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Comparative Selection of Industrial Robot Simulation Systems for Educational Purposes

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***Abstract*— Using simulation tools to design and evaluate suitable function of industrial robot systems, is an easy and low-priced technique to shape multipart robot applications. At the current software market, all name-like robot manufacturers offer proprietary robot simulation software. This concerns simulations referred to the industrial robot systems as well as to the mobile or other kind of robot systems. Which software application is appropriate for use for educational purposes, depends on different factors and especially the circumstances on-site. In this work, based on experiences and diverse decisive factors at Rheinische Fachhochschule Köln gGmbh, a University of Applied Sciences, such a selection processes has been analyzed, explained and vindicated.**

***Keywords*— Robot, Simulation, KUKA Sim, RoboGuide, Codesys, RobotStudio**

I. Introduction

The robot based production and process innovations require, in view of the competition of the companies, an exact knowledge of the program, communication and movement possibilities and abilities of the robot system in adaptable workrooms. The central demand for secure industrial robot planning, can be still well realized by prior three-dimensional graphics simulations and feasibility study of the planned robot application. With the simulation of motion sequences and peripheral objects the possibility exists, without cost intensive hardware-robot solution, to plan the assembly and manufacturing process, but also to predict the needed cycle time, modifying and optimize it during visualization process. Today is, beside a broader applicability of an open simulation program, in particular the high user comfort with easy learnability one of the main judgment criteria about the quality of the software. It is beside other criteria, a relevant and decisive factor for evaluation of the goodness of the used robot simulation program. It means in the practice, that not only special user groups like engineers should be able to use such simulation programs, but also all user with far less technical knowledge, meaning also those with only basic technical knowledge. On the subject of the robot simulations, it was already written since middle of the 80-s [1], [2]. Accordingly various research teams have been assigned with the task, to develop suitable user-friendly robot simulation frameworks [3]. The first useful simulations as e.g. so called “Robocad” application, have been actively used in the technical departments since the beginning of the 90-s [4] [5]. In the middle and at the end of the 90s, object-oriented robot simulation applications based on Java were developed and used [6]. In addition and consequently, suitable robot libraries were developed for simulation, also of older robot models served with it [7]. Besides, applications were developed "to place the emphasis on using the knowledge of the geometry of the parts and machines in a production cell to automate those aspects of the traditional design method that can be performed by the computer" [8, p.21].

II. Simulation Applications for Industrial Robot Systems

Due to the vast amount of today's robot simulation applications, in the following are briefly introduced four simulation applications and are shortly mutually evaluated. Robot simulation applications which will be introduced are presented in the following table:

TABLE I Industrial Simulation Systems for Industrial Robots

Name of the application	Producer
RoboGuide	FANUC K.K.
RobotStudio	ABB AG
KUKA Sim	KUKA AG
CODESYS	3S-Smart Software Solutions GmbH

These above named simulation applications of the companies FANUC K.K., ABB AG, KUKA AG and 3S-Smart-Smart Software Solutions GmbH are often used in the industrial applications. Furthermore it is to be pointed out that intermutually translation applications exist, as e.g. “SubitoRun”, which enable translation of the application of the one company into other, here of FANUC GUI into KUKA GUI. Such translation modules exist also in the case of KUKA C4 interfaces which are translated into

Siemens S7 GUI. Even translation of Siemens TIA portal exist, which is offered by "FTP Robotik" [9]. It indicates the necessity of the development of such specified translation-software market. The Codesys (CODESYS, CoDeSys) is an application development system for programmable logic controller (SPS), developed according to IEC 61131-3 standard for the application development in the industrial automation. All above mentioned applications allow simulation of robot systems, with the exception of the CODESYS software application, which offers basically a simple simulation module connected with the internal PLC kernel and it is not specified application on robot systems. For simulations of other kinds of robot systems as e.g. humanoid running robots, mobile robots or other movable systems, it is pointed out to applications specialized for such applications like Microsoft Robotics Developer Studio, Anykode, SimplyCube, V-REP or Eureka, which are mostly offered as a freeware.

III. Results Benefits and Weaknesses of Robot Simulation Applications

Compared with other technologies, also simulation technology has its benefits and drawbacks. Using modelling tools to design robot systems is an easy and low-priced technique to shape complex robot applications, at least virtual robot systems of different kind, as humanoid, mobile or industrial robot systems. The main pros and cons by using of the robot simulations software are listed and shortly explained below:

A. Benefits for user, by using of robot simulation software

- Lower costs in the case to produce a robot system from scratch
- In many cases, sometimes indirectly, it is possible to test programming code according to specifications
- Possibility to modify design of robot cell without additional costs
- In some cases, some robot parts and peripheral components can be tested and simulated
- In a multifaceted project the robot systems can be replicated in stages
- A whole simulation can define if the robot solution meet the wanted conditions
- Nearly all simulations software are well-matched with a extensive variety of programming languages and interfaces
- Elapsed period stuck between the start of the project and its finishing point can be reduced

B. Weaknesses for user, by using of robot simulation software

- The real-world robot systems may focus the robot at too various more situations than a virtual-world robot systems
- All simulation, also the robot simulation programs, simulate what are automated to simulate with a specific level of accuracy

Summarizing the most important benefits for the practical decision to buy simulations software, the most included argument for acquisition of simulation software is the lowering of the general costs of the robot system, if preplanning phase of robot supported production plant development is properly done. While all of the simulation utensils provide the option to act out the robot system in diverse scenarios, the programming code can also be tested to conclude the compatibility with the mandatory conditions, and many more structures. Surrounded by other disadvantages, as a main weakness of robot simulations software are regarded the programming problems that can't cover all the scenarios that may occur in the real world. In the most cases 1:1 transmission of the simulation into the physical robot system is not possible. Also, tests of the simulations have to be done in any case.

IV. Comparative Examination of Industrial Robot Simulation Systems for Educational Purposes

Four robot simulation systems which illustrate the market portion of the industrial robot manufacturers at the European market were selected from the fullness of the industrial robot simulation applications. According to topical studies [10] the following robot manufacturers are market leaders at the European market in the segment automotive industry: Fanuc, Yaskawa, ABB, Nachi, Comau, Reis. The company 3S-SmartSmart Software Solutions GmbH is not a robot manufacturer, but for it, this company is permanently stronger representing supplier of universal PLC and simulation application solutions and becomes a counterpart at the German market to the big companies like Siemens. Alike it looks at the Chinese market. According to statement of International Federation of Robotics (IFR) Statistical Department „The robot market in China is topically still by foreign robots of 4 most important manufacturers ABB, Fanuc, KUKA and Yaskawa dominated"[11]. Hence, it makes sense, on account of the industrial requirement and inquiry, to look at robot simulations of these stated manufacturers for the use in the educational purposes. Yaskawa application was took out of consideration, because of the less spread at the European and especially German market. With the choice of software - as an essential subrange of the software procurement - for an economic sphere, the following demands / criteria were laid in support of the study [12]:

1. Functional demands, as e.g. functionality
2. IT-technical demands, as e.g. performance or ITliability
3. Demands to the architecture of the software, as e.g. Software Multitenancy
4. Other criteria, as e.g. price, reputation, support

Before of any purchase of the software, comparative study according to defined criteria has been made. The basic criteria stated, has been enhanced with the specific demands for educational purposes, especially by students' and lecturers' view an on-site circumstances. Furthermore the choice of the robot simulation software has been strongly impacted by the already used hardware in the laboratories of Rheinische Fachhochschule Köln gGmbh

(RFH). It means that robot simulation software has to be compatible with already installed and used robot systems.

Therefore following two additional criteria has been introduced:

5. Trial version of the software for min. use of 30 days is available
6. Hardware demands has been taking into consideration

In the following, performances of the four systems are represented, which will be later on scrutinized on appropriate application in robotics laboratory of the RFH.

A. *RoboGuide*

As stated by [13] Roboguide is software which can be separated in four different main applications: WeldPRO, PalletPRO and PalletTool, PaintPRO Software, HandlingPRO. WeldPRO is very new FANUC's product and off-line programming tool which permits users to simulate a robotic arc welding procedure in 3-D space. PalletPRO simulation software can be used to fully shape, correct and test a palletizing application offline. The figures created in PalletPRO can then be transferred to a real robot controller comprising the PalletTool software. PaintPRO software is a graphical offline-programming software application that make simpler robotic path teach-in and paint process progress. HandlingPRO permits users to simulate a robotic system in 3-D space or carry out feasibility studies for robotic applications deprived of the physical need and payment of a prototype work cell setup. It can be connected to the real robot cell. HandlingPRO can be used as trial version with duration of 30 days.

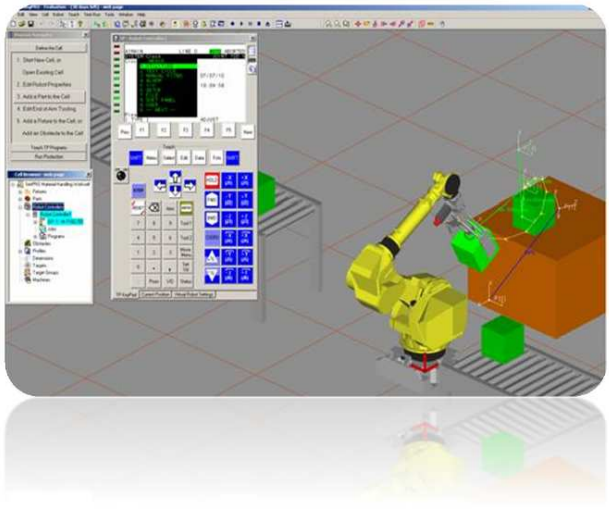

Fig. 1123 RoboGuide HandlingPro [18]

B. *RobotStudio*

According to [14] RobotStudio is a PC application for modelling, offline-programming, and simulation of robot systems.

Fig. 2 RobotStudio [19]

It contains so called RAPID editor which is useful for editing of all robot tasks other than robot motion. RAPID programs and modules are generally stored in the RobotWare structures, as they are created. For evaluation purposes, Premium Functionality needs to be used in combination with so called PowerPacs which are for 30 days free of charge. RobotStudio is constructed on the ABB Virtual-Controller, a careful copy of the real application that runs the ABB robots in production. This permits actual accurate simulations to be completed, using real robot programs and arrangement files equal to those used on the plant floor.

C. *KUKA Sim*

In the case of KUKA Sim application there are five different simulation applications offered [15]. These are KUKA.Sim Viewer, KUKA.Sim Layout, KUKA.Sim Tech, KUKA.Sim Pro and KUKA.OfficeLite. All these products are developed by external company in collaboration with KUKA Company. Furthermore KUKA offers also own developed simulation software, the KUKA WorkVisual, which is used for programming, configuration, loading, testing, diagnosis and archiving purposes. KUKA.Sim Viewer is the instrument which allows to look at simulations made in KUKA.Sim Layout or KUKA.Sim Pro. KUKA.Sim Layout is a sole program to create simple 3-D plans of installations with KUKA robots. Substitute layouts and ideas simply can be built and validated. KUKA.Sim Tech combines the use of KUKA.Sim Layout with KUKA.Sim Pro's powerful COM interface, enabling the use of own CAD data. The product can be used for cycle-time analysis or robot program development and is linked in real-time to KUKA.OfficeLite, the computergenerated robot controller. KUKA.Sim Pro is enhanced replacement of KRSim which allows I/0 programming, creation of own components and in combination with KUKA.OfficeLite complete simulation of the robot cell. KUKA.OfficeLite allwos to create and optimize offline programs for KUKA robots. KUKA.OfficeLite is almost identical to the Standard Software KRC. Programs created by KUKA.OfficeLite can be transmitted in a ratio of 1:1 to real robot, by means of a disk or via the network. The

same is possible with KUKA WorkVisual. Trial version of KUKA Sim is offered only for 7 days.

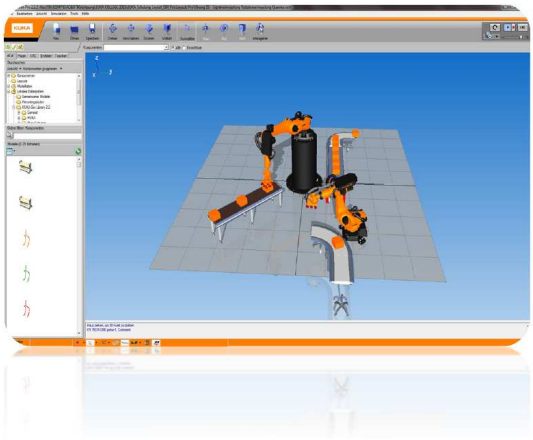

Fig. 3 KUKA Sim Pro Ver.2.2 (own screenshoot)

D. CODESYS

CODESYS is the general software suite for the automatic control engineering. It is a software platform for many settings of tasks in the industrial automatic control engineering. Base for the software developers is the IEC 61131-3 program tool CODESYS Development System. The tool offers integrated solutions with the aim to support practical realisation of tasks. CODESYS Visualization allows project engineering of Human Machine interface (HMI) masks directly in the IEC 61131-3 program surroundings. Project engineering of the HMI together with the PLC application in the same developing surroundings is possible. CODESYS contains an integrated visualisation editor: arbitrarily complicated visualisation masks on the basis of available visualisation elements. At least it allows simple visualisations compared with advanced robot visualisation systems, but it allows universal PLC programming compatible with many know producers represented on the European and international market. It is free of charge open source tool with no time constrained trial limitations.

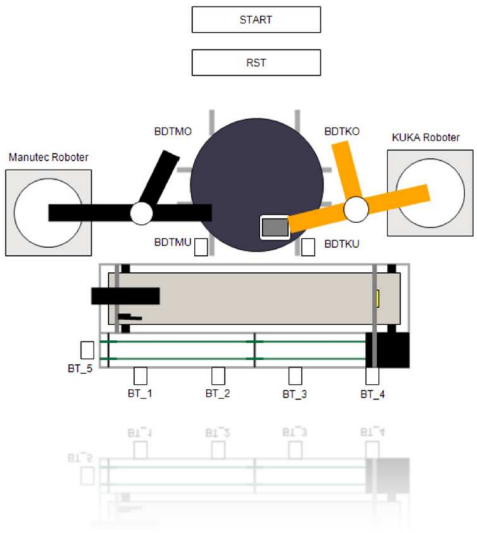

Fig. 4 CODESYS Visualisation in RFH laboratory (own screenshoot)

V. Choosing the Appropriate Simulation Software Based on Operational Criteria

In order to find pros and cons of the stated application according to defined criteria, a rating matrix according to [17] has been developed. Each criteria has been scored with the score n=1…10, whereby is the 10 the best score and 1 the worst. The alternative with the highest score result is the winner choice.

TABLE II Industrial Simulation Systems for Industrial Robots

Target	Wei-ght (w)	Robo-Guide		Robot-Studio		KUKA Sim		CODESYS	
		n	n*w	n	n*w	n	n*w	n	n*w
Functional demands	20	7	140	8	160	7	140	4	80
IT technical demands	15	6	90	7	105	5	75	8	120
Demands to the architecture	10	7	70	7	70	7	70	9	90
Price, reputation, support	20	6	120	7	140	5	100	10	200
Trial version of min. 30 days	10	10	100	10	100	0	100	10	100
Hardware demands	25	10	250	0	0	10	250	8	200
Sum			770		575		735		790
Rank			2		4		3		1

According to analysis the first rank belongs to CODESYS software despite of the functional shortage regarding visualization functions (please see Figure 4.). Main reason for it, is its functionality as a universal software platform for different devices, supporting modern communication protocols as FDP, it acts as a counterpart product to Siemens products winning as a product more and more at European market share and especially because it support existing hardware in the laboratory. Second rank place is belonging to FANUC's RoboGuide software, which slightly seems to be more appropriate for educational practice as KUKA SIM. FANUC's functionality is similar to the other robot simulations products. Main reason for its second rank is the duration of the trial version of 30 days, which is very short but sufficient for practical projects made by students supporting with its hardware compatibility. KUKA policy of supporting the trial version only for 7 days, is not acceptable for educational practice at higher educational institutions and will be possibly earlier or later one an marketing flop of the company's policy. ABB's RobotStudio seems to be very appropriate software for educational purposes, with well-done online tutorial for applicants. Also the trial version with duration of 30 days is comparable with other big provider of

similar applications. Main reason why this software haven't found the application at RFH university is, that it is not compatible to the existing hardware, which exists of the industrial robots produced by FANUC, KUKA and Manutec company. Also, with the ABB company RFH still haven't developed joint educational certification programs for the students as in the case with FANUC and KUKA.

VI. Conclusion

Choosing the appropriate simulations software for educational purposes requires scrutiny not only of the simulation software, but also by the choice affected interfaces and involved organisational sectors. The software functionality can, according to this principle, have almost the same importance as the ITsystem landscape or hardware requirements on-site. Summarized it can be stated that, especially the on-site hardware, existing collaborations with industrial partners, analysis of current market as well as with it connected added value for the students, have key impact for the selection of the appropriate robot simulation software.

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