A Concept of an Industry 4.0 Research Lab for Future Intralogistics Technologies and Services

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Abstract. The purpose of this research is to identify new Industry 4.0 technologies in an intra-logistics environment. Due to new forms of interaction between humans and machines new possibilities of materials handling can be developed with support of real-time motion data tracking and virtual reality systems. These services will be provided by a new research centre for flexible human-machine cooperation networks in Dortmund. By the use of various reference and experiment systems different real-time scenarios can be emulated with digital twin simulation concepts. Big data is an important paradigm in this research project where all systems are made flexible in terms of networking which is analysed by high performance computing cluster. This leads to the challenge of finding a common syntax for inter-operating systems. This paper describes the design and deployment strategies of the research centre with the possibilities and the design insights for a futuristic Industry 4.0 material handling facility.

1 Introduction

The technological base for Industry 4.0 is formed by data networked production facilities, products and materials as well as transport technologies, which are equipped with sensors and decentralized IT intelligence. These intelligent cyber-physical systems (CPS), which are connected over the Internet, are able to autonomously organize, control and adapt the sequence of value-added processes and the corresponding logistical functions to external requirements. [1]

Companies are required to redesign solution approaches, which are strongly oriented on the dimensions of technology, human and organization (framework). In addition to the question about the organization of responsible and goal-oriented action in the human-machine interaction, there should be a need-oriented debate on the topic of hybrid services. The hybrid services are created by an innovative combination of software and hardware and are increasingly integrated in new business models, autonomous shuttle systems or intelligent bins. Innovative technological solutions, like head mounted displays or tablets, allow reliable interaction between humans and machines. That's why hybrid services promote horizontal and vertical networking of the economy.

Modern service packages in a socio-technical perspective and the related changes of logistics and industrial production are major challenges. A key factor for the successful transition to Industry 4.0 is the physical implementation of demonstrators and the execution of experiments in a realistic intra-logistics environment.

2 Conceptual description and scientific objective

The following are a few of the factors that massively increase the dynamics and complexity of the company-, especially of the logistics-environment:

- shorter delivery times
- reduction of lot sizes

- shorter product life cycles
- increasing number of product variants
- hardly predictable and volatile customer demands

To increase the adaptability of processes and business models, it is necessary to generate adaptation measures that combine the advantages of technological innovations as well as human skills. An interdisciplinary research project is initiated in Dortmund funded by the German Federal Ministry of Education and Research (BMBF) and entitled as "Innovationslabor - Hybride Dienstleistungen in der Logistik" [2]. Within the scope of this project a research centre is being developed, which serves as a novel experimental test environment for innovative hybrid forms of cooperation between humans and machines in logistics.

The research centre follows the basic concept of the flexible, not permanently installed equipment. A large number of different autonomous and networked entities are used, which can arrange themselves ad hoc and are controlled decentral in temporary combinations to provide intra-logistics services. To simultaneously investigate ground-based and flying participants of the hybrid cooperation network, the room concept of the research centre is designed to experiment in the three-dimensional space. Fig. 1 provides a structural insight into the research centre.

Derived from the three basic pillars decentralization, networking and localisation of an efficient hybrid work environment the strategic equipment is oriented to the following thematic areas:

- Decentralized control by wireless communication
- Localization and navigation of all mobile entities in the hybrid cooperation network

A networked computing system is used to evaluate ongoing tests in real-time, to record large amounts of data for subsequent processing or to forward data in real-time to downstream systems. Furthermore, the computing system is used to create a digital simulation-based twin of the test field. [3]

The entire intra-logistics process chain will be represented with the main focus on future work models. New technological as well as work-sociological findings are iteratively recoupled into technical developments. This novel form of research environment is intended to contribute, amongst others, to answer the central questions:

- How responsible, secure and purposive can action be designed and organized in the future human-machine interaction?
- How can the innate abilities of employees optimally be combined with the abilities of technical (assistance-) systems?
- How can technical systems perceive, analyse and evaluate their environment more intelligently?
- How can the emerging data volume be transmitted securely, wirelessly and in a system guaranteed time?

3 Reference and Experiment Systems in the Research Centre

The research centre will implement the ideology of reference and experiment systems. These systems will be used together to emulate and simulate a futuristic use cases that could later be implemented in a real process or system in parts or as whole.

3.1 Reference Systems

3.1.1 Optical reference systems

The motion tracking system is a real-time localisation system (RTLS). The RTLS system requires markers to be attached to the objects and with a minimum calibration effort, the objects can be tracked using the Tracker software. This provides location of the objects in a precision close to a millimetre.

3.1.2 Radio reference system

A network of Software defined radios (SDR) equipped with an array of antennas is used for sensing, tracking and analysing the wireless communication.

3.1.3 Laser project system

A visual system to create virtual objects and to represent temporary markings is created using a laser projection system. The system can be used as a guidance system for robots or to simulate virtual reality systems and scenarios.

3.1.4 Virtual reality system

To facilitate concepts such as digital twin a virtual reality wall with millimetre precise markings are printed in a roll shutter of dimensions 200 sq. m. The markings are used as reference markers for the virtual reality device camera to estimate the position, orientation and geometrically represent objects in the virtual world in correspondence to the physical world.

Figure 1. Structural insight in the research centre

3.2 Experiment Systems

3.2.1 Robot Systems

Mobile robot and drone swarms complement to the complexity of diverse machines in Industry 4.0. Each mobile entity has its own dynamics and kinematic properties for carrying out specific tasks. Robots fitted with lifts can carry mobile racks from point A to point B. Programmable drones are used as a research platform for tasks in coordination with humans and other machines.

3.2.2 LR-WPAN and other wireless networks

Wireless sensor networks (WSN) are a derived terminology of internet of things (IoT) which targets a specific kind of IoT devices that are low power, low data rate devices that are used for sensing physical parameters. This has been standardized as low rate wireless personal area network (LR-WPAN) in the IEEE Standard for Information technology - Telecommunications and information exchange between systems. The data recorded can be reliably used for predicting and forecasting the processes. A wireless sensor network with 550 nodes is deployed under the floor as shown in fig. 2. On the one hand this experimentation system provides for developing and testing seamlessly numerous large-scale wireless materials handling applications. On the other hand it provides for performing analysis on the radio characteristics to compute parameters like signal quality, channel energy, signal to noise ratio and coexistence with other wireless devices.

3.2.3 Networked Computing System

The future of an Industry 4.0 material handling facility will highly rely on the data because of the autonomy of the elements. It does not only depend on the amount of data that is produced, but also on the generated metadata, which gives context to the data and also the availability of the data. To provide context and to provide the data to other systems as it is available, the Networked computing system is used as a data sink.

The challenges for such a system lies in finding a common syntax for inter-operating systems which also provides guarantees for the time at which the data is available.

4 Conclusion

The research project “Innovationslabor - Hybride Dienstleistungen in der Logistik" focuses on new forms of human-machine interaction to develop technological innovations for an effective and efficient hybrid work environment. The novel success factor of the research centre is the interdisciplinary collaboration of logistics, IT, engineering, business as well as sociology experts.

Through the emergence of hybrid cooperation networks in materials handling where humans are supported by machines and machines complement each other in a common work space, the dynamics of a process will become complex to parameterize. Flexible reference systems and experiment systems could be used in combinations to create real-time process emulations where data can be gathered in a granular way and processed with diverse heuristic

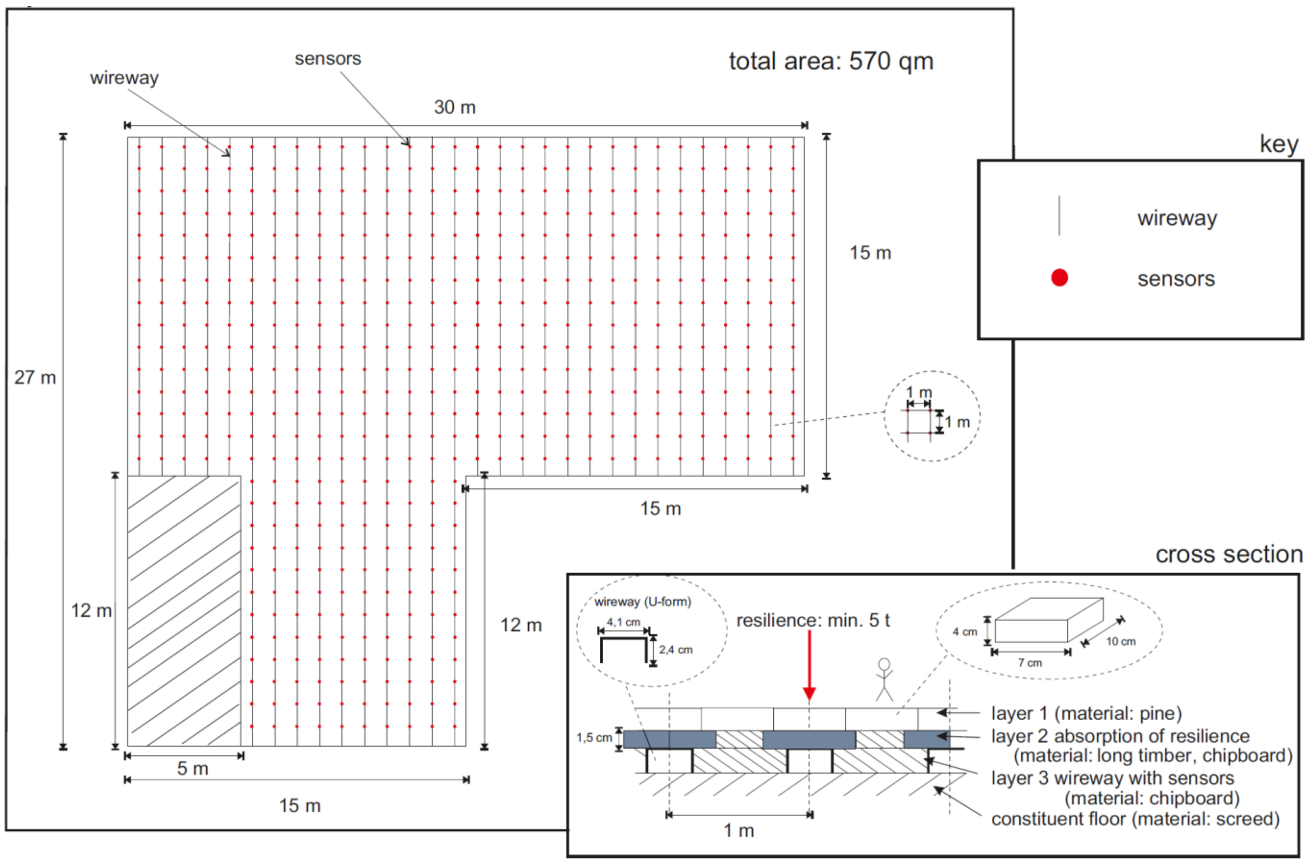

Figure 2. Layout of sensor floor

algorithms to provide insight for such multi-dimensional data generated by each system taking part in the experiment scenario.

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