a formalization for them. Although they are formalized based on cases, it is also valuable for the teams to calculate them based on an individual activity, process, or even by a robot, in a way that the team has enough information to point where the deficiencies are: activity implementation, process design, robot virtual environment, etc. These kinds of metrics provide a general assessment of the hybrid process, which should improve by running the proposed method cyclically. Assessing these metrics and analyzing the collected data would help to answer the following and other questions which will be the improvement vector of the new cycle of the method: .

- Regarding shifting activities from human to robot:
  - What new activities that humans currently do can be done by robots? As acknowledged in recent literature (Fung, 2014), the best candidate processes to automate are those that fulfill certain criteria related to the volume of cases or the human failure rate. This information exists in the system and UI logs both inside and outside the transfer points, although the amount of collected data may hinder it. In the following section, process mining is suggested as an appropriate tool to deal with this issue.
  - Which ones would produce more impacts regarding its occurrence? The literature is dense in formulas to calculate the *economical* impact of an automation project (Wanner et al., 2022; Viehhauser et al., 2021). Such formulas rely on metrics like the human time involved or waiting times that can be obtained by analyzing the system and UI logs similarly to the previous question.
  - Which information is mainly used by humans that robots would need to perform such a task? Ideally, all the information that the human requires to complete a task is given in the inputs views of the transfer point, however, analyzing its system and UI logs might reveal both (1) additional data which is accessed but not given and (2) given data that is never used. When it becomes stable between versions of the hybrid process, it means that the potential robot that automates the activity of this transfer point would require such input to start.
  - Which information would be necessary to generate to let the human continue with the process? Similarly, the information which the humans repeatedly access at the start of their tasks is a candidate to be part of the required input.
- Regarding solving problems:
  - Which robot activities systematically produce KOs and, then, generate unforeseen workload to the humans? Since robots' KPIs include their execution states both per instance and per activity, the aggregated information of all cases (i.e., the PRC metric) would point to those activities on the robot side which require being rescued more frequently.
  - Do new manual activities exist that were not considered initially? As mentioned before, the KOs of a robot task might mean a system malfunctioning but, when they happen only in some cases of a new version of the hybrid process, it might also mean that the robot is unable to continue since the system requires some manual actions that the human does after rescuing the case. The concrete actions can be obtained by analyzing the system and UI logs of the rescued cases.
  - When the ownership is transferred to a human, does the human require additional information to conduct the tasks more efficiently? The logs of the transfer points reveal the concrete behavior of the human. This analysis would make sense if the OMT *pure* of this activity is rather high in comparison to other activities that could mean that the human is wasting time gathering information to complete the activity.
- Regarding enhancing the flow between robots and humans:
  - Is there any bottleneck due to a limited availability of resources? The occupation of robot grouped by task type is a clear indicator of bottlenecks when it gets close to 100%. It may affect the RHT metric since work shifts from robots to humans when they can not cope with a work peak.
  - Are the worker queues well-sized and prioritized to avoid waiting times? As the velocity of humans and robots differs on completing their tasks, humans and robots queues act as a buffer to keep them working independently. Low levels of occupation might point to an inefficient working flow.
  - Does the collected data from the process support both the run-time operation and governance, and the "post-morten" analysis? A high OMT *around* implies that operation mechanisms are not efficient enough.

Example 6. Let consider that the process of Fig. 2 is executed by the humans except for the activity "Look for the invoice". Analyzing the gathered data, it is seen that humans typically start their next activity (i.e., "Validate Data") copying all the information given in the form into a spreadsheet since many validation calculations are done with formulas. Including a "Export to Spreadsheet" button in this

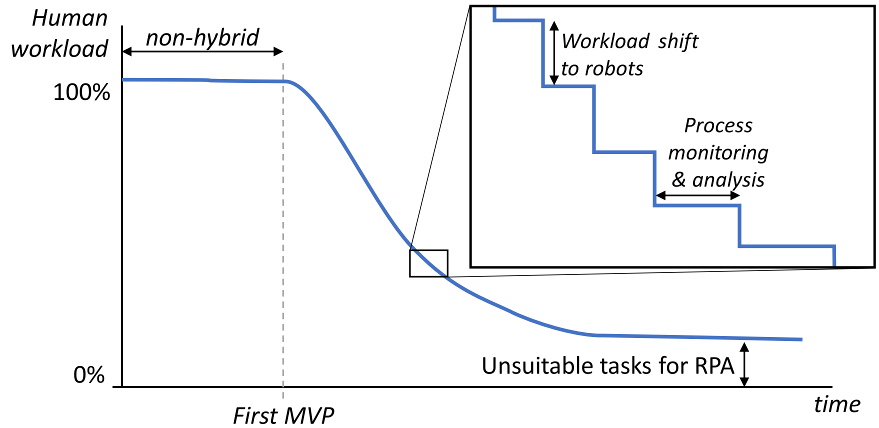

Fig. 7. Human workload evolution throughout the iterative application of the method.

transfer point would have a positive effect on the *OMT* metric, i.e., the next cycle of the method would generate a hybrid process with higher human efficiency.

4.3. Enriching with process mining

Since the proposed method heavily relies on process data and its continuous analysis, process mining (van der Aalst, 2016) features as the most suitable technology to support and boost these developments. In this data-related context, RPA may be simply seen as a technology that allows human-like actions for business processes, and thus, data gathering and integration may be seen as simple too.

The successful development of hybrid RPA implies a sequence of small steps, instead of a "big bang", which ends up with the desired robot-human collaboration. Starting with a Minimum Viable Product (MVP) which defines a basic collaboration, process mining facilitates continuous process monitoring and, then, progressively producing robust and fluid hybrid process versions by leveraging the mining results. Although process mining would initially allow for identifying activities that humans perform, it can also be used to analyze their resource consumption. This outcome is vital to efficiently assess the human effort of these activities, which is later used to evaluate and prioritize the complete business case based on metrics like the estimated Return On Investment.

In contrast with other analytical approaches for process performance, an important feature of process mining is that the obtained results and derived metrics can be generated faster and with high accuracy. This is critical for making decisions on the hybridization of processes, e.g., robotizing activities that effectively impact the human workload. However, the major challenge of process mining in this context of hybridization is precisely obtaining quality traces from human behavior while conducting their tasks. Whereas information systems use to log activities at the transaction level, these logs lack many human interaction details. Although some research efforts have been done in this line recently (Agostinelli et al., 2020; Jimenez-Ramirez et al., 2019), the industry lacks an out-of-the-box solution for this low-level monitoring currently, which would reduce the uncertainty and improve the quality of the AS-IS process identification.

Considering that process analysis plays such an important role in the process hybridization context, experience shows that it is not advisable to focus on a comprehensive AS-IS or TO-BE design process while leaving small efforts to monitor. In contrast, better results are obtained with a strategy as the one shown in Fig. 7. Herein, a relatively small thirty percent of the effort is invested in identifying the key challenges and critical aspects to end up with a design of the MVP. Thereafter, seventy percent of the effort is focused on deploying an efficient and effective process monitoring. Once the first MVP is deployed, it should allow logging both robot and human activities within the hybrid process. Therefore, process mining is iteratively applied to help to produce continuous improvements in the hybrid process (i.e., shifting the workload from the humans to the robots) based on the monitoring evidences which are arisen. Consequently, according to the process defined in Fig. 3, process mining applies to:

- Segmentation and Isolation of Process Activities: automating this analysis by examining systems and UI logs to provide analysis of processes (e.g., candidate or priority activities to be robotized), or specific process instances (Kirchmer and Franz, 2019).
- Design of the Human-Robot Transfer Points: analyzing the behavior of robots and operators through the system and UI logs generated in the transfer points (Agostinelli et al., 2020; Jimenez-Ramirez et al., 2019) so that a greater number of activities can be shifted to the robots. For instance, by automatically detecting a repetitive activity where the human passes the data received from the robot to another system before analyzing them. This task could be easily detected and robotized, reducing the effort on the human side and, consequently, improving the efficiency of the transfer point.
- Deployment of the Governance and Control Tools: calculating direct metrics and KPIs (e.g., activity duration or resource utilization) based on the process information through a traditional BPM approach (van der Aalst et al., 2016; Dumas et al., 2018), facilitating the task of creating indicators for the process supervisor.
- Assess Improvements: calculating general metrics and KPIs of the processes, allowing comparisons to be made between different processes globally to re-engineer them, if necessary.

5. Learning from the trenches. Industrial evaluation

The proposed method has been inspired by the practical experience gained from several industrial projects. They were performed by Servinform S.A.[12], which has a long track record of RPA projects. This section describes two representative projects developed in two different companies, which agreed to participate in this research. For them, Servinform carried out the analysis of the required process and the subsequent implementations of the hybrid RPA. In the context of this paper, we name them Company A (cf. Section 5.1) and Company B (cf. Section 5.2) since we have not been

[12] Serviform is a Spanish Business Process Outsourcing company with an IT consulting area.

authorized to disclose its real names. Therein, the proposed method was applied, and this section reports the concluding results and the lessons learned from them. In addition, a final joint discussion of the industrial experience is included (cf. Section 5.3)

5.1. Project in Company A

This company is one of the major firms in the Spanish national electricity scope. The project consists of managing the customer claims that come from digital means, i.e., email or service desk systems.

The process involves gathering information for a given claim by accessing a commercial information system and the company's Customer Relationship Management (CRM). Most of the time —around 70% of the overall process— is invested in this step since many information is necessary to be extracted. Based on analyzing that information, one of the 45[13] possible solutions are applied for the claim. Here, it is important to note that deciding on one solution or another requires a cognitive effort. Finally, the decided solution is performed, and the resolution information of the claim is written down in the CRM of the company. This process receives around 6000 cases per month.

The solution adopted for this project implies the following steps:

- Application of process mining techniques to discover the process model behind the system logs to be robotized. Since most of the activities consist of accessing several information from information systems, the initial segmentation delegated most of the activities to the robots. Making the ultimate decision was the single activity on the human side.
- The hybrid process starts with a farm of robots implemented in UiPath that extracts the information systems' claim information. To avoid collisions with the human employees and to have the extracted data prepared before they start their working day, these robots work on a temporal window from 00:00–12:00. Process mining was critical for detecting which information was relevant for the human to be presented in the transfer point design. The extracted information involves around 100 variables identified as beneficial for the human to decide which resolution applies to the claim.
- In later versions of the transfer points, the outcome of the previous step was integrated with a prediction system to raise a recommendation of the resolution. This prediction system consists of a Machine Learning model, which was trained with six-month-length datasets and is deployed in AWS Sagemaker[14], i.e., a managed Machine Learning service. More precisely, the system was trained to predict the 3 most common out of the 45 resolution alternatives since these 3 constituted 60% of the cases. The resulting prediction and the confidence threshold provided by the algorithm are then stored in a database that populates the task queues of the humans.
- As depicted in Fig. 8, the human-robot interface (i.e., the designed transfer point), named "Dispenser", is in charge of displaying in a web front the robot information to the back-office workers. Among other information, it shows, (1) the case data, (2) the recommended resolution to apply, (3) the confidence threshold, (4) all the information that the robot gathered in the first step, and (5) the information that the robot reports that is missing. Thereafter, the human can perform the decided resolutions —which may differ from the recommended one— and the Dispenser system allows to register the steps performed by the worker. This information enables a continuous refinement of the algorithm.
- A generic governance and control tool was deployed that monitors the metrics of the UiPath robots and the human workers.

The project requires an initial design and construction of the hybrid process, which required 3 months. The last version of the process was obtained after 12 iterations of the method during a period of 10 months. The first version of the hybrid process was able to improve the cost efficiency[15] of the process a modest 10%. However, high values in the humans OMT revealed room of improvement in the design of this transfer point. The last version includes several improvements:

1. Optimization of the initial activity that extracts data from the information systems.
2. A improved Machine Learning models as a result of 10 training iterations performed with the newly received data.
3. Implementation of rules that were learned based on the steps performed by the human. This deterministic solution was combined with the Machine Learning algorithm.

In this last version, the cost efficiency was improved a 60%, which results in a reasonably good value.

The experience of conducting the project in Company A arose the following conclusions:

- The usability of the Dispenser (i.e., the human-robot interface) supposed a critical factor since there was a huge amount of data to be transferred to the human. The easiness to access the cases and their information had a significant impact on the efficiency. Similarly, it was critical to the efficiency that the missing information is clearly depicted. The human should be able to unequivocally identify such items and access the robot traces to see the actions on the system that it has operated. Since these kinds of errors or malfunctioning may occur, the Dispenser had to be designed to avoid degrading the efficiency of the process.
- Since the queues of the human workers depended on the outcome of the robot activities, a system to control the extraction rate of the robots had to be designed and incorporated into the governance and control tool. Such a system allowed to increase the number of robots to guarantee that the human workers had enough work in their queues during their working hours, thus ensuring the absence of bottlenecks caused by the robots.
- Surprisingly, although the overall process gained efficiency and the initial step of data extraction was highly reduced due to the robot intervention, the time spent by humans in their cognitive activity increased reasonably. After some wrong hypothesis, it was discovered that when the humans had to do the data extraction, they acquired part of the knowledge that was later needed to make the decision, i.e., they start performing the reasoning activity in a 'hidden' manner. Once the hybrid process was set, and this extraction step was shifted to the robots, humans had to do the whole reasoning after the extraction, which irremediably computed as a more extended period.

5.2. Project in Company B

This project was developed for one of the leading telecommunication companies in Spain. The process to hybridize consists of validating requests for adding a new customer or modifying

[13] Although more solution alternatives may exist, they rarely occur in practical settings.

[14] https://aws.amazon.com/sagemaker

[15] This general measure both the cost savings of human's FTE and the robot licenses. However, individual and absolute values are not permitted to be disclosed.

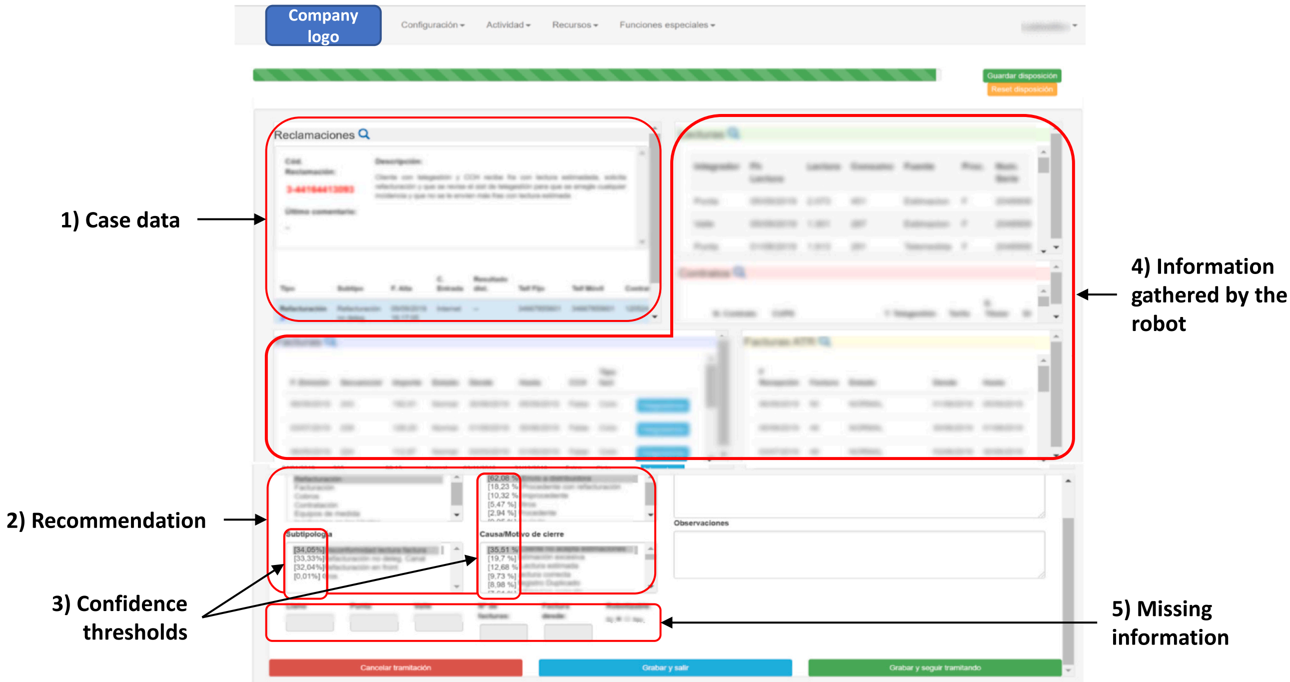

Fig. 8. The anonymised version of the "Dispenser" transfer point after some iterations of the method of project in Company A.

existing ones, e.g., acquiring a new SIM card, modifying the payment method or contract, etc.

The main workload of this process is on the analysis of the provided documentation to ensure that it is correct. It implies accessing different information systems of the company like the CRM, the service desk system, and other support systems, e.g., the email, the *suspicious customer* files, etc. Based on the information provided by the customer and the extracted information, a validation decision must be taken. The goal of the process is to ensure the fulfillment of the company protocol and avoiding fraud, e.g., nonpayment risk, phishing, etc. This process receives more than 8500 cases per month.

The solution adopted for this process implies different processes which were detected analyzing the systems logs using process mining. After the initial segmentation, it was divided into two different hybrid processes:

1. The first process, with 40% of the cases, deals with the already created cases in the service desk system. It includes 8 consecutive activities where only 2 are assigned to the humans regarding some validation of the robot activities. At a glance, the robot activities include more than 140 steps in total, which are performed over all the information systems.
2. The second process, with the other 60% of the cases, deals with the cases that come through the email. It includes 7 consecutive activities where 3 are assigned to humans. Eventually, in a normal situation, this process generates a case for the first process.

Unlike the case of Company A, monitoring the user interface and applying process mining to these UI logs was crucial to discover the details of the steps which were included in the robot behavior. Similar to the project of Company A, (1) a farm of robots implemented in UiPath is used, and (2) a family of human-robot interfaces is deployed as web fronts.

Although this process entails a tighter interaction between robots and humans than in Company A, each transfer point requires a simpler design which were similar to each other (cf. Fig. 9). That is why the design and construction of the first hybrid process required less than 2 months (i.e., 9 weeks). Similarly, it just required 3 iterations of the method during a period of 3 months. This last version obtained a 93% of effectiveness, i.e., the other 7% were cases where the robots failed for some unexpected reason. Related to the reduction of required human FTEs, the process passed from 4.5 to 1.83, which implies a reduction of 40.6%. Nonetheless, this tighter interaction required to deploy more elaborated govern and control tools that in Company A. It comprises a set of views, e.g., the task analysis view that is depicted in Fig. 10. Among other information, it shows, (1) the process and time frame selection for the analysis, (2) the specific task selection within the selected process, and (3) the metric analysis, which includes the volume of cases and OMT temporal analysis of this task.

Beyond the human FTE reduction, further benefits were brought to the telecommunication company:

- There was observed an improvement in the speed of the resolution of cases. Where, in the manual process, the ratio of cases closed in less than 24 h was rather low —< 50%—, the hybrid process scores an 82%. Moreover, since some cases do not require human intervention, they are solved immediately, even during the weekends or other out-of-office periods. That has a direct effect on customer satisfaction.
- In the manual process, the human workers were involved in the whole process. Each worker had their own way of performing the process, and so, no other could easily retrieve the process at a working state to complete, for instance, when someone becomes ill. Thanks to the division into smaller sub-processes (i.e., vertical segmentation), each of them are now standardized thus, simplifying the process and enabling workers or teams to specialize in some exclusive sub-process but not on the whole one.

5.3. Industrial experience discussion

The development of two successful cases applying the proposed method allows discussing the lessons learned during this process. Firstly, it is worth noting that the results obtained in the executed projects are relatively good in terms of FTE reduction, which is how

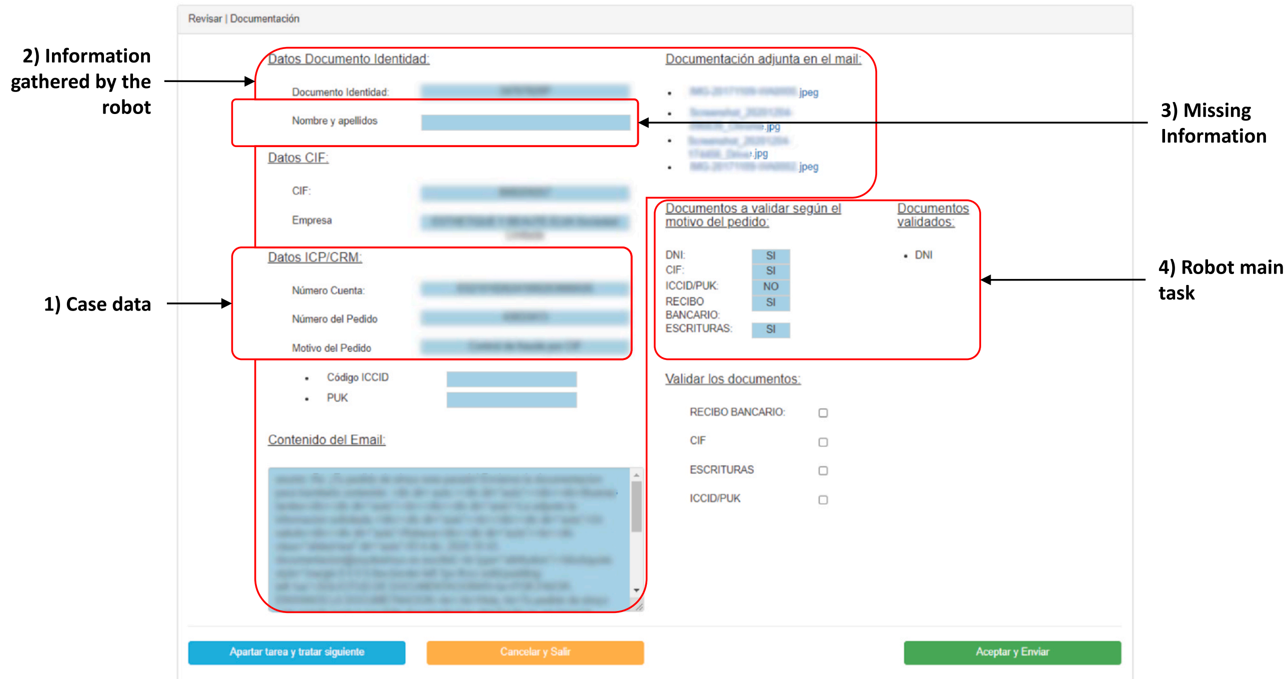

Fig. 9. An anonymised version of a transfer point design of project in Company B.

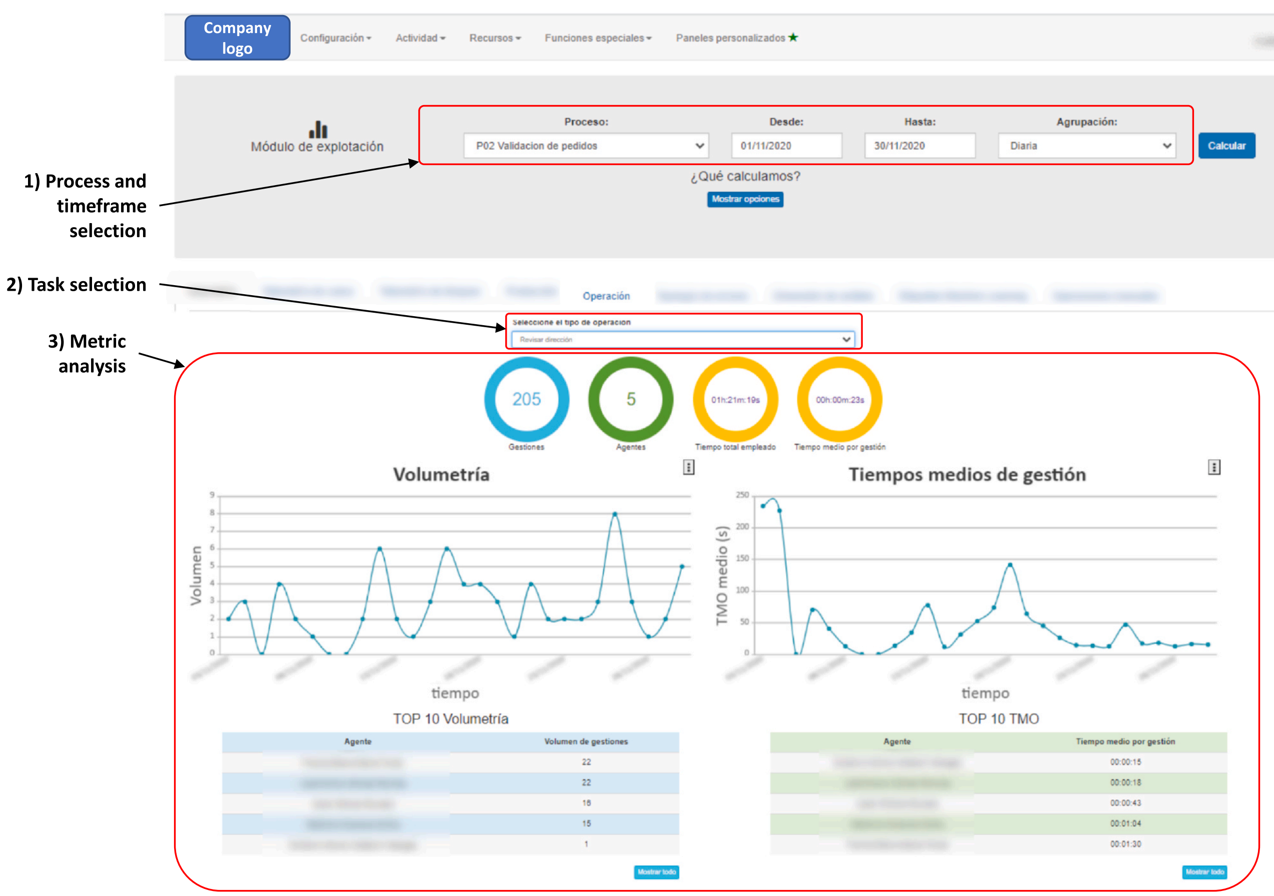

Fig. 10. The anonymised version of the task analysis view of the govern tool of project in Company B.

the impact of automation is usually measured (Wanner et al., 2022). Nonetheless, further strengths of the method can be observed and discussed.

The iterative execution of the method is understood as a road map to hybridize a process. Unlike a big bang approach, it starts from small pieces of the process that tend to be interpreted as less harmful by the human workers.

The isolation of activities enables dealing with them as black boxes, i.e., changes can occur while the input and output format are respected. Transparently to the humans, it enables the incorporation of technologies to the process, e.g., adopts a Machine Learning algorithm to classify the cases (cf. company A) instead of a rule-based approach. In the ultimate case, this isolation mechanism enables the substitution of the RPA technology with a traditional API-based automation —in case it becomes possible— without affecting how humans work.

Deploying a govern and control tool along with the hybrid process allows, among other things, the assessment of the improvement and the capability of further automation initiatives. Project managers may consider this assessment when deciding about investing efforts to shift more human work to the robot side or to improve the performance of an already automated part. Similarly, this governing and control tool brings together humans and robots under the same system, which avoids shifting between two different sources, thus enabling a comprehensive view of the whole workforce of a process.

One of the most significant advantages of this method is that the knowledge acquired in one project can be leveraged in subsequent ones. On the one hand, the first versions of the transfer point designs use to share similar shapes that are later evolving according to the business context. On the other hand, the governing and control tool share many similarities between projects. Although general solutions typically are not efficient enough, they may serve as a fast initial starting point before tailoring.

Additionally to all these strengths, certain drawbacks that need to be addressed in the future have also been identified. First, the proposed method implies the development of IT solutions which implies costs and, thus, must be analyzed. The projects described in this section can be considered as medium-large projects, and the method turns out to be cost-effective. Nonetheless, it is supposed that a different conclusion can be achieved for small projects.

Moreover, this method requires to —partially— move from existing interfaces of RPA vendors. Similar to the previous point, it implies adapting and developing systems from scratch. Even more, managers or supervisors may be skilled in vendor-specific solutions and, therefore, they would require training for adopting the new tools. However, this drawback is diminished because these kinds of BAM tools are suitable for intuitive and similar interfaces that facilitate its adoption (Kang and Han, 2008).

Finally, it is important to note that applying these methods becomes more cost-effective when several projects are performed. That is, the first time the method is applied, several decisions and new developments are required. As stated before, the following projects leverage knowledge and technology. For this, it seems reasonable that adopting this method or other method should be part of a company's strategic decision instead of a single decision for an automation project.

6. Discussion and limitations

One of the advantages of the considered approach is that it considers humans a key participant in the RPA development from the very early stages. Moreover, this human-in-the-loop approach aims to empower them by providing an increasing set of virtual workmates whose evolution is foreseeable. What is more, the human-robot interaction is faced through both the technical side and the sentimental side. That is, the effective transfer of the process ownership from the robot to the human is performed in a trustworthy environment where humans keep the feeling that the robot is helping them and not the opposite. Finally, the method is designed to isolate and concentrate the work of both humans and robots, paying particular attention to the process information which flows from one isolated part to the other and thus, setting up an appropriate scenario for leveraging the goodness of process mining.

However, the method presents some drawbacks when trying to generalize to the wide paramount of RPA contexts. First, cognitive activities (i.e., those where human-like intelligence plays an important role to be conducted) represent a relevant fraction of the whole activities in nowadays' processes. Thus, the systematic part of the process may not be that high. The impact of the hybridization in these kinds of knowledge-intensive processes is expected to be low regarding the volume of cases and the efforts that imply this method. In these specific contexts, the method should incorporate additional techniques in the area of Machine Learning that can coexist with process mining. In that way, some parts of the "unsuitable tasks for RPA" (cf. Fig. 7) that was considered before could be addressed with these new techniques.

Regarding the profitability of the method, some projects present a relatively low ratio of the volume of cases/system stability. That is, the related information system is in a continuous change and, therefore, the execution of the robots is too fragile. This would require a continuous adaptation of the robots, which would, in the end, prevent a cost-effective hybrid solution unless the number of cases is reasonably high between each change of the system. Although deterministic robot designs are more likely to be accepted, these highly changeable scenarios require robots to be flexible in detriment to the robustness. The hybridization of these kinds of processes should imply more but shorter robot activities that can be repaired quickly and efficiently when KOs start occurring.

In line with the current Big Data trends, the wide variety of data and data sources that are sometimes involved in the processes prevent designing a structured robot-human collaboration. This situation may bring difficulties for a robust hybrid process design. Nonetheless, an intelligent strategy is to identify the whole set of potentially required data so that the robot is forced to gather all of them. Then, the human is the one who decides which data is certainly needed to be used in each situation. In that strategy, the robustness of the process is guaranteed, although the human is offered less-processed information.

Lastly, some contexts are subject to extremely short temporal windows where processes must be completed, e.g., tight service level agreements, which are quite popular in the BPO scope. In these contexts, any execution KO in the robot tasks leaves a narrow margin of maneuver for its resolution. This is even more dramatic when these KOs occur during out-of-office periods (e.g., during nightly batch processing) to accumulate considerable delays. Additionally, this may impact the human queues since the human tasks that continue the cases are not pushed to the queues since they are in KO state. It is crucial that companies evaluate the risks of each context before starting with a hybridization process like the method proposed in this paper. Although it is out of the scope of the current proposal, this risk assessment would suggest some countermeasures to apply in the case that the risk appears, e.g., keeping a 24/7 human team to mitigate KOs during nightly executions.

7. Related work

As in the present proposal, some works identify the importance of involving humans in process automation. Axmann and Harmoko (2020) define three modes of RPA, i.e., unattended, attended, and hybrid, where humans have an active presence in the latter two. In addition to this classification, Agostinelli et al. (2019) review different RPA platforms available on the market to classify the type of automation they offer. Both approaches identify the hybrid mode as one of the most important, considering that the robot coexists with the human throughout the execution of a process. Kirchmer and Franz (2019) reinforce the importance of humans within the automation ecosystem. In this sense, the authors argue that RPA projects would not be possible without their enablement and empowerment.

The concept of "human-in-the-loop" refers to systems where an operator controls a device with the desired task (Stanciu and Oh, 2003). In the RPA literature, this concept has been coined from different perspectives. Ravindranath and Bhaskar (2020) define it as a method where a human agent manually validates a process activity. Taulli (2020b) has identified some RPA vendors, e.g., UiPath, that introduces the concept of "human-in-the-loop" by providing human interaction at any activity of an unattended robot. From Mohanty and Vyas insights (Mohanty and Vyas, 2018), in processes involving Artificial Intelligence (AI), humans spend much time collecting data. Their "human-in-the-loop" approach promotes leaving these types of activities to robots. In this sense, the authors propose that humans perform activities related to making sense of data and feeding those lessons back to the AI strategy for better performance.

The inclusion of humans within the RPA lifecycle has also been considered in the literature. Jimenez-Ramirez et al. (2019); (Jiménez-Ramírez et al., 2020) propose the automation of robot testing, taking as a starting point the monitoring of the human work behavior in an outsourced process. Sigurðardóttir Sigurðardóttir (2018) defines the RPA lifecycle as a set of six main steps, i.e., process breakdown, development robots, process testing, execution, and verification in production and evaluation of benefits. Herm et al. (2020) present a framework for implementing RPA projects. However, in these approaches, the human is considered superficial, e.g., throughout the process analysis phase or process breakdown of the RPA lifecycle or during the automation need identification, not in the complete process.

From a different point of view, Siderska (2020) enhances the human figure by delegating the most creative or strategic activities to him, leaving the robots to perform more routine ones. Furthermore, Kopeć et al. (2018) propose a human-centered method to design and maintain robots. Nonetheless, in this method, the human is not involved in the process execution.

In summary, the current literature focuses either on including one human activity in an automated process or on just one phase of the RPA lifecycle. Conversely, these perspectives do not fit with the one presented in this paper, where the human factor has a holistic vision of the whole process or lifecycle. In addition, the proposals found rarely present case studies or industrial validations. In this sense, this paper has presented a running example based on industrial experiences in the sector where the approach is validated.

8. Conclusions and future works

The movement of RPA has been raising the attention of both research and industry in the past years. Medium and large-sized companies have successfully adopted RPA to increase their competitiveness through this advanced automation solutions. Nonetheless, a broad set of environments were still unsuitable for robotic automation, like the small and medium-sized companies. Therefore, this paper brings a discussion about how different environments can become suitable by considering the *human-in-the-loop*.

In that context, this paper describes a method to develop RPA projects when the collaboration between robots and humans is a must. Its goal is to end up with an efficient, robust, and fluid hybrid processes. For this, five steps are suggested covering from the initial segmentation of activities until the deployed processes' design of control and governance mechanisms. This is an iterative approach where analyzing the process data is crucial to perform sound steps towards an optimized collaboration. Therefore, process mining plays an important role in the method.

The method has been applied in real-life settings to show the applicability of the approach. Results indicate that the method provides substantial benefits in the efficiency, which is greater than 40% in the two conducted evaluations.

Nonetheless, the method presents some limitations. First, it provides a set of steps that, although they are concrete, do not provide specific techniques or tools to perform them since they might depend on the company or the process itself. Second, the proposed method starts once the automation decision is already done. Therefore, the analysis of the organization, the selection of RPA tools, and other previous steps remain out of scope. Lastly, in the same way, the method scope ends with the design of the mechanisms to measure and govern the hybrid processes. Nonetheless, the precise rules or actions to conduct to scale or move the workload are not covered in the paper.

For future work, we plan to (1) experiment with different metrics and rule patterns for the process governance in such a way that they can be automatically discovered, (2) elaborate more on the psychological and socio-ethical part of the method to disclose the barriers that keep appearing and can generate frictions in the hybrid process, and (3) perform controlled case studies in different size companies and processes to improve the soundness of the initial results.

CRediT authorship contribution statement

Rafael Cabello Ruiz: Conceptualization, Supervision. **Andrés Jiménez Ramírez:** Conceptualization, Methodology, Investigation, Writing – original draft, Investigation. **María José Escalona Cuaresma:** Writing – review & editing, Supervision. **José González Enríquez:** Conceptualization, Methodology, Investigation, Writing – original draft, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

Research was partially supported by the NICO project (PID2019-105455GB-C31) of the Spanish Government's Ministry of Science, Innovation and Universities, Trop@ project (CEI-12-TIC021) of the Junta de Andalucía and by RAIL project (Platformfor the automatic and intelligence learning of Software Robots).

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