Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, Volume 23, No.1, ISSN 2304-1382
ISBN 978-3-901509-91-9, CDROM version, Ed. B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2012
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2012

PROGRAMMING AN INDUSTRIAL ROBOT BY DEMONSTRATION

STIPANCIC, T[omislav]; JERBIC, B[ojan]; BUCEVIC, A[nte] & CURKOVIC, P[etar]

Abstract: *The constant need for reducing production costs and faster arrival tothe market of new products requires changes in product design,material selection, and production processes. While applying the changes, a level of complexity of contemporary industrial systems is undoubtedly increasing. Despite the fact that industrial robotic systems are becoming more and more complex, they should become user-friendlier and easily accessible for human operators at the same time.Such systems should have a smaller number of well-trained and highly educated employees who manage the production.This paper present an approach in programming a robot for doing assembly tasks based on Programming by Demonstration principles. The system tracks gestures and movements of the human operator by using Microsoft Kinect ® sensor.To enable an interaction between the system and the human operator,a simple gesture command list is developed. This methodology could help non-expert users to teach robots how to perform new assembly tasks in more human like ways. The command list present a very first step in a development of more powerfulgesture language that should provide a simple and an intuitive way forexchaniging information between people and machines.*

Keywords: *programming by demonstration, context awareness, machine vision, cognitive robotics*

1. INTRODUCTION

Robots in their essence have the purpose to replace a human labor, not only in industrial applications but in other human activities too. There are many applications connected to robotics, as for example in: medicine, rescue operations, industry, research, aiding the disabled people, etc. In order to fulfill the requirements of everyday life, robotic systems are inevitably becoming more and more sophisticated. The level of complexity demands novel or different research perspectives to be considered. Due to an increasing competition in the world production market, contemporary production systems have to be capable to produce even more and cheaper. In their essence, they have to be flexible, reprogrammable, and as cheap as possible. Such prerequisites raise more issues affecting almost every contemporary industrial factory in the world: a lack of space, a rigidity of production systems, an increased overall degree of system complexity [1, 2], etc. Programming of such systems requires a highly educated and experienced professional staff. The problem of expensive education and training of such personnel is obvious. To speed up the process of training of employees to work in factories of the future, researchers and experts in the field are developing a variety of educational techniques.

Within the paper, the method based on Programming by Demonstration (PbD) methodologies is described. Aconsidered scenario includes a human operator who teaches a robot to follow his movements, andMS Kinect ® sensor used to track gestures, and a Personal Computer (PC) used as an application host computer (Fig. 1). A monitor is used to provide a two-way communication channel between the human operator and PC.

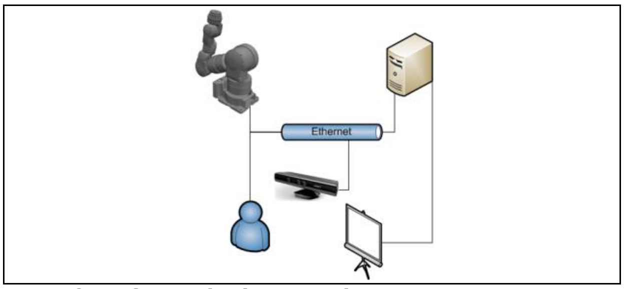

Fig. 1. The application development and testing environment

The operator uses a specially defined gesture languagethat contains a set of commands to controlthe robot movements and actions. This simple language allows the operator to program industrial robots to perform various actions, e.g., linear and arc point-to-point motions, opening and closingarobot gripper, precise positioning, etc. Problems with mappingof a real world environment and an inner world of the robot are well known today [3].A mapping function presented within this paper is developedfor two different purposes: to map spatial movements of the human operator and the robot (so-called, aspatal calibration), and to establish a simple interface used as a communication channel between the operator and the robot. By using the gesture language, the human operater can demonstrate the actions that the robot needs to perform. MS Kinect ® sensor has proven to be a great opportunity for researchers because it is cheap, easy to use and easily available for end users. It has a powerful, intuitive and portable Software Development Kit (SDK) that is relatively easy to be used in various applications.

Fig. 2 shows the environment for model development and testing. This environment is a part of the Laboratory for assembly system planning, at Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia. It is characteristic for assembly/disassembly industrial applications and contains different types of sensors, including MS Kinect ® and couple of 6-axis FANUC robots (www.fanucrobotics.com).

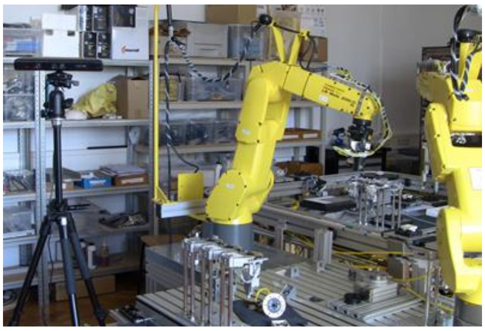

Fig. 2. The environment used for application development and testing

2. STATE OF THE ART

During the short analysis about demonstration based learning techniques, it is determined that many authors are using different terminologies for similar techniques and methodologies [4], including Learning by Demonstration (LbD), Learning from Demonstration (LfD), Programming by Demonstration (PbD), Learning by Experienced Demonstrations, Assembly Plan from Observation, Learning from Showing, Learning by Watching, Learning from Observation, Behavioral Cloning, etc.

Leon A., et.al. [5] described the model that relies on PbD techniques and MS Kinect ®. Presented model uses a method based on reinforcement learning to improve an overall learning performance. The main focus of research is set on tracking thejoint movements at the operator's hand. The presented methodologyis focused on achieving theprecise final spatial tool coordinate, as it is the case with general point-to-point robot programming. Spatial movements of the robot joints are precalculated and defined in advance by inverse cinematic model of the robot. The information about joint coordinates is not used in process of teaching the robot.

Within the reference section it can be found a short list of selected papers that represent this area of research [6, 7, 8, 9, 10]. Deeper analysis goes beyond the scope of the work presented within this paper.

3. GESTURE RECOGNITION

The Programming by Demonstration process starts by acknowledging the system with a signal meaning that the human operator is ready. In this very first step the system should knowthe starting position of operator's hand.

This step represents an initial and very simple calibration procedure and it is essential either as the operator guiding the robot can stand anywhere in the space or MS Kinect ® can be moved from its original position. After the initial calibration setup, the process of demonstration starts when the operator lifts his right leg (Fig.3).

Fig. 3. The gesture for remembering the starting possition

The system then starts to measure operator's relative hand movements and transmit the calculated differences to the robot. These relative movements are proportional to the movements of the robot. To ensure more simplified guiding there are developedtwooperational modes so far. While the first mode is used to control the movements of the robot, the second one is used to change the status of the gripper (tool) that robot uses while manipulating with objects. Because all available tools can perform only two states (opened and closed), one gesture is used to control both. Moving its left arm away from the body (as seen in Fig.4) the operator can change the state of the robot hand (tool).

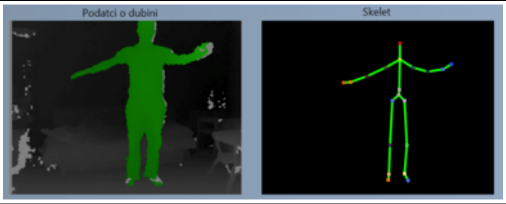

Fig. 4. Opening and closing the tool

Because all gestures that are describedwithin this paper so far are used either for guiding the robot or to control the state of the used tool, a gesture for saving (remembering) a current robot position is required.

Fig. 5. The gesture for storing the robot's current position and the tool status

This gesture will enable the robot to perform its point-to-point movements after the learning phase ends.

Fig. 6. The gesture used to change the mode for moving the robot

By raising the left hand above the shoulders and lowering it back (Fig. 5), the operator gives the command to store the current position and the status of the tool. For fine-tuning the robotic movements, a *fine mode* gesture is developed. By going over the body with the left hand (Fig.6), the operator is able to put the system into the *fine mode*.That results with small movements of the robot. This mode is suitable for programming the robot to do precise actions, e.g. putting the object in a hole with a small clearance, performing precise measurements, etc. Using the same gesture, the operator can return to *the normal mode*again.

To have a control over the system, it is essential to have the control over the data stream. For purposes of the communication between system components, the model relies on TCP/IP communication protocols (Socket messaging). Either by moving the left foot in front of the right or by moving the right foot behind the left, the operator is able to stop the data stream (Fig. 7). Thestream can then be continued at any time after the operator moves his left foot behind the right again.

Fig.7. The gesture for controlling the data stream

To stabilize the movements of the robot for performing so-called, extra fine movements, *the only z mode* is developed. This mode limits the movements of the robot to z-axis only, and it is especially applicable for inserting of objects into holes with tight clearances. The system is in this mode when the operator raises his left foot. This mode can be used only when the *fine mode* is activated.

4. MODEL OVERVIEW AND WORKING SCENARIO

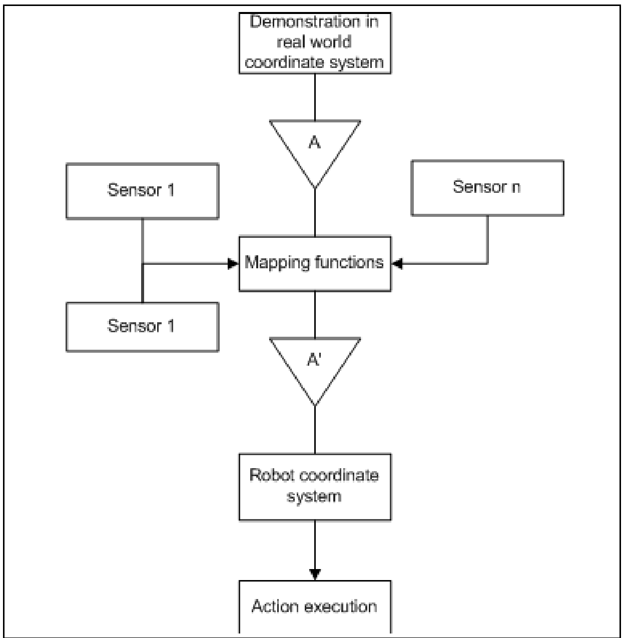

Fig.8. The general PbD model

Fig.8 shows the block diagram containing the general model developed for programming the robot by demonstration application. The model includes following components: information gathering by means of MS Kinect ® along with all other sensors integrated into environment and used by the robot, the mapping function used for a sensor data fusion and real world to robot space data transformations. As can be seen in the figure, the letters *A* and *A'* represents the data flow before and after the mapping and the data fusion is being performed. After the data transformation process, all data are prepaired for the robot. Based on these data, the robot is able to learn the operator's movements and to understand its commands.

Fig. 9 shows the block diagram with a working scenario for controlling the data stream.The very first step after the program rutines are started is to perform the system components check. The main goal of this step is to determine that all system components are connected and ready to be engaged. Before the human operator positions himself in a front of MS Kinect® sensor, he should leave enough space to be able to see the robot.

Using *the normal movement mode*, the operator is able to position the robot above the object before a picking operation. After the positioning, *the fine mode* should be used for extra precise movements of a robot's hand over the object. After stopping the stream and checking if everything is in place as it should be, the operator enters *the z mode* and continues the stream to get the robot to the grabbing position. From time to time, and respecting the configuration of the environment, the operator needs to save positions to learn the robot how to repeat the actions. By controlling the tool, the operator can grasp the object to perform pick-and-place operations.

The system works by sending relative coordinates of the moved hand in relation to its first position, which is directly connected to the first position of the robot tool.Using the first gesture he can always change this position. The generated TCP data stream coming from PC to the robot contains the following data stored in vector (1), as:

$$Data = [x, y, a, b, c, d] \quad (1)$$

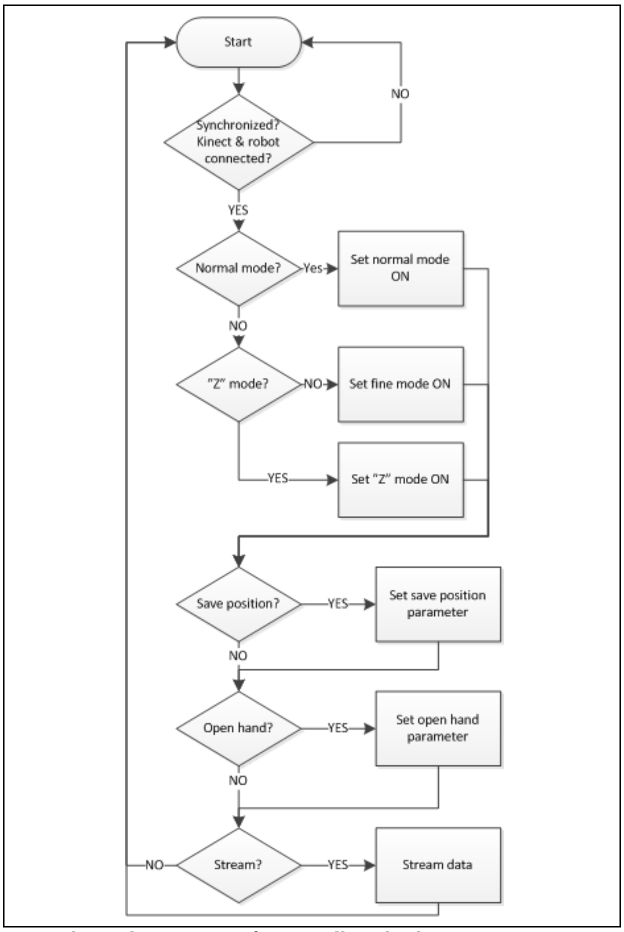

Fig.9. The working scenario for controlling the data stream

Each operation can easily be turned off or on by changing the numbers 0 or 1 respectively.

Each mode defined in (1) can be edited separately without effect on the other. As can be seen in the flow diagram, the system continuously checks for changes as MS Kinect ® sensor itself is constantly scanning the environment. The program on the robot only needs to read this stream and act accordingly. The aim was to make the least programming on the robot side as much possible, so that the system can be used on a wider variety of robots.

5. LIMITATIONS AND FUTURE WORK

The main limitation of the presented approach lies in the fact that the gesture language that has been developed, is relatively difficult to learn and to apply. It is hard to watch a monitor screen showing a system output feedback containing significant information and to track the robot movements comparing them to spatial positions of hands at the same time. To improve the language, the main idea is to make it more expressive and intuitive for the human operator. This is possible by integrating contextual information into the language. By their nature, machines can understand onlyexplicit knowledge [11].

On the other hand, a contextual perception of the environment, which can be partially classified under the context-aware computing, presumes much more implicit understanding.The gesture languageshould enable a transition from implicit to explicit, enabling the system to act based on implicit situational information. By doing so, the gesture language will become much more intuitive enabling the human operator to use its natural gestures.This approach can be compared to ones that living beings use for contextual understanding.

6. CONCLUSION

This paper shows a way how it is possible to lover down the overall system complexity by using MS Kinect ® and other similar sensor, combining them with methods based on artificial intelligence.

The introduction part of the paper contains information about current trends in robotic, explaining the motivation for developing the methodology and its later implementation.

The state of the art part of the paper shows a short introduction into the Programming by Demonstration techniques and methodologies.

The gesture recognition part of the paper introduces a current state of the simple gesture language that has been "invented".

The fourth paper section discusses the methodology and explains how communication between the robot, computer and the operator is being handled.

As can be concluded, PbD shows a great potential for a developmentof production systems that can compete on the global market. Teaching a robot how to perform new tasks has already become a very relevant topic within new areas of service robotics [12].

7. ACKNOWLEDGEMENTS

Authors would like to acknowledge the support of Croatian Ministry of Science, Education and Sports, through projects No.: 01201201948-1941, Multi- agent Automated Assembly and joint technological project TP-E-46, with EGO-Elektrokontakt d.d.

This article presents a part of methodology developed during the work on a student's master's thesis.

8. REFERENCES

[1] Stipancic, T.; Jerbic, B. & Curkovic, P. (2011). Probabilistic Approach to Robot Group Control, *Advanced Materials Research*, p. 742-749

[2] Stipancic, T.; Jerbic B. & Curkovic, P. (2012). Bayesian Approach to Robot Group Control, in: *Electrical Engineering andIntelligent Systems. Lecture Notes in Electrical Engineering 130*, Ao, S. & Gelman, L.(Ed.), pp. 109-119, Springer

[3] Stipancic, T.; Curkovic, P. & Jerbic, B. (2008) Robust autonomous assembly in environment with relatively high level of uncertainty. In: *MITIP 2008*, S.R.O., pp. 193-198, Press, Czech Republic Bily Slon

[4] Argall, B. D.; Chernova, S.; Veloso, M. & Browning, B. (2009). A survey of robot learning from demonstration, *Robotics and Autonomous Systems*, Elsevier B.V

[5] León, A.; Morales, E.F.; Altamirano, L.& Ruiz, J.R. (2011). Teaching a robot to perform task through imitation and on-line feedback. *In Proc. of the 16th. Iberoamerican Congress on Pattern Recognition*, CIARP-2011

[6] Billard, A.; Callinon, S.; Dillmann, R.& Schaal, S. (2008). Robot programming by demonstration, in: B. Siciliano, O. Khatib (Eds.), *Handbook of Robotics*, Springer, New York, NY, USA, (Chapter 59)

[7] Schaal, S.; Ijspeert, A. & Billard, A. (2003). Computational approaches to motor learning by imitation, *Philosophical Transactions: Biological Sciences 358*, p. 537–547

[8] Chen, J. & Zelinsky, A. (2003). Programing by demonstration: Coping with suboptimal teaching actions, *The International Journal of Robotics Research 22*, p. 299–319

[9] Nehmzow, U.; Akanyeti, O.; Weinrich, C.; Kyriacou, T.& Billings, S. (2007). Robot programming by demonstration through system identification, in: *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems*

[10] Argall, B.; Browning, B. & Veloso, M. (2007). Learning from demonstration with the critique of a human teacher, in: *Proceedings of the 2nd ACM/IEEE International Conference on Human–Robot Interactions*

[11] Dey, A. K. (2010). Context – Aware Computing. In: Krumm, J. (Eds), *Ubiquitous Computing Fundamentals*, pp. 321-352

[12] Group of authors (2009). Robotic Visions – The strategic research agenda for robotic in Europe. *European Robotics Technology Platform*, Brussels