Towards a novel learning assistant for networked automation systems

Yongheng Wang, Michael Weyrich

Institute of Industrial Automation and Software Engineering, University of Stuttgart, Stuttgart, Germany
yongheng.wang, michael.weyrich@ias.uni-stuttgart.de

Abstract. Due to increasing requirements on functionality (e.g. self-diagnosis, self-optimization) or flexibility (e.g. self-configuration), future automation systems are demanded to be more and more intelligent. Therefore the systems are desired to learn new knowledge from other systems or its environment. The purpose of this work is to propose a prospective concept of learning assistant for networked automation systems. With the help of the assistant, an automation system can obtain new knowledge by collaborating with other systems to improve its prior knowledge. So that the system user is liberated from continuously providing new knowledge to an automation system.

Keywords: learning assistant · networked automation systems

1 Introduction and Motivation

Nowadays, industrial automation systems are always demanded more functionality (e.g. self-diagnosis, self-optimization) or flexibility (e.g. self-configuration). In this case, they are developed to be more and more complex with increasing integration of information and communication technology. The situation becomes even more complex, when the automation systems are networked together. Therefore, industrial automation systems are more difficult to be operated than before. In order to ease the operability of these systems, assistance systems are introduced to support system users, who can then neglect the complexity of the systems.

The intelligence of assistant systems lies in their knowledge base, which has been predefined by the system developer. The knowledge is nothing more than a collection of facts, events, beliefs, and rules, organized for systematic use [1]. There has been a lot of research on intelligent assistants. Most of the concepts have the following two features: (1) the intelligent assistants are always developed for an individual automation system which is not connected to other systems; (2) the prior knowledge of the system will not be changed or only changed in a small scope.

With the emerging of industry 4.0, automation systems are required to connect with each other and coordinate themselves in different responsibilities. In this context, the intelligent assistant should be improved with the consideration of a networking environment and learning new knowledge from other systems in the same network. This art of assistant is named learning assistant. Compared to conventional assistants, the learning assistant is able to adapt to a new or different environment.

The following is the outline of this work. In section 2, a survey on the existing research on assistant system is introduced. In section 3, the requirements on learning assistant to support the learning process in a network environment are discussed. In section 4, the concept of a learning assistant is proposed. A preliminary application scenario is presented in section 5, which is followed by a brief conclusion.

2 State of The Art

Nowadays, intelligent assistants have been utilized in industrial automation systems within a wide application area. A survey of them has been made in this section.

In order to ease the cooperation between human and robot during assembly process, a cognitive system is developed in [2], where the cognitive simulation model (CSM) can be considered to be an assistant. The CSM unit has a prior knowledge and a simulation module to generate an assembly plan and to optimize the assembly sequence. The prior knowledge involves the knowledge of the assembly process, e.g. feasible assembly sequence. It has to be provided by the developer. Obviously the CSM can work well in mass production. However in the view of industry 4.0, which aims to produce individual products, the assembly sequence and parameters of each individual product may vary. Therefore, a prior knowledge is required to be extendable, so that it is able to adapt to the new individual products. A similar example can be found in [3], where a fault prevention model is introduced. The prior knowledge (about system profile, error prevention functionality, abnormity and error, etc.) of fault prevention model determines the performance of the fault prevention. More knowledge means more errors or faults can be recognized. However, in case of large production plants, which involves the net-working of several automation systems, the prior knowledge of each automation system is not enough to predict the error of the whole production plant.

In [4] an ontology based assistant is introduced, which extracts knowledge by a KDD (Knowledge Discovery in Databases) Process Model from large amount of data. However, it is not cleared that, how the existing model can be extended. In the DFG project „*Kontext- und Community-basierte Assistenzsysteme für Personen mit Behinderungen (D02)*" a context- and community based assistant for disabled people is discussed. The system is used as an intelligent navigation system, which relies on environment model and calculates the route plan automatically. The system can be improved by integrating the communication ability, which allows the system to learn from other systems to adapt more new environment.

There are still more examples of the intelligent assistant. There is no need to mention all of them. Mr. Jasperneite and Niggemann have already concluded the common model of intelligent assistant in [5]. An intelligent assistant (see Fig. 1) always possesses the system objective and a prior knowledge being comprised of domain and equipment knowledge. The system is able to identify its current situation, and then find the solution strategy based on its prior knowledge and system objective.

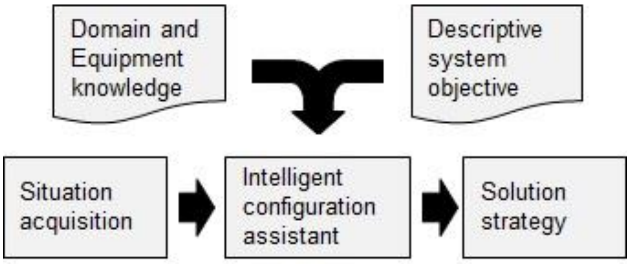

Fig. 1. Conventional intelligent assistant [5]

3 Idea of the Learning Assistant

As concluded in the previous section, the conventional assistant cannot help the systems to obtain new knowledge from its environment. For this reason the idea of a novel learning assistant is introduced as an extension to the conventional assistance (see Fig. 2).

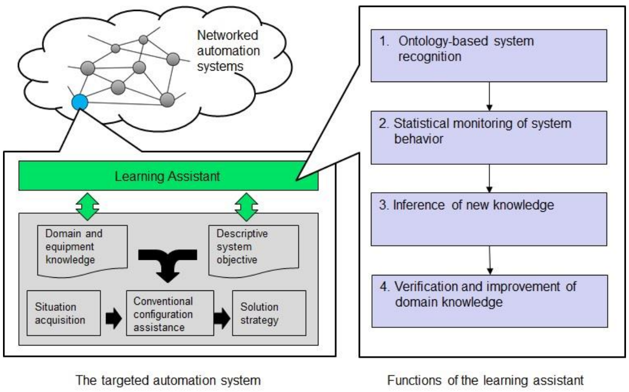

Fig. 2. Idea of learning assistant

In the scenario it is assumed that an industrial automation system is a part of networked systems. The system has a conventional assistant which can determine the solution strategy based on a prior knowledge and predefined system objective. As explained in the previous section, the prior knowledge (domain knowledge) is usually not enough to counter all the possible situations in the networked environment. In this case, the system model is not valid in some situations. For this reason, the proposed learning assistant can search and interact with the similar systems in the network, so that it is able to obtain new knowledge. The intelligent assistance has the following four basic functions: (1) ontology-based system recognition, (2) statistical monitoring of system behavior, (3) inference of new knowledge, and (4) improvement of the domain knowledge.

The prerequisite of system recognition is a compatible communication interface and protocol between systems. Each system will be described by a unique ontology, whereas an automation system can be described in 2 dimensions. At the first dimension the system will be described according to its devices architecture (so called equipment knowledge, involving functional profiles, inputs, outputs, I/O modules, variable types, constraints, etc.). While at the second dimension, the system is described according to its domain knowledge (e.g. diagnosis knowledge). In this respect, the ontology-based device description in [6] and ontological learning assistant in [4] will be employed. The ontology-based system description enables the possibility of communication and accessing between systems.

After step one, the system behavior of all relevant systems in the network will be monitored with respect to the knowledge base. The reason is that, the knowledge base of the targeted system is usually constructed by a limited number of samples, which don't represent the real facts. A typical of this phenomena is the concept drift which has been discussed in [7]. Therefore, the statistical monitoring is able to show which system behavior is strange, and lies away from the typical behavior in the knowledge space. The advantage of step 2 is reduce the human work by means of extending the system behavior model by itself during operation time, instead of considering all behavior possibilities during the development phase. At step 3, the interpretation of these system behavior will then be compared in order to derive new knowledge. If a new interpretation based on other systems can be accepted by the system user, the corresponding knowledge of other systems can be integrated into the target system. When the newly derived knowledge has been verified by an expert, it is demanded to introduce step 4, which will verify and improve the domain knowledge of the targeted system.

4 Realization of a Learning Assistant with an Application Scenario

The previous described idea shows the framework of the learning assistant. The recent section will present how to realize the learning assistant through an application scenario (see Fig. 3). The application scenario can be considered as an extension based on [8] and [9], which have proposed a learning assistant for a single image processing system. For the extension, the application scenario assumes a network with image processing systems in variant countries (e.g. Germany, Spain and Italy). The image processing system is denoted as blue points in Fig. 3. The image processing systems are developed to classify the fruits into different classes. Each of the system has a prior knowledge about the classification of fruits. In order to ease the illustration, it assumes that the systems have learned the different classifications of fruits by using the learning method of Support Vector Machine (SVM). Therefore the prior knowledge is considered to be class boundaries in the feature space. Learning new knowledge means to adapt the class boundaries in the SVM feature space. Based on the assumption, the following content illustrates the functions of the learning assistant in a networked image processing systems.

The first function of the learning assistant is ontology-based recognition of nearby systems. In order to realize this, the individual ontology system has to be developed, including the components, functions, database, knowledgebase, access, security and so on. Since the complexity of creating an ontology for all the networked systems, it is assume that the networked systems can access each other easily.

During the first step, only the systems that have the similar knowledgebase will be remained. This step provides the possibility of learning knowledge from other systems. The second function of the learning assistant is to monitor the classification result of the image systems. The reason can be declared in [9]. The number of training samples for machine learning methods is usually limited, therefore the prior knowledge generated by machine learning is usually not valid during long time operation in the real application. In this case, monitoring of the classification result can help to discover real (fruit) data distribution, which may deviate from the training samples to generate the prior knowledge. As the result of the second function, a stack of points (each point stands for a fruit in the feature space), which are different from the sample points, are identified.

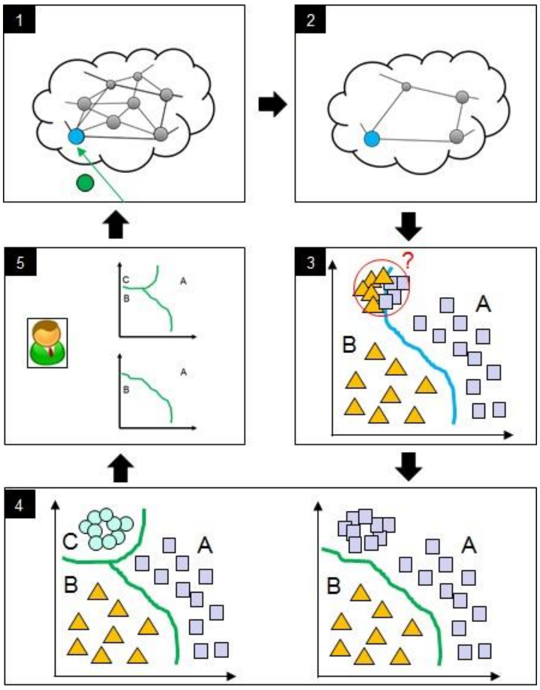

Fig. 3. Application scenario of learning assistant with the example of SVM classifier

The third function of the learning assistant is the inference of new knowledge. The new knowledge is generated by incremental learning, which adapts the old class boundaries to the new found points (being identified at the second step). The prerequisite of using incremental learning is that, the class labels of the new found points should be given. For this purpose, the class labels of the new found points can be generated by two ways: (1) the class labels of the new found points are generated by other systems; (2) the class label of the new found points are generated by the data consistency test being described in [9]. The data consistency test is to analyze the data by using variant distance measurements: Euclidean, Mahalanobis, Bhattacharyya. Based on the measured distance, the class labels of the new found points can be suggested. The result of this function is two new generated classifiers, which have already adapted the class boundaries for the new found points.

The new function of the learning assistant is the verification and improvement of domain knowledge. To approach this, two new generated classifiers will be tested, and the classification accuracies of them will be compared. The user can choose the classifier which has higher classification accuracy. Afterwards the chosen classifier can replace the previous one in the targeted system.

5 Conclusion

The objective of this work is to propose a concept of a learning assistant, which learns new knowledge from other systems in the same network.

Usually a conventional assistant possesses only a certain amount of prior-knowledge, which helps the automation systems adapt to the environment. However prior-knowledge is obtained by only a few number of observations or samples. In this case, the system user always needs to provide the new knowledge to automation systems. Therefore, the recent assistant is not able to adapt to a changing environment automatically. The proposed learning assistant consists of 4 functions: ontology-based system recognition for providing the communication between systems, statistical monitoring of system behavior for detecting unknown system behavior, inference of new knowledge based on the unknown behaviors and evaluation of generated new knowledge. The proposed learning assistant is able to access the knowledge base of other systems, and improve its own knowledge base in order to accommodate itself to changing environment. Especially in the emerging world with internet of things and cyber physical system, the system developer is not able to predefine all the necessary knowledge for a system, but the system is desired to learn new knowledge from other systems in the network.

6 Reference

1. International Organization for Standardization: Information technology, ISO 2382-28:1997, (2011)
2. Schlick, C.M., et al.: Erweiterung einer kognitiven Architektur zur Unterstützung der Mensch-Roboter-Kooperation in der Montage. 239-263, (2014)

3. Bordasch, M., Göhner P.: Fault Prevention in Industrial Automation Systems by means of a functional model and a hybrid abnormity identification concept. Industrial Electronics Society, IECON 2013-39th Annual Conference of the IEEE, pp. 2845-2850. IEEE (2013)
4. Choinski, M., Chudziak, J.: Ontological learning assistant for knowledge discovery and data mining. In: Computer Science and Information Technology, 2009. IMCSIT'09. International Multiconference on pp. 147-155. IEEE (2009)
5. Jürgen, J.; Niggermann, O.: Systemkomplexität in der Automation beherrschen. atp edition-Automatisierungstechnische Praxis 54.09, 36-45. (2012)
6. Dibowski, H., Kabitzsch, K.: Ontology-based device descriptions and triple store based device repository for automation devices. In Emerging Technologies and Factory Automation (ETFA), 2010 IEEE Conference, pp. 1-9. IEEE (2010)
7. Zliobaite, I.: Learning under Concept Drift: an Overview, Technical Report, Faculty of Mathematics and Informatics. Vilnius University (2009)
8. Wang, Y., Weyrich, M.: An adaptive image processing system based on incremental learning for industrial applications. In Emerging Technology and Factory Automation (ETFA), 2014 IEEE, pp. 1-4. IEEE (2014)
9. Wang, Y., Weyrich, M.: An assistant for an incremental learning based image processing system. In Industrial Technology (ICIT), 2015 IEEE International Conference, pp. 1624-1629. IEEE (2015)