COVR - Towards simplified evaluation and validation of collaborative robotics applications across a wide range of domains using robot safety skills

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ABSTRACT

Challenges surrounding human safety have become one of the main barriers to the promotion and availability of collaborative robotics technology in different domains. The EU-funded project "Being safe around collaborative and versatile robots in shared spaces" (COVR) aims to break down these barriers to support more widespread use of collaborative robots in a wide range of industries and domains (e.g. manufacturing, logistics, healthcare and rehabilitation, agriculture). In this paper, we will describe our approach to engage various stakeholders and encourage widespread use of collaborative robots. This includes the development of a toolkit employing a methodology based on robot safety skills, and the development of a set of testing protocols that clearly define the safety-related validation procedures. A crucial aspect of the project is active consultation with regional stakeholders from standardization, national agencies, accident insurance, and safety verification bodies to create a consensus on the validity of the toolkit and protocols. Additionally, the COVR consortium is opening their doors to operate as shared safety facilities, where interested third parties can receive training, gain access to measurement systems for validation, and receive support in using the toolkit and applying the protocols. Finally, COVR will offer over five million Euros in funding to third parties seeking to engage with COVR, to test and expand the toolkit and protocols with specific use-cases, and to provide background research and experimental data for determining best practices.

Besides a description of the various project mechanisms, the first project results including the toolkit design and initial set of protocols for safety validation will be presented in this paper.

1 INTRODUCTION

The need for collaboration between robots on human tasks is evident in all sectors of the European market, as demonstrated in the Strategic Research Agenda[1] from euRobotics aisbl. Collaboration however inevitably raises safety issues, and European legislation is very careful to promote the protection of workers, elderly and weak subjects as a top priority. Market operators therefore perceive the need for "certification", i.e. the compliance with mandatory Essential Requirements of Safety and Health, as a pressing need.

In our experience with end-users, robotics components manufacturers, and system integrators, safety has become a barrier to the promotion and availability of collaborative robotics technology in all domains. This is due to a number of issues, both technical (e.g. robotics are complex, reconfigurable systems that can change their behaviour over time) and non-technical (e.g. understanding and correctly applying the current standards and directives to prove compliance is a challenge, especially for smaller companies).

The EU-funded project "Being safe around collaborative and versatile robots in shared spaces" (COVR) aims to systematically break down current barriers to support more widespread use of collaborative robots in a wide range of industries and domains. Our particular focus in the project is on manufacturing, logistics, agriculture, healthcare and rehabilitation.

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[1] https://www.eu-robotics.net/cms/upload/topic_groups/SRA2020_SPARC.pdf

In this paper, we will describe our approach to engage various stakeholders and encourage widespread use of collaborative robots.

2 COVR APPROACH FOR SUPPORTING STAKEHOLDERS

As mentioned in the introduction, COVR aims to foster the use of collaborative robots in a variety of domains, by specifically addressing challenges regarding safety. In order to ensure a meaningful impact, it is necessary to have a clear understanding of who the main stakeholders for this issue are and how they relate to one another. In particular, we have identified three main types of stakeholders, namely those who state the rules on safety and check that they are being fulfilled (e.g. accident insurers, safety verification bodies, and national agencies), those who define best practice (e.g. standardization bodies and the research community), and those who use and/or sell robots and robotic components (manufacturers, end-users, system integrators). Figure 1 depicts these stakeholders and identifies how COVR interacts with them to take their individual needs into account.

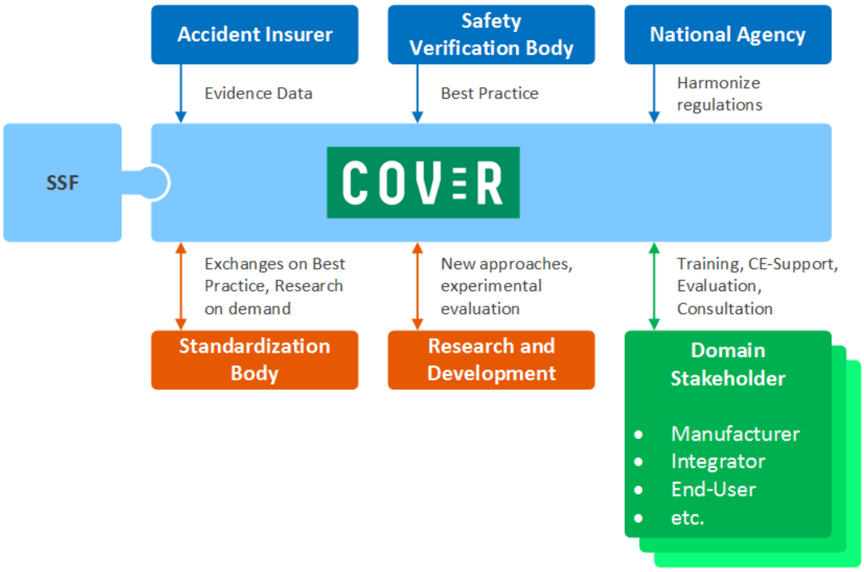

Figure 1. *COVR Stakeholders and their interactions with the project*

COVR will offer four different means for supporting the stakeholders. First, we are developing a *toolkit* to advise domain stakeholders when identifying the relevant standards and guidelines for their application and domain. The toolkit relies on the concept of robot safety skills – i.e. a complex combination of safety functions and protective behaviours that are valid across domains. Second, we are writing *validation protocols* that are easy to follow, so user of collaborative robot (so called "coboteers") can prove that their systems fulfil the necessary requirements. Third, we are updating our laboratories to become *shared safety facilities*, where third parties can receive training, gain access to measurement systems for validation, and receive support in using the toolkit. Finally, we are offering over five million Euros in funding to third parties from the robotics community seeking to engage with COVR, to "stress test" the toolkit and protocols with specific use-cases, and to provide background research and experimental data for determining best practices. The following section will describe these four means in detail.

It should be noted that none of these activities will have a meaningful impact unless we have accident insurers, safety verification bodies and national agencies on board and willing to accept our approach. Therefore, a further important aspect of the COVR project is dissemination and consensus building activities with these stakeholders, so that the entire community can agree on best practices.

2.1 Toolkit

The COVR toolkit is a guided procedure for listing the requirements to be satisfied for compliancy with relevant safety directives. It can be used by coboteers with different levels of knowledge about the processes of safety assessment according to ISO 12100 [1] and ISO 14971 [2]. The main steps of the safety assessment, as specified in ISO 12100 are:

- hazard identification,
- risk estimation,

- risk evaluation,
- risk mitigation,
- validation of protective measures.

The purpose of the toolkit is to assist users when carrying out different activities along the lifecycle of the safety assessment and evaluation. It provides explanations about the process with the goal of simplifying the finding and interpretation of mandatory procedures that are available in published normative materials. It consists of a graphical-user interface (GUI) which provides a walkthrough along the analytical steps necessary to derive the safety requirement checklists. Furthermore, the toolkit provides support to identify the necessary methods for validation of implemented risk mitigation solutions, including a collection of validation protocols for selected risk mitigation solutions. Each protocol represents a step-by-step guide on carrying out the required measurements for safety validation. If necessary, the toolkit also supports novice robotics users in taking the preliminary steps to assess hazards and associated risks of applications, entire systems, or particular components.

While the toolkit may be helpful along steps of the risk assessment and evaluation, it is not primarily intended to implement such methodology. The COVR toolkit is NOT intended to be:

- A replacement for risk analysis and assessment
- An automatic selection of risk mitigation solutions to be implemented (The users will be given a list of possible risk mitigation solutions; they will have to choose them according their risk assessment or possibly look for other solutions)
- A certification.

The COVR toolkit will be accessible as a web service. It offers multiple entry paths, depending on the level of knowledge about the domain, the regulations and standards, and the safety skills and safety functions used. The technical design of the GUI and web services is currently in implementation. A first version of the toolkit will be available to COVR Awardees by spring 2019. Section 3 describes the toolkit design and our methodology in detail.

2.2 Validation protocols

Validation is defined as a set of actions to evaluate (i.e. provide evidence through metrics) that a (set of) *safety functions* meets a set of *target conditions*. Safety validation is the evaluation of whether or not a product, service, or system complies with a defined operational condition characterized by a given level of risk. Safety validation serves as a public evidence that a product (including functions and algorithms), or system meets a set of safety requirements agreed by stakeholders.

One of the main objectives of the COVR project is to provide support for the validation of protective safety measures. This entails assistance for creating the necessary documentation (e.g. checklists for showing compliance to individual requirements), as well as step-by-step instructions for performing the validation tests themselves. Especially regarding the validation of systems, we see a lot of uncertainty in the robotics community today. One reason is the complexity of robotics installations, as discussed in [4]. Furthermore, some of the standards applicable to robotics safety were published prior to the existence of collaborative robots, such as the ISO 13855 [3].

The COVR consortium has applied two distinctive methodologies to identify protocols. On one hand, by focusing on the two relatively mature domains of manufacturing and rehabilitation, we have identified safety functionalities that require verification by standardized measurement. This methodology can be termed to be a “standards-based” approach. We consider this approach to be valid, as the required measurements for validation are the state of the art and mandatory for collaborative robotics manufacturers and end-users, when relying on the given safety skill. In order to investigate domains that do not yet have advanced standards, we used a “top-down” methodology, whereby collaborative robotics applications from specific domains were the starting point for identifying protocols. In this methodology, we briefly described specific applications, identified corresponding risks and hazards, before describing options for the risk mitigation. These risk mitigation measures can be considered to be safety skills, and the means to validate their proper function under the appropriate conditions are the validation protocols we are developing.

2.3 Shared safety facilities (SSFs)

The COVR partners within the project are upgrading their facilities and equipment to become shared safety facilities (SSFs) within their domains of specialization. Currently, COVR partners specialize in the domains for manufacturing, healthcare and rehabilitation, logistics, agricultural, and civil domains. At the SSFs we can offer a range of services on a fee basis such as:

- Safety validation (either at the SSF or on-site w/ customer)
- Individual consultancy for the customer's particular case with relation to human-robot collaboration and safety
- Training courses on cobot safety (generic content plus specialist options, depending on customer needs, including different content for various domains such as healthcare, industry, etc.) – the term "customer" includes:
  - Large end-users (training for their safety experts and unions)
  - Small companies and spin-offs making new components for collaborative robot use (e.g. sensors, grippers, peripheral components, or even robots themselves)
- Support in preparing for ethical procedures and related documentation for clinical research with medical devices.
- CE certification of a medical device not only requires technical safety to be evaluated, but also a clinical investigation may be mandatory to support the claimed purpose of the medical device. Many smaller companies, especially when starting in the field of medical devices, are not always fully aware of how to set up and perform a clinical evaluation. Therefore, for rehabilitation robots, some COVR SSFs will offer support in preparing a clinical evaluation for ethical approval by a Medical Ethical Committee and compiling the required documentation.

Additionally, we will provide to FSTP beneficiaries and other interested parties services and training on use of the toolkit and protocols.

2.4 Financial support for third parties to run realistic trials

One special aspect of the COVR project is the financial support to third parties for realistic trials. By realistic trials, we understand a number of activities around the COVR project that a single institution or small consortiums (between two and four partners) can carry out to support the development of new protocols, or to evaluate and improve existing protocols or the toolkit. A single institution can be awarded up to 60.000 Euro for a single award and a maximum cumulative total of 100.000 Euro for multiple awards. There are three rounds of open calls planned during the course of the COVR project coming up in November 2018, July 2018 and March 2019. There are many unique use-cases featuring collaborative robotics in a variety of domains. In acknowledgement of this challenge, the COVR consortium has designed the open calls to serve as a kind of outreach, allowing users and developers of robots with very specific and non-mainstream use-cases to answer open questions in standardization and to investigate best practice for their specific application. Ideally, the standardization community will also use COVR awards to test hypotheses and determine for example the pros and cons of certain methods for validating the safety of specific systems or components.

2.5 Concept of safety skills

An important concept of COVR and its idea to support a cross-domain approach are *safety skills*. This concept arose out of the current challenge with domain specific standards. In the current situation, a domain stakeholder would start the process of evaluating the safety of a system by first identifying which domain is applicable, and then gathering requirements from the relevant directives and standards. This may work for well-established domains such as manufacturing or healthcare, but for other domains (e.g. agriculture), there are often no relevant standards. This further implies that for a large number of domains there are currently no validation protocols available, leading to uncertainty on the part of domain stakeholders. To overcome this situation, the toolkit unifies the protocols according to abstract "safety skills". We have defined safety skills as an abstract representation of the ability of a robot system to reduce some risk, deploying a suitable risk-reduction measure or displaying an inherently safe design feature. Skills have specific instances (i.e. actual methods for implementation) which depend on the specifics of the application. Validation protocols are then derived from these skills and consider domain-specific conditions, without requiring the availability of domain-specific standards. This skills-based approach to safety will need to be discussed with all stakeholders to gain consensus and acceptance in practice.

3 INITIAL TOOLKIT DESIGN

The toolkit was designed by first identifying the target users and surveying them to learn about their needs regarding safety. Target users as defined by COVR include:

- System integrators of various level of expertise
- Robot developers and manufacturers
- Robot end-users, including:

  - End-user from management of large /small company
  - End-user from technical staff with intermediate skills (people who work with automation technology, engineering, planning)
  - Rehabilitation specialist (nurse, occupational therapist)
  - Rehabilitation patient (to be informed)
- Certification institutes
- Developers/manufacturers of safety components for robots and robot applications (e.g. safety sensor)
- Safety consultants.

The primary needs of the identified users with respect to general usage of collaborative robots, across all domains, are:

- Preliminary risk and hazard identification
- Knowledge of “best practices”
- Reassess the risk after a robot work-cell modification
- Identify a measurement protocol to validate a risk reduction solution.

Based on the users’ needs, we derived a general usage profile. A user has a number of open issues about different aspects and steps in the risk assessment and validation process, depending on his/her level of expertise. A general understanding of the need for conformity is usually present among stakeholders (so-called safety “certification”), but exact procedures are not clear.

The toolkit is designed to unify the protocols according to abstract “safety skills”. Domain-, product- or function-specific protocols are then derived from these skills. The user is in charge of understanding and selecting the adequate safety skills (themselves often composed of specific safety functions) for attaining risk reduction, and then responsible for performing the associated validation tests.

The analysis of applications or devices does not follow a linear workflow, especially when specifications and/or regulations are partially known or unclear to the user. The toolkit allows for multiple paths of entry through separate perspectives, which are interactive controls in a website dedicated to grouping homogeneous sets of analytical tools (questions, flowcharts, etc.). The perspectives we have designed to date are:

- Document Finder: a set of perspectives that enable the user to browse through the analytical steps using multiple entry points and cross-links. Main navigation tracks are designed (i.e. “by Directive”, “by standard”, “by product”) in order to help the user in finding the correct references to requirements to attain.
- Skill Finder: a perspective for giving the user some limited knowledge about the methodology of risk assessment and help the user to identify “skills” to be validated. This perspective redirects the user to the “Document Finder” in order to reach a final checklist or protocol to implement.

The toolkit will be available to COVR Awardees by spring 2019.

4 INITIAL SET OF VALIDATION PROTOCOLS

Based upon the bottom-up method of identifying validation protocols from known robotics safety standards from the domains of industrial manufacturing and healthcare, as well as the top-down method of identifying robotics safety skills for a wide variety of domains, we have created an initial list of six safety skills, which feature a range of safety functions. These main safety skills are:

- Ability to limit the power and force during a collision
- Ability to stop travel before colliding
- Ability to reduce the impact effect during contact
- Ability to restrict a single mobility degree of freedom
- Ability to restrict multiple mobility degrees of freedom to defined area or volume
- Ability to compensate for effects of joint misalignments

These skills are by definition cross-domain and can be used for safeguarding a wide range of applications. For each of these safety skills we have then defined a set of validation protocols, which a user can carry out to validate the skill. One important issue to consider is the difference between verification and validation. Verification is defined as a set of actions that provide evidence (i.e. metrics needed) that a safety function meets a set of design specifications. Validation on the other hand is defined as a set of actions that provide evidence (i.e. metrics needed) that a safety function result meets a set of target conditions. While the safety skills and validation protocols are generic and cross-domain, the target conditions for a specific application and domain are necessarily coded into the protocol. This means for a single generic protocol, there can exist a large number of related sub-protocols with specific conditions and parameters under which the validation should be carried out.

5 DISCUSSION

In this paper, we have briefly highlighted some of the main barriers to more widespread use of collaborative robots with regard to safety. In particular, there is a lot of uncertainty regarding which standards and directives to apply, as well as how to validate that the safety of a system has been correctly implemented. This is a particularly large challenge when robots are applied to domains outside of manufacturing and healthcare, where standards and best practice are often non-existent and where technological capabilities are further along than the regulatory framework. We introduced the four main actions that the EU project COVR is undertaking to systematically reduce uncertainty and support the all stakeholders involved in the safety of collaborative robots. These include:

1. A web-based toolkit to support robotics users in identifying the applicable standards and directives,
2. the development of validation protocols that are a step-by-step guide for how to measure and prove that safety systems for a specific application are correct,
3. the transformation of our laboratories into Shared Safety Facilities (SSFs) to offer the community a range of services around the safety of collaborative robotics, and
4. COVR Awards where we fund third party work to support the development and improvement of the toolkit and validation protocols.

Furthermore, the concept of using "safety skills" as a representation of the risk reduction measure was put forth by the COVR consortium. We view this approach, together with the toolkit and the validation protocols as having a large potential to support users and developers of collaborative robotics applications, regardless of the domain of interest.

One major goal of COVR is to build consensus with all relevant stakeholders so that our approach is approved within Europe and all over the world. We look forward to the discussion with relevant stakeholders from standardization, occupational and health insurance, safety verification bodies, and national regulation agencies, and the robotics community about whether this approach will be acceptable, how it can be improved, and how it can be successfully implemented to remove current barriers to safety.

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