Collaborative Model-Based Process Assessment for trustworthy AI in Robotic Platforms

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Abstract. The use of robots in combination with artificial intelligence (AI) is a current trend with the promises to relieve humans from difficult-, time consuming- or dangerous work. Intelligent robots aim to solve tasks more efficiently, safer or partly more stable. Independent of the domain-specific challenge, the configuration of both (a) the robot and (b) the AI currently requires expert knowledge in robot implementation, security and safety regulations, legal and ethical assessments and expertise in AI. In order to enable a co-creation of domain-specific solutions for robots with AI, we performed a laboratory survey – consisting of stakeholder interaction, literature research, proof-of-concept experiments using OMiLAB and prototypes using a Robot Laboratory – to elicit requirements for an assistant system that (i) simplifies and abstracts robot interaction, (ii) enables the co-creative assessment and approval of the robot configuration using AI, and (iii) ensures a reliable execution. A model-based approach has been elaborated in the national funded project complAI that demonstrates the key components of such an assistance system. The main concepts paving the way for a shift from research and innovation into real-world applications are discussed as an outlook.

Keywords: Robotic, Artificial Intelligence, Model-based Approaches.

1 Introduction

Digital transformation has the potential to create additional value of about 100 trillion $ (in Europe “billion”) in the next decade [1]. Industry aims to capitalize this potential by creating new businesses and improve existing businesses by applying digital technology.

Robotic, AI and the corresponding and enabling key technologies like but not limited to edge computing, industrial Internet of Things (IoT), block-chain, Big-Data and cloud computing introduce huge business-, social- and technology-potentials. In this paper we address the challenge of autonomous, adaptive or even intelligent robotic systems that promise to (a) be active in dangerous or unhealthy environments, hence relieve human worker from unsafe or unhealthy work, (b) transform or optimize business by either introducing a new form of business and income or by extending, enlarging or improving an existing business model, (c) reduce volatility by not exclusively relying on human power but relying on human power in combination with supporting robots and the capability to shift some of the workflow between humans and robots.

This paper is based on a one-year survey performed in the national funded project complAI with the aim to:

- Reduce the complexity and the necessary technological background that is required to realise a robotic application.
- Empower domain-experts and business managers to co-create innovate new robot scenarios.
- Enable transparent, audit-proof and compliant solutions “by design” that are assessed and approved according security-, safety-, legal-, ethical- or gender relevant criteria.

Our approach was to develop a model-based assessment environment that has the capability to:

1. Introduce a model-based approach using business processes and workflows in order to abstract and hence simplify the complexity of a robot implementation.
2. Enrich the model-based approach with assessment-, approval- and reliability- capabilities to support the generation and execution of compliant workflows at robots.
3. Introduce AI that supports or takes over decision making and enables therefore the introduction of adaptive or autonomous systems.

In the **second chapter**, we introduce which requirements we have derived by first working within the survey on a hypothetical sample of a digital supermarket, and at the end of the survey, when enough findings were available, worked on a sample in the cultural as well as industrial domain.

The main aspects of the survey are then introduced in **chapter three** – the introduction of the model-based approach, in **chapter four** – the assessment criteria and how they can be used to support the generation of compliant workflows, and finally **chapter five** – the linkage of executable workflows and assessment criteria. **Chapter six** lists the results and how they can be downloaded and used for further research. **Chapter seven** provides a short summary and an outlook on the next steps transforming the survey into a use case driven project.

2 Motivation and Use Case Requirements

We started the discussion on innovative business models [1, 2] that are enabled by autonomous robot applications, by the hypothetical idea of the digital supermarket, as this gave us the possibility to (a) identify innovative use cases, without limitations that arise when having a realisation in mind, as well as (b) enable a so-called "association" of the interdisciplinary partners that speeded up the generation of a common-understanding and simplified the communication as independently of the technical and professional background, the situation in supermarkets where well known by all participants.

We consider this as a so-called "physical experiment", that simplifies a real-world challenge and introduces a common understanding through association, as certain challenges are understandable via various viewpoints. Based on a retailer investigation[1], challenges like (a) store traffic recognition using cameras or other shopping cart tracking devices, (b) in-store concierge [3] in form of guiding robots helping customers to find the right articles, (c) automatic check-out shopping cart [4] that automatically scans goods, offers similar products and checks-out without the need of cashier, (d) smart building like automatic inventory checks [5] performed by robots, or (e) other not robotic relevant ideas like in-store voice commerce or consultancy.

Based on those high-level ideas we derived concrete use cases like:

- ***Workflow creation and abstraction*** for mobile platforms and robot arms. Executable workflows that steer mobile platforms and robots via invocation of platform-specific interfaces have been abstracted to become platform-independent workflows defining so-called artefacts of movements. The more abstract a workflow can be defined; the less technical knowledge is needed for the interpretation.
- ***AI for decision making*** for adaptive workflows. An adaptive workflow has the capability to change its behaviour either immediately before execution – in case of pre-binding – or even during execution – in case of late-binding. In case those decisions are provided by intelligent systems, we consider this as an automated system.
- ***Legal and business compliance*** of mobile platforms (e.g. self-driving shopping carts) and robot arms (e.g. assembly of products packages in cold warehouse). This was realised by assessment criteria that have been applied on robot execution models.
- ***Assessment of workflows and AI*** according legal and business compliance criteria. This was addressed by providing a model-based questionnaire system that links aforementioned workflow models – and abstract workflow models – with AI – semantic lifting and inference as well as rule-based decisions – with a questionnaire model that is extracted out of assessment criteria.

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[1] Based on innovation talk „AI in Retail" at Retail Austria at 24.01.2020 from enlite.AI

3 Model-Driven Robot Applications

3.1 Introduction into Model-Driven Approach

Conceptual models are used to represent the so-called "system under study" – in our case the robot application – with the aim to reduce the complexity and therefore simplify the interaction with the real-world. In complAI we use the OMiLAB innovation corner in order to interlink the (a) business layer that is concerned with creating new business models, (b) the proof-of-concept layer that is concerned with engineering prototypes and (c) the conceptual modelling layer that is concerned with creating organisational models in order to link the business with the proof-of-concept layer.

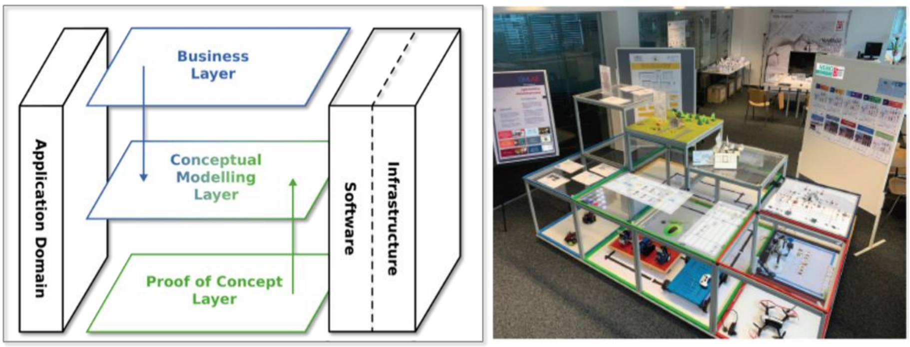

Fig. 1. Introduces the three abstraction layers of the OMiLAB Innovation Corner, whereas the conceptual description is on the left part and the realisation of the industrial OMiLAB Innovation Corner at BOC in Vienna is shown in the right part of the figure.

The OMiLAB Innovation Corner [6] is based on the following principles:

1. **Business Layer: Focus on Business Model Creation**
   A business model describes the "rational of how an organisation creates, delivers, and captures value" [7]. The aim is therefore to either improve existing or to generate new business models in order to generate added value. This layer therefore provides a high-level overview of the domain, the application scenario as well as the overall eco-system in which the organisation operates. It follows the "Outcome based approach" principle, where digital innovation is always justified by the outcome.
2. **Conceptual Model Layer: Focus on Organisational Model**
   Conceptual models are successfully applied in enterprise modelling [8] and information systems [9] and hence capable to describe how the digital solution is applied within an organisation. The digital innovation is therefore described in a technology independent way using a knowledge-based approach. The knowledge can be interpreted by computer algorithms or by human experts, depending on its model-representation. Hence, we follow the principle to "Invest on use cases and not technology" as the organisational models can be realised with different technologies.
3. **Proof-of-Concept Layer: Focus on Robot Interaction**

Rapid prototyping [10] is "… the idea of quickly assembling a physical part, piece or model of a product". We apply rapid prototyping for both the development of a software application as well as for the development of a physical device. The engineering of rapid prototypes is performed by configuring and integrating pre-packaged features that are provided as services. Instead of fully implementing the prototypes, we apply the "Fail Fast, fail cheap" principle by rapidly composing features in form of services that emulate the main behaviour of the intended solution.

Although the aforementioned layers of the OMiLAB Innovation Corner can be mapped to the three phases of design thinking, "Ideate", "Prototype", and "Test" [11], we explicitly consider that projects either focus on only one or two phases, that phases are visited in no particular order as well as that the phases are worked out in a sequence. In complAI we focused on the proof-of-concept layer mainly, by using workflow models to steer a proof-of-concept robot device in the OMiLAB Innovation Corner and then steer a real-world robot prototype in the robot laboratory.

3.2 Presentation of Workflows for Robot Interaction

The steering of a robot platform hast been worked out in complAI [12] by using workflows that are specified in BPMN notation and that can be interpreted by a series of workflow engines.

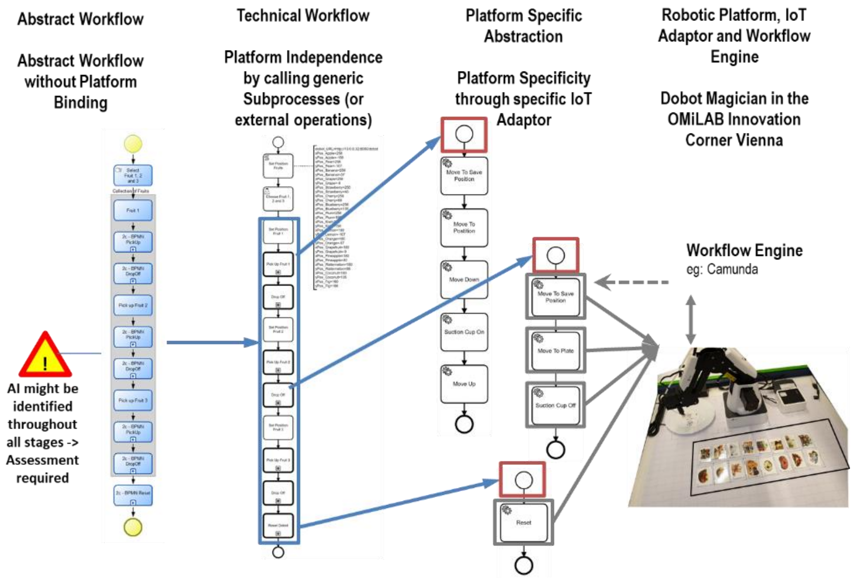

Fig. 2. Introduces such an instantiation of different abstraction layers of workflows, demonstrating that the platform-specific workflows access a specific command of a robot device. In this sample the robot arm from Dobot Magician that is accessed by the Camunda Workflow Engine as well as more abstract workflows – like the technical workflow that accesses only so-called movements artefacts – are shown.

The concrete movement of a robot, like picking up an object from particular x, y, z coordinates, is implemented as an application interface in form of a method “picking up” with three input variables for the x, y and z coordinates. This computer program uses platform specific interfaces, in our case these are the dll commands provided by the Dobot Magician, to implement the move of the robot arm to the position x, y, z and start to pick-up the object, in our case to start the suction cup unit with a certain power and a certain amount of time to suck a card that is laying at the corresponding position. All details are provided in the open-source download package [18, 19].

Such a platform-specific command will be exchanged when interacting with the Universal Robot (UR) arm that is used in the robotic laboratory. Hence the movement to pick up an object from position x, y, z may be differently implemented but the abstracted move is the same.

This simple sample raises a series of questions like, (a) which tool is used to “pick-up” an object either by grabbing or sucking, (b) is additional information needed for picking and placing like the position when picking and the position when placing, (c) are additional security considerations required like the speed or the power the robot arm moves and the like.

Hence, the simple move of an abstract workflow raises several technical and safety relevant questions. In the proof-of-concept environment we aim to free the user from technical questions but focus on issues like picking up an object and placing it. Therefore, we consider this as an “abstraction” to reduce the technical details and enable the focus on other challenges like, who decides what, when and where something is picked up.

In a simple form, we can pre-define a fixed sequence of picking-up items and placing them in a fixed order. In case to make the system adaptive and therefore flexible to react on the situation of the environment, we can introduce a sensor that is checking if a certain object is actually available and hence can actually be picked up, or if another object has to be picked up instead.

In the following, we describe a layered software stack for executing workflows on a robotic platform, which is further developed from the work presented in [20]. Figure 3 shows a realization of the stack for a mobile manipulator consisting of a Mobile Industrial Robot (MiR 100) and aUR arm. The individual layers can be described as follows:

1. Robots and drivers: Provide hardware specific drivers for individual robots and additional hardware (sensors, etc.).
2. Integration: Provides modules for integrating the underlying hardware, like full body compliance, sensor fusion or robot motion planning.
3. Workflow abstraction: The workflow manager (WFM) provides an execution engine for executing pre-defined sequences of actions. The state provider collects information of the individual system components and provides it to all other components.
4. Execution: The WFM-API is a re-usable component providing a REST-Interface, which is configured according to the capabilities of the underlying robotic system. In our sample the WFM-API provides methods for executing action sequences like moving the arm to a certain position, relocating the whole platform, or detecting an

Augmented Reality-Tag with the camera mounted on the arm's end effector. Similarly, the State-API provides an interface for fetching the current system state from the state provider.
5. User and top-level application: On the top layer the user and/or (external) client components can utilize the APIs in order to run or teach in robotic applications on the underlying platform.

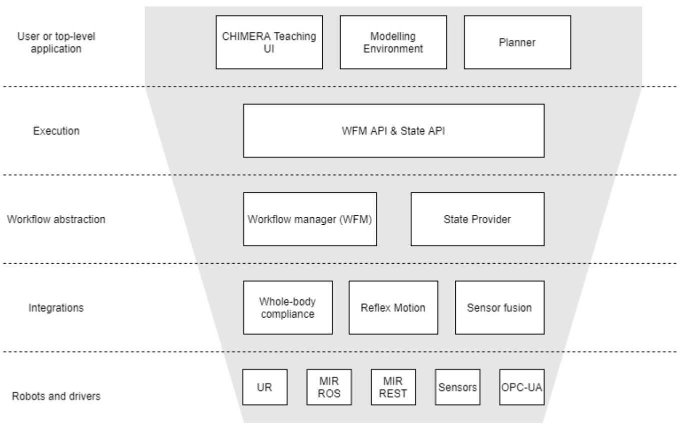

Fig. 3. Software stack for executing abstract workflows on a robotic platform – in this sample a mobile manipulator consisting of a MiR 100 and a UR arm is used.

3.3 AI Integration

The mechanisms to implement and integrate AI in the workflows, are the introduction of adaptive workflows, either pre-binding or late-binding workflows and the introduction of a decision-making component that "binds" the workflow. In our case the "binding" means which values are used for the variables x, y, z, and the decision-making component is either a human who selects which object to pick up next, or an AI component that inferences which object to select next.

In the complAI project, we specifically focused on the model-based aspects and how intelligent decisions related to business [16] can be integrated into the execution models. However, we did not extend the survey on how to identify the environment with sensors or how to perform intelligent inferences. We are confident that with image recognition, light-sensors, or weight sensors the existence or not-existence of objects can be identified, hence we started the integration into our workflows based on the assumption that an object is either available or not.

We implemented two approaches within the OMiLAB Innovation Corner in order to then decide how to "bind" the workflow. First, we used a rule-based approach following the Decision Model and Notation (DMN) [22] to define "if object a is not available then object b should be taken instead". Such rules can be implemented using a DMN model and the corresponding rule engine that interprets DMN, or it can be programmed in a script, that "if a is not available then object b" should be taken instead.

A more sophisticated approach is the semantic lifting of an object with concepts from an ontology. In case this object is not available anymore, a semantic discovery is performed and the most similar object is used instead. Those and some other AI implementations are provided by ADOxx.org [17]. In case decisions are performed not by trusted human experts but by a software, the trustworthiness of such a system needs to be ensured, in particular when robot arms or mobile robot platforms autonomously perform movements that need security, safety, legal and ethical reflection. The creation of a questionnaire in order to assess aforementioned aspects is elaborated in the next section.

4 Assessment Criteria

Criteria on Laws and Ethics

Trustworthy AI has grown to become an increasingly important aspect in the quest for ethically sound and legally feasible AI. This has induced many research areas to start thinking about how to (a) build an AI that is trustworthy, and (b) increase the (justified) trust human users put into these systems. And while there are still considerable challenges, especially related to approaches and understandings of *trust* and *trustworthiness*, the overall incentive of this quest is not only important, but necessary.

The complAI project [13] addresses some of the practical and theoretical challenges that arise with the realization and implementation of such trustworthy AI. In this, the main task of the ethics team comprised the elaboration of an applicable ethics criteria catalogue.

However, before delving into a short summary of this ethics criteria catalogue, it is important to emphasize the above-mentioned differentiation between trust and trustworthiness. While human agents already – sometimes irrationally and blindly – *trust* technologies (e.g. the trust in navigation systems, phones, etc.), a fundamental question lies in the aspect whether the underlying technology is actually trust*worthy*, or not [c.f. e.g. 29, 30]. This aspect is echoed in the main objectives of the elaborated criteria.

To approach the ethics criteria catalogue in an appropriate and viable way, the authors began with a wider and more abstract stance on different notions of trust in AI and trustworthiness of AI. Starting from questions concerning expectations towards technologies, over priorizations and values, to ecological and economical objectives, the ethics team put together a set of important key concepts of different disciplines (e.g. law and engineering) who are engaged in the development of trustworthy AI.[2] Some of these elaborated key concepts included i.a. *responsibility*, *risk*, *danger*, *ethical corridor*, and *AI* more generally. Based on these concepts, the emerging catalogue then focuses on six main pillars, which aim to bring interdisciplinary values and principles under one common denominator:

1. The prisonization of the quality of the technical products over the quantitative propagation
2. Human dignity

[2] Based on the conducted expert interviews.

3. The periodization of social wellbeing over economic benefit
4. Human-centredness of development of AI
5. Overcoming negative impacts of factual constraints ("Sachzwänge") and impossible backward compatibility ("ausbleibende Rückwärtskompatibilität") so that technological issues do not limit or prefigure human decision making
6. Risk Management as complex task in technical systems including Robotics and AI

To refine the ethical criteria, these key concepts are aligned with some of the existing literature on trustworthy AI. The catalogue orients itself at some of the key requirements given in the whitepapers and recommendations by the AI HLEG and the ACRAI. These are: Human Agency & Autonomy, Human Oversight, Technical Robustness & Safety, Privacy & Data Governance, Transparency, Diversity, Non-Discrimination & Fairness, Societal & Environmental Well-Being, Accountability, Responsibility, Values [26, 27, 28]. Since the resources and possibilities within the project were somewhat limited, the ethical criteria catalogue focuses on the design- and production-level at which these criteria could (should) be implemented.

In order to specify ethical criteria that (a) address the mentioned principles and values from the project consortium (especially with regards to the established key concepts), and (b) build on the requirements given by the AI HLEG and the ACRAI, the project consortium devised a case study for showing a potentially dangerous interaction situation between human and robot serving as a foundation for the criteria catalogue [13].

An arising example criterion related to the digital supermarket sandbox scenario could then be formulated as follows:

- General criterion: "Could the AI system affect human autonomy by interfering with the end user's decision-making process in any other unintended and undesirable way?" [c.f. 26]
- Case-specific: "Does the system stick to the shopping list of the human shopper? Or can it make suggestions according to the shop's incentives?"

This specific criterion is based on the HLEG's requirement on human agency and autonomy, and addresses the value of human dignity. With assuring that the human agent's decision and action process are not interfered by the AI, this criterion aims to ensure that the AI does not affect the human agent's autonomy (e.g. by means of manipulation, nudging, or coercion). In the digital supermarket case study, this means that the human agent's decision environment is not fundamentally changed by the AI, and that the human agent's decision and action can be understood to be the result of a free and autonomous choice.

Summarizing, the criteria given in the catalogue are, first and foremost, an adaption of the criteria given by the AI HLEG and the ACRAI, with the important extension of including the expectations, needs and wants towards values and principles of trustworthy AI, which were established within the project's consortium. These extensions include new learnings on insights, interpretations and understandings, which, so we hope, can be used as a further step towards the development of more trustworthy AI.

Criteria on safety and security

The assessment of a robot application for safety and security always has many application-specific aspects which are hard to generalize. However, in order to establish a criteria catalogue for an initial proof-of-concept, we have used corresponding standards as a basis for our work. In terms of robot safety, we have extracted general guidelines from the ISO-10218-2 [23] "Safety requirements for industrial robots: Part 2: Robot Systems and integration" for stationary robots and ISO-13482 [24] "Robots and robotic devices — Safety requirements for personal care robots" for mobile platforms. We have categorized the requirements and formulated questionnaire questions that can be presented for a later user. Both standards are hard to bring into a machine-readable form since they are not as much checklist-formed as others and have many requirements hidden in prosa text. For this proof-of-concept, we have extracted 45 requirements and associated question blocks from ISO-10218-2 and eight such blocks for ISO-13482 (since many are related to internal construction and not so much focusing on the safety of the end-product).

For security requirements, we referred to the IEC-62443 [25] "Industrial communication networks - IT security for networks and systems" standards series. It defines requirements and processes for multiple actors involved in developing a secure industrial system, namely the component vendor, the system integrator and the end user. We have specifically used sub-standards 3-3 and 4-2 which define the requirements for the integrator and the component vendor respectively. IEC-62443 defines multiple security levels depending on which kind of attacks a system should be secured against (ranging from incidental manipulation to highly-skilled groups with extensive resources). Based on the requirements tables contained in the standards and the associated explanations in the documents, we have formulated example questions for a later questionnaire presented in D5.1 [13].

5 Assistance System to Approve Models

This section provides an overview of the model-based assessment assistance system presented in D4.1 [14] by linking the different criteria with models that are used to operate robot behaviour. After the assessment a digital signature – enabling trustworthiness – is attached to the models, which are then sent to the robots. The prototypes demonstrates that among others, three key challenges must be considered:

1. The model can be checked with regard to legal, ethical and security & safety issues. Essential at this point is to find out how those catalogues can be modelled and assessed. In particular, the foundation for this challenge is tackled in D5.1 [13], which covers the collection of the assessment catalogues.
2. The next challenge deals with modelling AI and robotics as well as the assessment of compliance. Those issues are mainly handled in [14]. Approved models can be signed in order to avoid fraud and as the assessed models might be shared between different stakeholders, transparency within the assessment must be ensured. Therefore, the models are signed using a hash code, which means that any change in the model results in a mismatch when comparing the publicly available part of the

signature and the hash code – that is calculated from a textual (XML) representation of the model.

3. The third challenge is about operating compliant models on a robotic platform. D3.2 [12] deals with those aspects more specifically. Before using the models on the robotic platform their validity can be ensured by means of certification checks. This makes sure that only valid models are sent to the robot platform. A technical mounting on the robot is necessary that this validation check is performed before starting the execution.

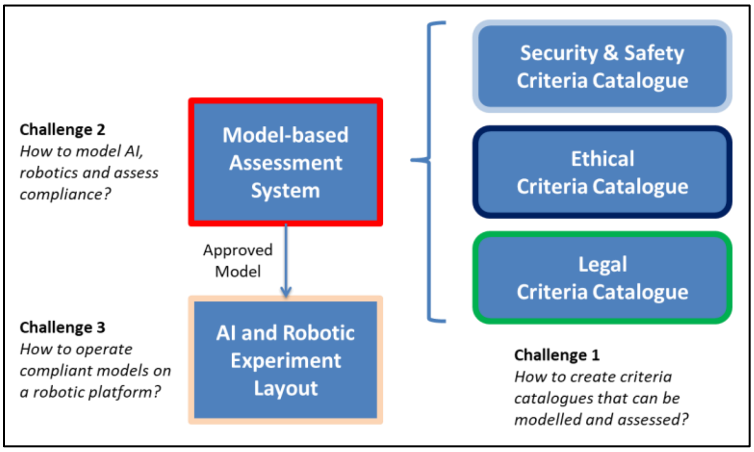

Fig. 3. Depicts how the assessment criteria that have been indicated in section 4 are linked with the executable workflows that have been elaborated in section 3 by a model-based assessment that converts the assessment criteria into a questionnaire model which is then linked to a workflow model in order to assess the workflow by answering the assessment questionnaire.

The assessment of a workflow is based on the idea that assessment criteria can be formulated by corresponding safety-, security-, legal- or ethical- experts. Those criteria are then transformed into a semi-structured questionnaire model. The meta model of this questionnaire defines answer types, such as single answers, multiple answers, or textual answers as well as how those answers are then used to calculate a so-called score value. This score indicates if answers to a set of questions can be considered as complaint – green values, not-complaint – red values, or yellow value that are in between and hence need further (expert) investigation.

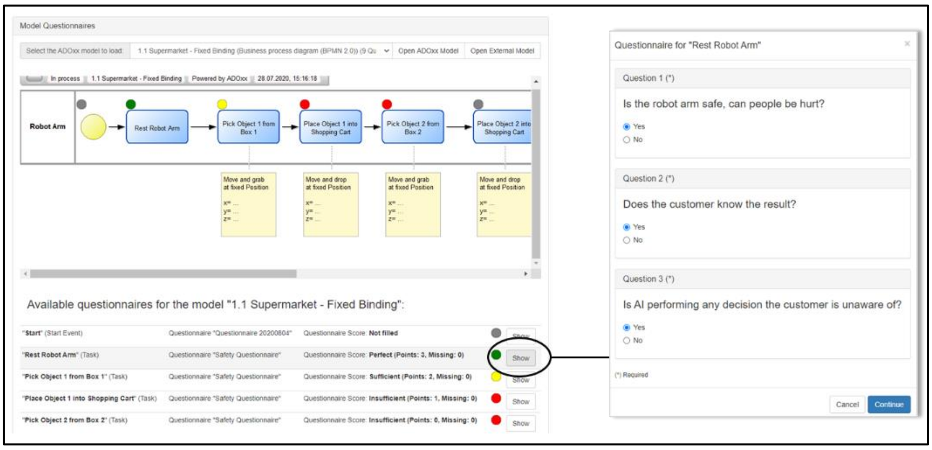

Fig. 4. Depicts the user interface of the assessment tool that applies a questionnaire – displayed on the right, which is configured by a questionnaire model – and a high-level workflow on the left, which displays the color-coded results of the assessment.

More details on how to link the questionnaire model with the workflow and how to translate semi-structured assessment criteria into formal models can be found in D4.1 [14] of complAI.

After successfully assessing the workflows, the model is digitally signed using an authentication environment and a digital signature of the model. A cryptographic environment has been designed to ensure that the whole process of developing, assessing, certifying and executing a robot program is secure. This environment has been described in D4.1 [14] and has also been published in [21].

The verification process is realized in form of a distributed ledger to ensure integrity, authenticity and non-repudiation of the artifacts resulting from the verification process as well as the development process itself. In this context the information shared by the peers is grouped in channels, which ensures privacy of sensitive information as the channel access can be restricted by the use of certificates. Every channel consists of a state which is serialized and stored in a database and a blockchain, which stores the transactions committed on the state. Later modifications of past transaction entries lead to an invalid blockchain and can be recognized by each peer, which guarantees data integrity. Furthermore, the transactions contain a digital signature of the issuer which ensures authenticity on the one hand and non-repudiation on the other hand.

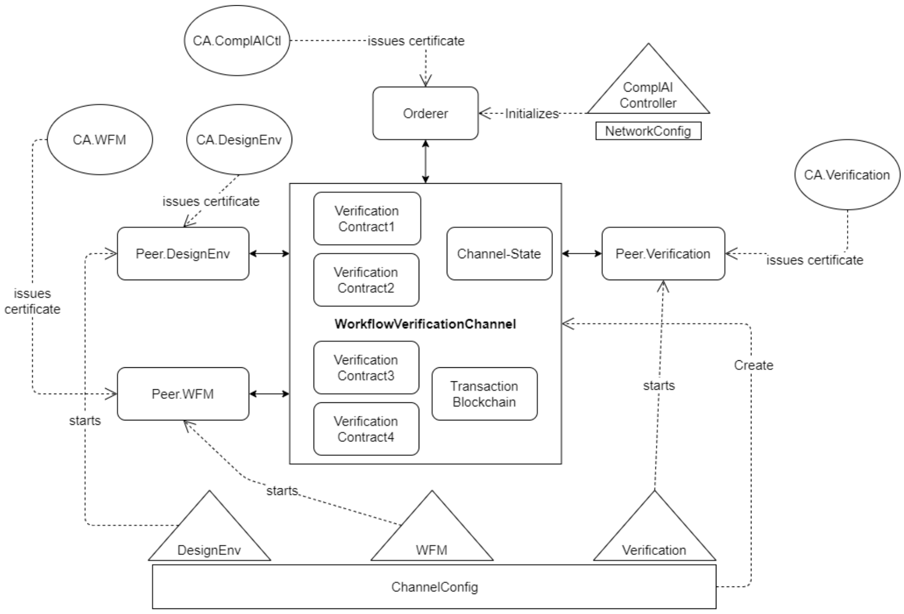

Fig. 5. Depicts the distributed ledger architecture of the compliant development and execution environment.

Based on this architecture and the presented software stack, a prototype for the digital signature and integrity checking of workflows has been implemented and demonstrated. A robot workflow is signed by a dedicated signature authority and the software stack will verify the signature and integrity of a workflow queue before it is executed on the robot [21].

All aforementioned chapters correspond to deliverables of the complAI project, hence more details and also material for download and usage can be found in the corresponding sources [2, 12, 13, 14, 19].

The next section, provide a short summary on available results.

6 Available Results

The digital supermarket has been chosen as a sandbox-scenario, so that the challenges in complAI (a) “Pick-and-Place” and (b) “Mobile robots” can be demonstrated. Although the use case of the digital supermarket is abstract and considered as a sandbox scenario, the worked-out mechanisms can be applied on concrete industrial use cases. In order to enable an open discussion on legal and ethical issues, we selected a hypothetical and abstract scenario allowing for more flexibility when discussion sensible issues.

For the “Pick-and-Place” scenario we consider a robotic arm that configures a basket of fruits for the customer. The idea is that the customer can choose the fruits from a mobile app, enter the shop and pick up the prepared basket of fruits. The challenge is to describe not only the process of picking fruits and placing them in a basket, but also on the decisions which fruit to pick and how to deal with the situation that fruits have been run out of stock. The simple sequence of picking up three fruits was modelled with a Petri-Net [15].

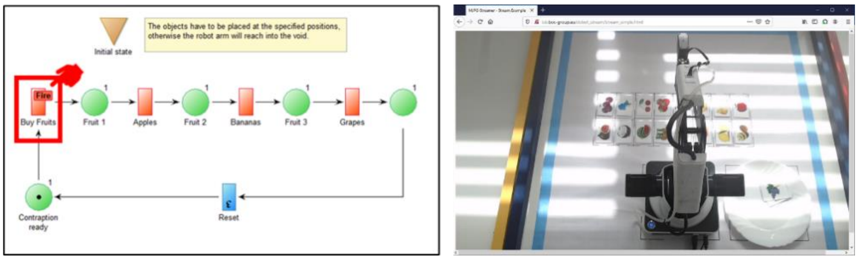

Fig. 6. Shows a Petri-Net describing a simple pick-and-place procedure for a robot arm. Each transition invokes an action from the robot that is shown as a life stream picture on the right.

The target platform is the representation of the pick-and-place workflow in form of a flexible BPMN workflow [16] that runs within a workflow engine. In order to transform and leverage the simple pick-and-place sequence, we switched to a flowchart representation, introducing sub-processes for certain robot movements and displaying user interfaces in form of selection boxes. This enables to explicitly demonstrate how an intelligent interpretation is performed. In our case the intelligent interpretation is based on sensor information if the selected fruit is available and how this information is interpreted to select an alternative instead. This sensor-based inference is demonstrated in form of the human interaction using the selection boxes. The flowchart representation therefore enabled a mock-up of the workflow and the intelligent interaction. The resulting BPMN workflow was implemented on a workflow engine combining the sub-workflows for movements, the orchestration of the movements and the indication of intelligent interaction.

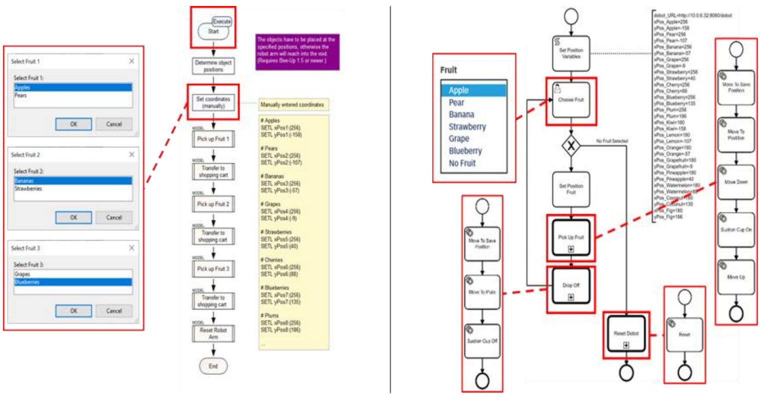

Fig. 7. Introduces the same simple pick-and-place procedure that picks up some cards with fruit-symbols but introduces a user interaction and sub-processes in form of a flowchart on the left and in form of a BPMN workflow on the right.

The proof-of-concept engineering of intelligent robot interaction using workflows was based on the following default setting:

- The pre-packaged Dobot Magician [18] was used to demonstrate the robot arm.
- The corresponding IoT Adapter – Raspberry-Pi – and corresponding software – Tomcat Web-Application, Dobot Magician interfaces.
- The pre-installed Modelling Toolkit Bee-Up is used for modelling the Petri-Net, the flowchart and the BPMN processes that accesses the IoT Adapter.
- A third-party workflow engine was used.

The configurations can be downloaded from the complAI ADOxx.org developer space [19].

7 Outlook and Next Steps

The complAI survey concluded by introducing:

- A modelling environment using the notations Petri-Nets, flowcharts and BPMN to model workflows that steer robots.
- A proof-of-concept environment with the OMiLAB Innovation Corner that enables to execute aforementioned workflows in a sandbox and demonstration environment.
- A prototype environment for robots that use the executable workflows from the OMiLAB Innovation Corner on real-world robot prototypes.
- An assessment criteria catalogue for safety-, security-, legal- and ethical- concerns, which can be transformed into a questionnaire model.
- An assessment tool that links the aforementioned workflow models with the questionnaire model in order to assess, if a workflow is compliant or not.
- A signature and verification tool that allows to sign approved workflows and enables the verification from the execution platform to ensure that only approved workflows are executed on the robot platform.

In order to enable a co-creation of domain-specific solutions for robots with AI. The performed laboratory survey – consisting of stakeholder interaction, literature research, proof-of-concept experiments within the OMiLAB Innovation Corner and prototypes using a Robot Laboratory – applied a model-based approach. This model-based approach including simplification and abstraction should ease and guide the transition from research and innovation into a real-world application – in particular by deciding for a concrete application case and applying the results of ComplAI step-by-step on this domain specific real-world case.

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