Industry: Safety ın Human-Robot Collaboration

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Abstract: Human-robot collaboration (HRC) defines a working scenario in which people and autonomous machines work and share the same workplace. The latest model, developed with the Fourth Industrial Revolution (cyber-physical system), promises highly flexible workflows, maximum system efficiency and productivity and economic efficiency. However, when HRC fulfils these promises, proper security technology is required for implementation.

One of the most important robot issues associated with Industrial 4.0 Revolution is to make processes flexible. Integrating the human capability and ability to the robots offers production solutions characterized by improved run cycles, improved quality, and lower cost. However, human and robot interaction requires new security concepts that provide effective support to make production processes more flexible.

Keywords: Industry 4.0, human robot collaboration, Risk assessment.

1 Introduction & motivation

The first appeared of the term "robot" in a science fiction play "Rossum's Universal Robots" by Czech author Karel Čapek in 1920. In the author mother language, the robot means "hard work" and refers to artificial "people" who were created to do work for humans in the play [1]. At present, the term robot is generally used to describe a machine that programmable by computer algorithms to perform simple and complex tasks.

The idea has been aimed at robots to imitate people in the best possible way. The robot intelligent is trying to access features such as visual perception, tactile perception, mobility and road intelligence. The first robot in the industry, UNIMATE, was introduced at General Motor's car factory in 1956 as prototype. In 1961 it has been deployed commercially and massively [2]. During the period of time following, many private institutions and universities began to research on this issue.

In the first industrial revolution considered as the introduction of mechanization, hydro power and steam power. The second industrial revolution is understood as the introduction of mass-production techniques by using electric energy. The third industrial revolution is based on the application of electronics systems and information technology for enhancing manufacturing automation. A significant breakthrough is now expected as the fourth industrial revolution by introduction so-called cyber-physical systems [3]. The effect of industrial development on production techniques is given in Figure 1, together with its historical processes.

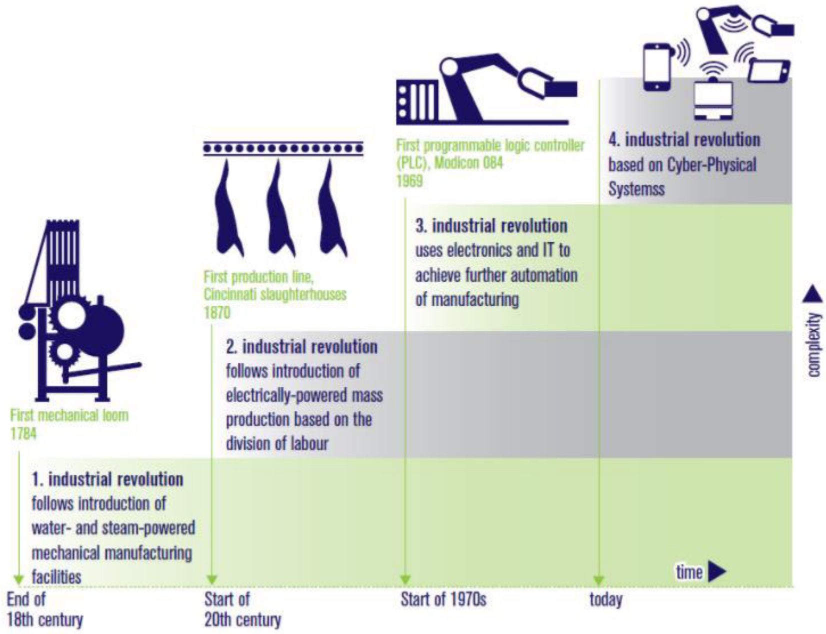

Figure 1
The 4th industrial revolution (source: [4])

Safety is one of those things that humans take for granted until it's too late. In the industries, human and machine are able to work together to make work efficient at the same time, however, this places greater demands on safety [5]. The interaction between human and robot increasingly demands new technologies and solutions. All safety functionality must be considered, from the sensor to the logic and beyond to the actuator.

Over the recent fifteen years, intensive studies have been done and various automation methods have been developed ın order to increase productivity. Today, industrial robots are often used in unsafe, health-conscious jobs and in uniform works with high repetition. They consist of different types of applications such as material handling, assembly, welding, cutting (plasma, water jet, laser, etc.), painting, tool changing and so on [6]. These robots are used in production lines of different types without additional safety features. The philosophy in the field of collaborative robots aim to develop robots in a way that is reliable enough to work with people in a real sense [7].

2 Functional safety

High automation grade and flexible production processes: If humans and robots are to work together in close proximity while maintaining a safe environment, functional safety will take today's production systems one step closer to more flexibility. HRC looks at how this can be achieved.

There are different automation forms depending on how humans and robots work together. When the final goal is complete collaboration in which humans and robots share the same workspace and carry out their work at the same time, then it is meaningful to develop solutions that employ coexistence or cooperation as the first steps toward this. This not only requires a thorough understanding of robotic applications but also requires expertise in assessing risks and accessing the appropriate portfolio of security solutions.

Every process in the development of HRC systems begins with a risk assessment. To conform to the Machinery Directive [8], a comprehensive assessment of possible hazards must be carried out for every machine as defined in EN ISO 12100 [9].

Since robotic systems often have to complete very complex motion sequences, the robotic safety standard EN ISO 10218 requires that each motion sequence is analyzed in addition to the hazard being assessed [10]. Environmental factors and basic conditions related to HRC application must also be considered and documented in risk assessment.

These are absolutely necessary steps to define what to take in the appropriate safety precautions. As a result, the HRC includes a wide range of technology types and components that are required to produce solutions for the various safety measures required, which have to work together as efficiently as possible and avoid any impact on the workflow and thus on productivity.

3 Basics of human-robot collaboration

Industrial classical robots follow a fixed program performs predetermined work and cannot go out of the program. Security measures for robots are also provided with the help of fences and cages. However, collaborative robots (cobots) are designed for people or to work with people. They do not need security measures such as a cage, they work in the execution of complex tasks, or they help technicians.

3.1 Safety related monitored stop

In safety-related monitored stop application, the cobot stops and remains before the operator enters the common workspace. The application must be restarted for repetition by the operator [11].

3.2 Hand guiding

In a hand guide application, the cobot allows the operator to manually move the robot to various positions, allowing a limited amount of motion control to be released. This application has been used to teach programs, especially when new parts are frequently added [12].

3.3 Speed and separation monitoring

In speed and separation monitoring application, the cobot and operator move at the same time in the same collaborative work area. Risk mitigation is provided at every moment of the work by leaving a minimal protective separation between these two. In this application, when the minimum approach limit is reduced, the robot pulls itself back or changes its movement [13].

3.4 Power and force limiting

In Power and force limiting application, the operator and cobot may work in the collaborative workspace concurrently. There is a possibility of contact between the cobot system, including the end effector and work piece, and the operator [14].

In such applications, it is understood that the contact between operator and cobot is allowed, but the force applied by the cobot cannot exceed the limits allowed in the technical documentation. This is due to the reduction of inertia, appropriate robot geometry and soft material selection, and appropriate control functions.

The ISO / TS 15066: 2016 Technical Specification defines the biomechanical limit values of impact strength and severity for 29 points in the body region [15]. Biomechanical force experiments are performed by contacting a standing prosthesis slowly with a test probe, and the limit values reflect static conditions. However, dynamic experiments are already being carried out and will probably be reflected in the relevant document.

4 Risk assessment

Risk assessment is the most important task for the person who designs, analyzes the robot application and evaluates it in a complex system. As a starting point, every person involved in the design and implementation has to consider the current status of the international standards that deal with the specifically the safety robots for collaborative operation (ISO/TS 15066) [16] and safety of industrial robots (ISO 10218-1/-2) [17] [18].

The risk assessment must be applied on the entire robot system (full machine) when the robots are integrated into the main system (with end-effector, etc.). The resulting derived measures to reduce the risks will safeguard the safe collaboration operation. This risk assessment should be carried out even if the relevant robot has design features that reduce risk. According to the machine safety standards ISO 12100 [19], the risk assessment is an iterative process that involves two consecutive steps which is the risk analysis and risk evaluation as illustrated in figure 2. Risk analysis shows, (1) Determining the limits of machinery, (2) Hazard identification and (3) Estimating the risk. The risk estimation step, which is implemented for each specific hazard and hazardous situation, is important as its results will dictate the risk evaluation and thus select and prioritize risk reduction methods.

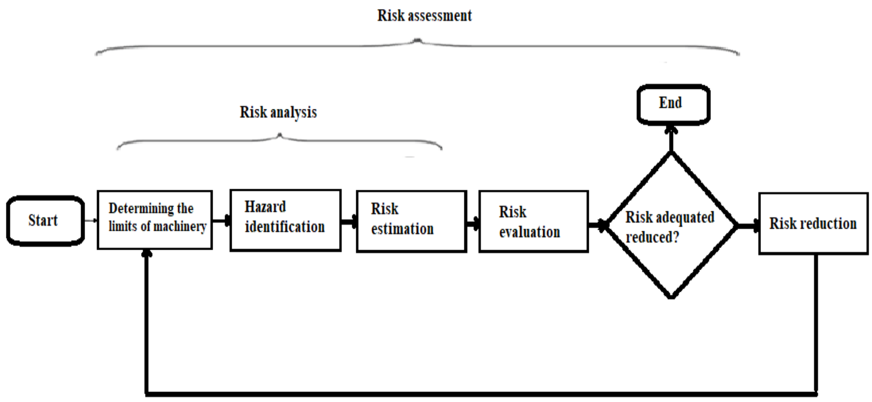

Figure 2. An overview of the risk based on ISO 12100.

5 The rise of collaborative robots market

The World Robotics Report 2017 [20], published by the International Federation of Robotics (IFR) forecasts 18% growth in industrial robot installations for 2017, with the growth of about 15% forecast for 2018–2020. Stronger-than-expected growth in the global economy, faster business cycles, better variety in customer demand, and the emergence and expected to scale up of “Industry 4.0” concepts are all factors behind the optimistic prediction [21].

The global cooperative robots market is expected to expand at a CAGR of more than 60% during the forecast period 2016-2023 and is estimated to reach $ 7 billion in 2025 [22]. Cooperative robots allow flexible manufacturing process, portable, and lightweight, require less programmable skills etc. Because of its many advantages, it has applications in automation industry, metal machinery, furniture and equipment etc. [23].

Geographically, Asia pacific has the strongest share in the global collaborative robot market. The growth of the global collaborative robot market in the Asia Pacific region is supported by the presence of major robotics companies. Asian Pacific countries such as Japan, South Korea, China and India accounted for almost 50% of the total revenue in 2015 [24]. At present, in 2017, Chinese automobile manufacturers use only one robot to perform a task equivalent to 25-30 worker [25]. However, this is expected to increase due to the advantages of homogeneous product quality above cost effectiveness. Furthermore, Europe was the first region to use the cooperative robots with the highest revenue in 2015.

The report on market shows that the most successful vendor so far been collaborative specialist Universal, based in Denmark. Other early companies such as US-based Ryntech Robotic have achieved some fame, after a slow start, major industrialists, including ABB ltd. (Switzerland), Kuka AG (Germany), and Yaskawa (Japan), have developed recently new cobots [26].

Conclusions

This article describes a brief overview of safety, risk assessment, and the global marketing of industrial cooperative robots. In many industrial sectors, the number of collaborative robots is expected to increase significantly. Occupational health, safety risk management, and cost assessment, are important to ensure safe and effective business by manufacturers and user of robots.

In the future, the collaborative robots will gain flexibility within the production technology. This development will directly change the factory automation applications concept where humans and robots are working together. Moreover, safety concepts will evolve and costs will be reduced by artificial intelligence and equipment progress.

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