Proceedings of the Workshop on Disruptive Information and Communication Technologies for Innovation and Digital Transformation

20th December 2019

Bragança, Portugal

Editors:
Paulo Leitão
Carlos Ramos
Javier Parra

Title

Workshop on Disruptive Information and Communication Technologies for Innovation and Digital Transformation

Editors

Paulo Leitão	Instituto Politécnico de Bragança
Carlos Ramos	Instituto Superior de Engenharia do Porto
Javier Parra	Universidade de Salamanca

Publisher

Instituto Politécnico de Bragança
Campus de Santa Apolónia
5300-253 Bragança
Portugal

Design

CeDRI - Researche Centre in Digitalization and Intelligent Robotics

Date: 2019

ISBN: 978-972-745-271-2

Available in: http://hdl.handle.net/10198/19917

URL: http://disruptive-workshop.ipb.pt/

Email: cedri@ipb.pt

Conference Committees

General Chair

Paulo Leitão (Centro de Investigação em Digitalização e Robótica Inteligente (CeDRI), Instituto Politécnico de Bragança, Portugal)

Local Committee

Filipe Alves

Flávia Pires

Gustavo Funchal

Jonas Queiroz

Lucas Sakurada

Luis Piardi

Nelson Rodrigues

Thadeu Brito

Tiago Franco

Victória Melo

Welligton Maidana

International Committee

Anibal Reñones (CARTIF - Fundación CARTIF, Spain)

Carla Geraldes (IPB - Instituto Politécnico de Bragança, Portugal)

Carlos Ramos (ISEP - Instituto Superior de Engenharia do Porto, Portugal)

Fernando de la Prieta (USAL - Universidad de Salamanca, Spain)

Goreti Marreiros (ISEP - Instituto Superior de Engenharia do Porto, Portugal)

Henar Olmos (ICE - Instituto para la Competitividad empresarial de Castilla y León, Spain)

Ignacio Caño (INCIBE - Instituto Nacional de Ciberseguridad de España, S.A., Spain)

Ignacio de Miguel (UVa - Universidad de Valladolid, Spain)

Javier Parra (USAL - Universidad de Salamanca, Spain)

Javier Prieto (USAL - Universidad de Salamanca, Spain)

Luis Conceição (ISEP - Instituto Superior de Engenharia do Porto, Portugal)

Marta Galende (CARTIF - Fundación CARTIF, Spain)

Maria João Samúdio (PRODUTECH – Associação para as Tecnologias de Produção Sustentável, Portugal)

Maria Arroyo (ICE - Instituto para la Competitividad empresarial de Castilla y León, Spain)

Paulo Leitão (IPB - Instituto Politécnico de Bragança, Portugal)

Ramón J. Durán Barroso (UVa - Universidad de Valladolid, Spain)

Sara Rodríguez (USAL - Universidad de Salamanca, Spain)

Tiago Pedrosa (IPB - Instituto Politécnico de Bragança, Portugal)

Invited Speakers

Umberto Pellegri

Senior Executive, with a consolidated manufacturing experience as Plant Operation Manager.

Talk:

CATRAPORT: Industry experience on expectations, current state, future state, plan and challenges in the implementation of the digital transformation required by the forth Industrial Revolution.

João Mourinho

IT Innovation Manager - PhD in Management and Industrial Engineering, MsC in Computer Eng.

Talk:

Data as the core of Industry 4.0”.

Flávia Pires, Victória Melo, João Victor (IPB)

Researcher at CeDRI in the area of Digital Twin.

Talk:

Digital Twin Use Cases Demonstration: What is a Digital Twin, its benefits, technologies and challenges to face? What you need to know for an industrial implementation.

Preface

The workshop on Disruptive Information and Communication Technologies for Innovation and Digital transformation, organized under the scope of the DISRUPTIVE project (disruptive.usal.es) and held on December 20, 2019 in Bragança, aims to discuss problems, challenges and benefits of using disruptive digital technologies, namely Internet of Things, Big data, cloud computing, multi-agent systems, machine learning, virtual and augmented reality, and collaborative robotics, to support the on-going digital transformation in society.

The main topics included:

- Intelligent Manufacturing Systems
- Industry 4.0 and digital transformation
- Internet of Things
- Cyber-security
- Collaborative and intelligent robotics
- Multi-Agent Systems
- Industrial Cyber-Physical Systems
- Virtualization and digital twins
- Predictive maintenance
- Virtual and augmented reality
- Big Data and advanced data analytics
- Edge and cloud computing
- Digital Transformation

The workshop program included 16 accepted technical papers, 2 invited talks and 1 technical demonstration of use cases.

This volume contains six of the papers presented at the Workshop on Disruptive Information and Communication Technologies for Innovation and Digital Transformation.

This workshop was organized by CeDRI (Research Centre in Digitalization and Intelligent Robotics) and mainly supported by the European Regional Development Fund (ERDF) through the Interreg Spain-Portugal V-A Program (POCTEP) under grant 0677_DISRUPTIVE_2_E (Intensifying the activity of Digital Innovation Hubs within the PocTep region to boost the development of disruptive and last generation ICTs through cross-border cooperation).

December 20, 2019
Bragança

Paulo Leitão (IPB)
Carlos Ramos (ISEP)
Javier Parra (USAL)

Table of Contents

Digital Transformation and Additive Manufacturing: The role of standardization

Cláudia Fernandes[1[CATIM]] and Nuno Araújo[1[CATIM]]

[1] CATIM – Technological Center for the Metal Working Industry, Porto, Portugal
claudia.fernandes@catim.pt

Abstract.
Digitization of industry is nowadays an evolving reality that is potentiated by the exponential growing of data and the convergence of affordable technologies. Additive manufacturing (AM) is considered one of the nine technologies with the potential for transforming industrial production, allied business models and with high impact on society.

Driven by research and politics most of the digitization's players worldwide have recognized the potentials of standardization to provide approaches, solutions and even some answers to industrial challenges posed by these "new" transforming technologies, namely AM technologies.

With the present paper the authors intend to discuss problems, challenges and benefits of using disruptive transforming digital technologies – specifically AM, allied with the development of supporting standardization initiatives that address industrial needs, market demands and societal challenges.

Keywords: Standardization, Additive Manufacturing, Digital Industrial Transformation.

1 Digital Industrial Transformation and Additive Manufacturing

1.1 Digital industrial transformation

Digital industrial transformation is a process based on the digitization of industry that arose from the Industry 4.0 (I4.0) concept sometimes addressed has the 4th industrial revolution [1] or other concepts. I4.0 is an approach much richer than a concept, and emerged for the first time in 2011, in Germany, with the objective of contextualization of highly digitized manufacturing processes where information flows among machines in a controlled environment so that human intervention is reduced to a minimum [2]. The Industry 4.0 concept, however, embraces the vertical and horizontal integration in the wider industry environment where a factory or production unit is part of a larger ecosystem composed of several pieces [3]. This approach encompasses more than a

definition, it has impact on technologies, methods, processes, competencies and even on safety and quality, within doors and outdoors.
Furthermore, this conceptualization and idea alignment, independent of the name – Industry 4.0, digitization of industry, 4th Industrial Revolution, among other - facilitates communication on innovation and modernization among several possible players: policymakers, enterprises and academia [4]. It also facilitates the communication of public policies and the recognition by industry itself, namely small and medium sized enterprises (SME), that changes are occurring with potential implications on their competitive landscape [5]. This “re”newed ecosystem allows also flexibility, innovation and resilient responses to the megatrends and drivers for the future of manufacturing.

1.2 Additive Manufacturing

AM is considered has one of nine technologies transforming industrial production [6] alongside with big data and analytics, autonomous robots, simulation, horizontal and vertical systems integration, industrial internet of things cyber security, cloud and augmented reality. AM is defining and will continue to define the development of all types of industry during at least the first decades of the 21st century [7].

AM is also referred to as three-dimensional printing (3D printing), encompassing a set of processes where a tridimensional object is produced from a digital model by adding successive layers of material. This technology stands in contrast with the traditional or subtractive manufacturing (SM), where material is removed through machining or other techniques. We are now facing hybrid technologies and process that encompass both AM and SM.

According to AMSC the process of production of AM parts may be summarized as follows:

- Design the part for AM;
- Specify the materials from which the part will be built;
- Establish build parameters;
- Control the AM build process to achieve the desired part’s dimensions, structure, and performance properties;
- Perform post-processing steps;
- Final testing;
- Certify the part’s fitness-for-use;
- Maintain/repair machines, parts, and systems.

Having in mind industrial manufacturing AM processes, its implied that only with standards (no matter the nature e.g. proprietary, ISO, ASTM), regulatory frameworks, specifications, conformity assessment, quality control, training and qualification programs, the approach is viable and accepted by the market and may function has a key enabler for the large-scale introduction and growth of AM [6, 7, 8].

1.3 Standardization and industrial transformation

Standardization is recognized worldwide has supportive to innovation [9] and industrial transformation, according to Gerundino, the most important aspects can be summarized as:

- Contributing to technical evolution by applying, at the right time, critical design constraints (i.e. avoiding re-inventing the wheel). Standards can help to reduce wasteful, redundant product development, allowing to free up resources that can instead be dedicated to fresh, inventive work;
- Facilitating the development of new markets and trade, by helping to establish and exploit network effects, increasing consumer confidence and allowing to reach critical mass;
- Permitting the sharing of investments and risks associated with the development of new technologies and applications (fostering innovation through collaboration);
- Helping the commercial exploitation of innovative ideas, providing a basis for the dissemination of information and an accepted framework within which patents can be drawn up, removing undue proprietary interests and barriers to trade.

On the other hand, its questionable the time needed to develop, market and transfer the standards in order to respond to industrial cycles needs. It can deepen that the human factor, namely qualifications, skills and ability to reshape the ways in which reality is apprehended are central to the success of standardization transfer to industry concerning the AM subject.

2 Standardization and Additive Manufacturing

2.1 Standards for AM

According to ISO [11] and other global players in standardization, standards promote innovation and provide solutions to address global challenges. These set of knowledge associated with AM (qualification, technology, processes, certification, global impact, etc.) is recognized has a horizontal subject, alongside with human capital, pricing, quality, sharing economy, amongst others. Can this be view be aligned with global megatrends and drivers for change?

There are several practical and concrete standardization initiatives, see Figure 1, that address some of these questions, trends and drivers related to AM technologies. Generally, there are three levels of approach to standardization in AM [12]:

1. General top-level AM standards;
2. Category AM standards;
3. Specialized AM standards.

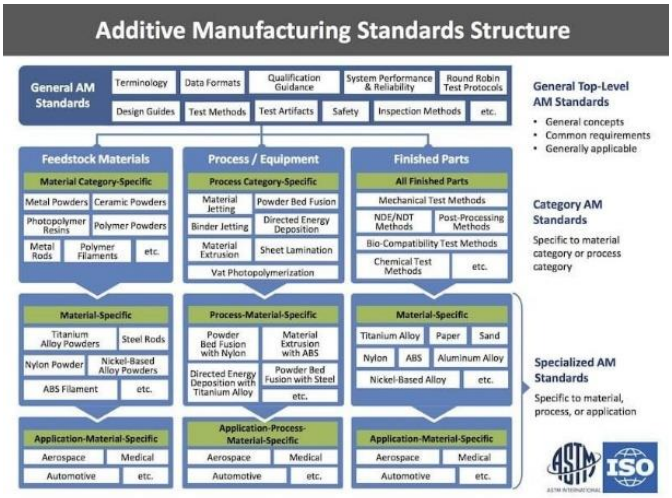


Fig. 1. Additive manufacturing standards structure [12].

General top-level AM standards encompass documents that deal with general concepts, common requirements and generalities it can be found working documents on design guidelines, safety, design, terminology, data formats, etc.

Category AM standards cover material specificities (e.g. metal powders, ceramic powders, metal rods, filaments), processes and equipment's (e.g. extrusion, deposition, bed fusion, jetting), and finished parts characterization, having in mind for example mechanical test methods, post-processing methods, bio-compatible test methods, chemical test methods.

Specialized or specific AM standards are those documents developed with the intent to address specificities has shown in Figure 1, and broadly according to ASTM [12], the structure's goals include:

- Identifying standards-related gaps and needs in the AM industry;
- Preventing overlap and duplicative efforts in AM standards development;
- Ensuring cohesion among AM standards;
- Prioritizing AM standards areas;
- Improving usability and acceptance among the AM community.

2.2 Limitations for AM standards approach

Additive manufacturing is already changing industrial manufacturing paradigms, in spit the bright side of it, there are limitations that can generically be clustered into technological limitations, non-technological limitations and societal limitations, each of these clusters have impacts on standardization:

- Technological limitations, those inherent to the very characteristics of AM technologies, only solvable through a development and increase of their capacities of the current technologies [13].
- Non-technological limitations, those associated with elements that, due to lack of adaptation to or experience of AM technologies, impede the full exploitation of the capabilities of the technology [13].
- Societal limitations, those associated with the lack of response to societal challenges such has aging, lack of competencies, business models evolution, blocking the full potential for the technology permeabilization into the industrial ecosystem.

Concerning specifically standardization although the efforts being made worldwide there are many different AM technologies, each one with its specificities and in the field, it might be difficult to generalize on how to design for AM. Alongside with different technologies it's also face different manufacturers of AM equipment's that introduce variability to the ecosystem, and this might be faced has a challenge to standardization and even a pro, allowing manufacturers of AM equipment to respond to market needs aligned with peer recognized standards.
Nowadays its available in the market several published or under development AM standards (see Figure 1 for areas) but its needed to encompass more user experience on industrial implementation. The standards need to go forward and accompany the industrial and societal development of the AM field, either theoretically or practically.

3 Discussion and future prospects

Nowadays, society, world economy and manufacturing are undergoing major changes, driving a major change in the way people live, work, behave and face available resources. An unprecedent increase in the speed of development in science and technology, a fast diffusion of knowledge, the scarcity of resources and the new generations of consumers will pose challenges and opportunities for manufacturing leading to a new paradigm shift at a global level [14]. AM is already a reality in our industry and manufacturing practices, and its being applied in several distinct fields, from biomedicine, to aeronautics to the homemade maker economy. Industry faces remarkable challenges in the adoption of these new technologies. To build and sustain a lead in the race to full transfer and implementation, its need to broaden and deepen the practical knowledge about digital technologies and the related use cases—and then develop and implement tailored digital manufacturing strategies [6].

The development of a dedicated AM standardization field will allow academia, industrial experts and other interested parties to interact in a more meaningful and productive way. Having a common working ground on standardization addressing AM also potentiates the integration and application of methods, techniques and technologies, accelerating the transfer to industry promoting innovation and renewal of manufacturing approaches alongside with the public and industrial recognition of subject. This scenario implies the rationalization of the incorporation of technology, people and the ecosystem. Industrial processes recognition and the way industry deals with questions of certification, quality assurance, and people qualifications will guide market and peer's acceptance. However, in AM like other disruptive technologies the market demands safe, sustainable and reliable products. The requisites for quality and operation of finished parts/products related for example with mechanical properties, control of dimensions, microstructure, potential defects, surface roughness, and residual stress must be considered in the industrial manufacturing processes. The needs for robust AM processes, besides the advertised potentialities for AM (complex structures and geometry, low weight, materials conjunction, time to produce), can result in designs that limit a part's use in high-value or critical applications [15]. Standardization can give some possible routes for answering the market and the industrial needs. Furthermore, market needs have awareness that where parts, products, methods and systems require regulator certification, requirement interpretations are still evolving [11, 15]. And this scenario many times leads to the development of proprietary standards in substitution for worldwide massive application standards.

The standardization activity will need to adapt as the ecosystem for additive manufacturing evolves due to technological innovations, business models evolution, market demands, and as additional industry sectors enter the additive manufacturing market.

Unveiling new technologies, such has AM drives change, but it also drives a shift in mental maps for reading reality. Our industrial tissue must be resilient to these inputs from the ecosystem so that it can integrate and incorporate these technologies having in mind differentiated quality control techniques, evolving certification and qualification referentials, evolving and disruptive business models alongside with one renewed way of thinking and the need for new mind maps for reading the constantly evolving, volatile, uncertain, complex and ambiguous industrial manufacturing ecosystem.

Acknowledgements

This work was supported by the project "Observ.Tech - Competitiveness, technological vigilance and intelligence", with the reference POCI-01-0246-FEDER-026730, financed by COMPETE2020 – Programa Operacional Competitividade e Internacionalização (POCI), under the Portugal2020 Partnership Agreement, through the European Regional Development Fund (ERDF).

References

1. Hermann, M., Pentek, T., Otto, B.: Design principles for industrie 4.0 scenarios. In PROCEEDINGS OF THE ANNUAL HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES, vol.1, pp. 3928.3937. IEEE Computer Society Washington, DC, USA (2016).
2. Qin, J., Liu, Y., Grosvenor, R.: A categorical framework of manufacturing for Industry 4.0 and beyond. In: Procedia CIRP (2016).
3. Hofmann, E., Rüsch, M.: Industry 4.0 and the current status as well as future propects on logistics. Computers in Industry (89), 23-34 (2017).
4. Reischauers, G.: Industry 4.0 as a policy-driven discourse to institionalize innovation systems in manufacturing. Technological Forecasting and Societal Change 132 (12), 26-33 (2018).
5. Smit, J., Kreutzer, S., Moeller, C., Carlberg, M.: Industry 4.0 a study for the European Parliament. http://www.europarl.europa.eu/studies, last accessed 2019/11/22.
6. BCG Homepage, https://www.bcg.com/en-pt/capabilities/operations/embracing-industry-4.0-rediscovering-growth.aspx, last accessed 2019/11/22.
7. Gonzaléz, D., Alvaréz, A.: Additive manufacturing feasibility study and technology demonstration: EDA AM; state of the art and strategic report. European Defence Agency (2018).
8. America Makes; ANSI Additive Manufacturing Standardization Collaborative (AMSC): Standardization Roadmap to Additive Manufacturing, Version 2.0. ANSI, AMSC, USA (2018).
9. ISO International Organization for Standardization Homepage, https://www.iso.org, last accessed 2019/11/22.
10. Gerundino, D.: Standartization and innovation. In: ISO Innovation ISO-CERN Conference Proceedings, pp. 5-12. ISO, CERN, Geneve, Switzerland (2014).
11. ISO: ISO Strategy 16-20, https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso_strategy_2016-2020.pdf, last accessed 2019/11/22.
12. ASTM Homepage, https://www.astm.org/COMMIT/F42_ISOASTM_AdditiveManuStandardsStructure.pdf, last accessed 2019/11/21.
13. PRODNTEC: Additive Manufacturing Feasibility Study & Technology Demonstration – EDA AM State of the Art and Strategic Report, https://eda.europa.eu/docs/default-source/projects/eda-am-study-and-strategic-report_v6.pdf, last accessed 2019/11/21.
14. MANUFUTURE-EU: ManuFUTURE Vision 2030: A competitive, Sustainable and Resiliente European Manufacturing. Report of the ManuFUTURE-EU High level group. (2018).
15. Russel, R., Wells, D., Waller, J., Poorganji, B., Ott, E., Nakagawa, T., Sandoval, H., Shamsaei, N., Seifi, M.: Qualification and vertification of metal additive manufacturing hardware for aerospacial application. In Additive manufacturing in the aerospace industry, 33-66 (2019).

TransformingTransport: Modelos de micro-simulación de tráfico *

Laura Sanz[1], Marta Galende[1][0000−0001−7397−7742], and Roberto Riol[2]

[1] CARTIF Centro Tecnológico, Boecillo, Valladolid, España
[2] Ayuntamiento de Valladolid, Valladolid, España
{laumar,margal}@cartif.es,rriol@ava.es

Resumen Mantener un flujo de tráfico fluido en el centro de una ciudad, mientras esta sigue siendo atractiva tanto para los ciudadanos como para el comercio, es un gran reto para los gestores de tráfico. Con el objetivo de garantizar la viabilidad de las operaciones de carga y descarga en el centro de la ciudad de Valladolid, y dentro del proyecto europeo *TransformingTransport*, se han generado modelos de micro-simulación de tráfico que van a ayudar a las autoridades locales en sus procesos de toma de decisiones relacionados con las posibles modificaciones de las normativas actuales de actividades de carga y descarga en la ciudad.

Palabras clave: Movilidad urbana · Modelo micro-simulación tráfico · Regulación Carga y Descarga.

1. Introducción

Según la Comisión Europea en 2050 el 80 % de los ciudadanos europeos vivarán en zonas urbanas, que se enfrentarán cada vez más asiduamente a problemas relacionados con o causados por el transporte y el tráfico. Mejorar la movilidad, a la vez que se reducen los atascos, la contaminación y los accidentes, son algunos de los retos que deben afrontar los gestores y planificadores de tráfico de las ciudades europeas [2].

Con el objetivo de guiar a las autoridades de la ciudad de Valladolid en su proceso de toma de decisiones relacionadas con la mejora de la logística urbana en determinadas áreas de la ciudad donde las actividades de transporte de mercancías es más intensa, CARTIF ha implementado diversos modelos de simulación de tráfico capaces de describir la evolución del tráfico en la ciudad así como el uso de las zonas de carga y descarga. Gracias a estos modelos se podrá predecir de forma anticipada el efecto de las futuras políticas locales de regulación del tráfico, y en concreto aquellas relacionadas con el reparto de última milla en el centro de la ciudad [3] [4]. El desarrollo de estos modelos formó parte de las actividades realizadas dentro del piloto "Movilidad Urbana Integrada y Mercancías en Valladolid" del proyecto europeo *TransformingTransport* (TT)[3].

* Este trabajo ha sido apoyado por el Programa de Investigación e Innovación Horizon 2020 de la Unión Europea bajo el acuerdo de subvención no. 731932.

[3] https://transformingtransport.eu/

El presente artículo expone, a modo de ejemplo, como se ha llevado a cabo el desarrollo de un modelo de micro-simulación de tráfico para el centro de la ciudad de Valladolid, así como algunos de los resultados más interesantes obtenidos con la simulación de escenarios.

El resto del artículo se organiza como sigue: la sección 2 presenta los objetivos generales del proyecto europeo TT y las acciones llevadas a cabo dentro del piloto de Valladolid. La sección 3 muestra la metodología seguida para el desarrollo de los modelos de simulación de tráfico, mientras que la sección 4 presenta los principales resultados obtenidos en las simulaciones. Finalmente la sección 5 presenta las conclusiones obtenidas.

2. *TransformingTransport: Integrated Urban Mobility and Freight Pilot* en Valladolid

El principal objetivo del proyecto TT fue demostrar, de manera realista, medible y replicable, los efectos transformadores que el Análisis de Datos puede tener sobre el mercado de la movilidad y la logística, aumentando significativamente la eficiencia operativa, ofreciendo mejores experiencias al cliente y fomentando nuevos modelos de negocio. El proyecto puso en marcha 13 proyectos piloto en 7 dominios diferentes de especial relevancia para el sector de la movilidad y la logística en Europa: autopistas; vehículos conectados; infraestructuras ferroviaria; puertos; aeropuertos; movilidad urbana; y logística de comercio electrónico [5].

Dentro del dominio de la movilidad urbana, una de sus pruebas piloto fue desarrollada en Valladolid, una ciudad del norte de España con una población aproximada de 300.000 habitantes. Este piloto de Movilidad Urbana Integrada de Mercancías fue liderado por CARTIF, y desarrollado junto con el Ayuntamiento de Valladolid, Grupo Lince, PTV Group y TomTom LTG.

Actualmente el Ayuntamiento dispone de una normativa que regula las actividades de carga y descarga en el centro de la ciudad, con plazas de aparcamiento pre-reservadas para realizar dichas actividades, y un limite de tiempo máximo de estacionamiento de 30 minutos [1]. Teniendo en cuenta dicha normativa, dentro del piloto de Valladolid se plantearon, entre otros, los siguientes objetivos:

O1 Mejorar la gestión de las áreas de carga y descarga, ayudando a realizar un proceso de toma de decisiones basado en criterios objetivos y respaldado por el análisis de datos.

O2 Mejorar la calidad del servicio de las empresas de carga y descarga.

A su vez, para poder alcanzar dichos objetivos, se definieron las siguientes acciones principales a llevar a cabo:

- Generar modelos de simulación de tráfico (para áreas particulares del centro de la ciudad) que incluyeran información real de los vehículos que circulan por la ciudad y comportamiento de empresas logísticas.
- Analizar diferentes escenarios para predecir el impacto de las futuras políticas locales de regulación del tráfico y reparto de última milla en el centro de la ciudad.

3. Modelo de micro-simulación de tráfico

El principal objetivo de cualquier modelo de simulación de tráfico es imitar, de la forma mas precisa posible, el comportamiento real del tráfico y su entorno. En el caso concreto de la ciudad de Valladolid, el objetivo era desarrollar un modelo de micro-simulación de tráfico que representará, no solo las condiciones reales del tráfico en el centro de la ciudad, sino también el uso de las plazas de carga y descarga. El modelo consta de:

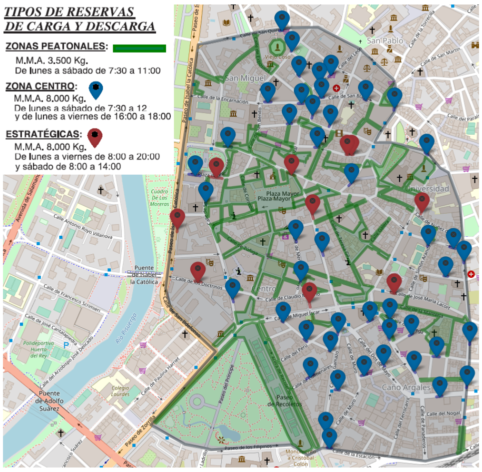
1. Una parte *estática* de diseño, que tiene en cuenta tanto la localización de los aforadores (sensores que miden, en periodos de 15 minutos, el número de vehículos que circulan por las calles) como de las plazas de carga y descarga. En la Fig. 1a puede verse la localización de las zonas reservadas en el centro urbano para realizar actividades de carga y descarga. Según su horario de funcionamiento, las plazas son clasificadas en tres categorías: centro, peatonales y estratégicas [4]. La Fig. 1b muestra la conformación final de las once zonas definidas en este caso, así como el número total de plazas disponibles en cada una de ellas.
2. Una parte *dinámica*, que hace referencia tanto al movimiento de los vehículos dentro del modelo como al uso de las zonas de aparcamiento establecidas. Para desarrollar el modelo se dispone de información real fiable, tanto en lo referente al número total de vehículos que circulan por las calles de la ciudad como al comportamiento (donde paran y durante cuanto tiempo) de las empresas de reparto de última milla. A partir de esta información, mediante cálculos estadísticos, se obtiene la frecuencia con la que se producen las paradas de carga y descarga en cada una de las zonas y el tiempo medio de estancia clasificado por el tipo de plaza de carga y descarga.

En nuestro caso concreto el modelo de micro-simulación de tráfico ha sido desarrollado utilizando la herramienta de simulación Witness [5], un software de simulación interactivo y visual de eventos discretos. Este software está destinado habitualmente para la simulación de procesos logísticos y de fabricación y que se ha utilizado de forma novedosa y experimental en este caso. La Fig. 1c muestra una imagen del modelo de simulación de tráfico desarrollado para la zona centro de la ciudad de Valladolid.

El modelo proporciona ficheros con el número de paradas de carga y descarga producidas en cada una de las once zonas y clasificadas según su horario. A partir de esta información se generan gráficas con la tasa de ocupación media de dichos aparcamientos. A modo de ejemplo, en la Fig. 1d se puede ver la tasa de ocupación de la zona uno en el aparcamiento de carga y descarga de tipo centro.

[4] https://www.valladolid.gob.es/es/perfil-contratante/expedientes-contratacion/contrato-gestion-servicio-publico-modalidad-concesion-estac.ficheros/311204-12.-Plano_Desplegable%20Disco%20Control.pdf

[5] https://www.lanner.com/en-us/technology/witness-simulation-software.html

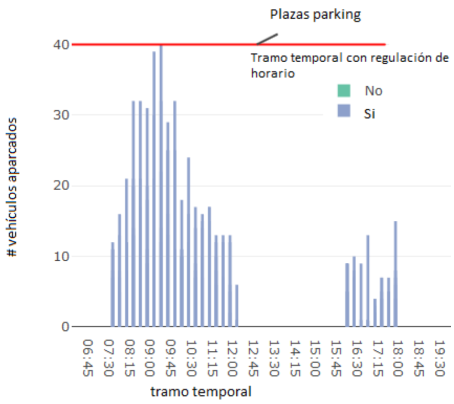


(a) Zonas de carga y descarga

ZONA	Nº de plazas Centro	Peatonal	Estratégica
1	40	39	4
2	6	0	6
3	5	102	2
4	2	0	9
5	2	34	4
6	6	14	0
7	1	0	2
8	6	0	0
9	19	28	1
10	11	0	0
11	9	20	0

(b) División del centro urbano en zonas

(c) Modelo de micro-simulación de trafico



(d) Tasa media de ocupación (Zona 1)

Figura 1: Valladolid: centro urbano

4. Simulación de escenarios

Una vez que el modelo de simulación está disponible, este puede ser utilizado tanto para analizar situaciones concretas actuales como para conocer los efectos futuros de posibles cambios a realizar.

En nuestro caso concreto, el modelo de tráfico desarrollado permitió analizar el nivel de servicio actual de las zonas de carga y descarga, así como predecir el efecto que tendría en el reparto de mercancías la puesta en práctica de modificaciones en la regulación actual. Se muestran a continuación los principales resultados obtenidos en alguno de los casos de estudio planteados.

4.1. Escenario 1: Análisis del número óptimo de plazas en cada una de las zonas establecidas como de tipo centro y/o estratégicas

En este primer caso, el objetivo de la simulación era conocer el número óptimo de plazas de tipo centro y/o estratégicas (plazas peatonales no incluidas) en cada uno de las zonas, minimizando en todos los casos el número de coches que desean aparcar en carga y descarga y que no pueden hacerlo por falta de plazas.

Se realizaron varias simulaciones que proporcionaron estadísticas con el número de plazas de cada tipo utilizadas en cada una de las zonas establecidas, obteniendo así el número de plazas óptimo que se muestra en la Tabla 1. Tal y como puede observarse, el número de plazas actual es inferior en la mayoría de las zonas en relación al número de plazas óptimo según el resultado de la simulación.

Plazas		**Zona**										
Tipo	*N^o*	1	2	3	4	5	6	7	8	9	10	11
Centro	Actual	40	6	5	4	2	6	1	6	19	11	9
	Óptimo	39	13	3	18	1	29	2	43	19	72	16
Estratégicas	Actual	4	3	2	9	4	0	2	0	1	0	0
	Óptimo	19	24	1	43	2	-	13	-	1	-	-

Tabla 1: Plazas de Carga y Descarga

4.2. Escenario 2: Análisis sobre el tiempo óptimo de estancia en carga y descarga en cada una de las zonas establecidas como de tipo peatonal

A continuación se realizó un análisis del tiempo óptimo de estancia en las plazas de tipo peatonal, que según la normativa vigente es de como máximo 30 minutos. Para ello, igual que en el caso anterior, se persiguió el objetivo de minimizar el número de vehículos que, queriendo aparcar, no pueden hacerlo por falta de plazas.

En este caso se llegó a la conclusión de que, con el límite actual, solo un 1,4 % de los coches que querían estacionar en carga y descarga no podían hacerlo. Dicho porcentaje de eventos de no aparcamiento se encuentra dentro de unos limites aceptables para los gestores de tráfico, por lo que la normativa actual se considera ajustada a la realidad.

4.3. Escenario 3: Análisis de un nuevo horario de carga y descarga en zonas de tipo peatonal

Por último se decidió analizar como afectaría un cambio de horario en las zonas de tipo peatonal, y cual sería el tiempo de estancia óptimo es ese caso. Se analizaron entonces las consecuencias de reducir el horario de estacionamiento de dichas zonas en una hora, pasando a ser el nuevo tramo horario permitido de 7:30 a 10:00 (en lugar de hasta las 11:00). En este caso, al igual que en los anteriores, el objetivo era minimizar el número de vehículos que no pueden aparcar.

El resultado de las simulaciones mostró que se producían un número notable de eventos de "no parking" por lo que se disminuyó también el tiempo de estancia a 20 minutos mejorando así el resultado.

5. Conclusiones

El principal objetivo del piloto de Valladolid realizado como parte del proyecto TT fue guiar a las autoridades de la ciudad, y en concreto a los gestores de tráfico, en su proceso de toma de decisiones. Para ello, teniendo en cuenta toda la información de tráfico disponible, así como el conocimiento experto, se desarrolló un modelo de micro-simulación de tráfico en el centro de la ciudad, a partir del cual se simularon distintos escenarios que han permitido conocer de antemano el impacto de futuras nuevas normativas relacionadas con las actividades de reparto de mercancías en la zona centro.

El presente artículo ha presentado, de forma resumida, como se ha llevado a cabo la implementación de un modelo de micro-simulación de tráfico en la ciudad de Valladolid, así como algunas de las simulaciones realizadas y los resultados obtenidos.

Referencias

1. Ayuntamiento de Valladolid: Reglamento municipal de tráfico, aparcamiento y seguridad vial. BOP Valladolid de 23/02/2006, https://www.valladolid.es/es/ayuntamiento/normativa/trafico-aparcamiento-circulacion-seguridad-vial-reglamento.ficheros/3261-ReglamentoTraficoAparcamientoSeguridadVial.pdf
2. Dirección General de Movilidad y Transportes: Movilidad Urbana Europea. Contexto de la Política. Tech. rep., Comisión Europea (2017). https://doi.org/10.2832/015218, https://op.europa.eu/en/publication-detail/-/publication/8262a9e0-da37-11e7-a506-01aa75ed71a1/language-es/format-PDF
3. Innolid: Tecnología big data para gestionar el reparto diario de mercancías. Innova +, pag 8. El Norte de Castilla. (Oct 2018)
4. TT project: Big Data to Streamline Urban Mobility. Issue 3 (Sep 2017), https://transformingtransport.eu/sites/default/files/2017-07/TT_NEWS_003_WEB.pdf
5. TT project: TransformingTransport Project Highlights (2019), http://transformingtransport.eu/TT_Project%20Highlights.pdf

Desarrollo de sensores medioambientales portátiles

Raúl Gómez Ramos[1[0000-0003-2998-5782]] y Ana Escribano Yáñez[1]

[1] CARTIF Centro Tecnológico, Parque Tecnológico de Boecillo 205, 47151 Boecillo, España

{raugom,anaesc}@cartif.es

Resumen.
Con el fin de medir la calidad del aire, se ha desarrollado una red IoT de sensores medioambientales portátiles para medir la contaminación. Este desarrollo está dentro del proyecto URBAN AIR, el cual propone alternativas innovadoras de movilidad sostenible para reducir el número de contaminantes de las zonas urbanas, concretamente de las ciudades de Valladolid (España) y Beira (Portugal). Este proyecto se encuentra dentro del programa Europeo "Interreg". Los sensores se transportan mediante bicicletas a lo largo de las ciudades para elaborar mapas diarios de contaminación. Los sensores de contaminación miden: temperatura, NO2, ozono y partículas (PM2,5 y PM10). Los datos recogidos por los sensores se representan en una plataforma de visualización para facilitar su interpretación. Los sensores cuentan con diferentes tipos de conectividad con el fin de garantizar el flujo de información. Todo el sistema está vinculado a una base de datos y a un servidor externo, los cuales recogen tanto los datos medidos por los sensores como sus parámetros de configuración.

Palabras clave: Sensores, contaminación, IoT.

1 Introducción

El aumento del uso del automóvil en las ciudades ha repercutido en un incremento de la concentración de contaminantes en el medio urbano. Esto provoca una caída en la calidad de vida de los habitantes de las zonas urbanas [1].

El proyecto URBAN AIR, por lo tanto, intenta reducir el uso de vehículos de combustión en las zonas urbanas sustituyéndolos por vehículos alternativos sin emisiones, las bicicletas. El objetivo es mejorar la calidad del aire y, para ello, se van a analizar dos ciudades en concreto: Valladolid (España) y Beira (Portugal).

Para medir la calidad del aire, se ha desarrollado una red de sensores de contaminación portátiles que se transportan mediante bicicletas en las dos ciudades mencionadas anteriormente.

El presente artículo expone el desarrollo de los sensores de contaminación, así como su verificación en laboratorio para aportar rigurosidad a las medidas.

2 Diseño de la envolvente

Para desarrollar la envolvente que recoge los componentes del sensor, es necesario en primer lugar tener en cuenta una serie de requisitos (tanto electrónicos como mecánicos) y, una vez hecho esto, tomar las consideraciones y las medidas correspondientes.

2.1 Requisitos para el diseño

El montaje y la manipulación del interior del sensor tiene que ser lo más rápido y fácil posible, intentando evitar el uso de adhesivos para facilitar la manipulación. En cuanto a las uniones, tienen que ser capaces de soportar vibraciones debidas al movimiento.

La parte electrónica debe estar separada de los canales de flujo de aire con el fin de evitar suciedad y la posible infiltración de agua o humedad. Por otro lado, es necesario incluir varios LED que informen a simple vista el estado del sensor. En cuanto a la batería, debe permanecer separada del resto de componentes para facilitar su desmontaje. Su puerto de carga tiene que permanecer visible para el usuario y además tiene que contar con un sistema para evitar infiltraciones que puedan alterar su funcionamiento.

El aire que circula por el sensor de NO2 y O3 tiene que seguir un flujo laminar para conseguir medidas con menos oscilaciones. Si el aire entra con flujo turbulento, la desviación de los datos se incrementa considerablemente.

2.2 Solución y medidas adoptadas

Teniendo en cuenta todos los requisitos que se le pedían a la envolvente, fue necesario realizar un diseño 3D para una posterior impresión en una máquina de fabricación aditiva, ya que las envolventes comerciales no ofrecen tanta flexibilidad a la hora de distribuir los sensores por su interior. Para realizar el diseño 3D de la envolvente, se ha utilizado el programa Autodesk Inventor 2018, en el cual se han realizado los modelos de todos los componentes del dispositivo, tanto de las piezas a fabricar como de los componentes comerciales, con el fin de ir viendo a medida que se va diseñando que todo encaja correctamente.

La fabricación se ha realizado en una impresora 3D cuya marca es: "*Stratasys Fortus 250 mc*" y se ha utilizado como material ABS de color hueso. Una vez termina la extrusión de material, las piezas se han introducido en una lavadora para eliminar imperfecciones y refinar el acabado.

3 Diseño electrónico

El sensor de contaminación cuenta con una serie de componentes que son los encargados de recoger y procesar los datos medioambientales. Además, fue necesario incluir una placa de transformación y adaptación de las señales obtenidas para que sean recogidas por el controlador. Los componentes que incluye el sensor de contaminación son los siguientes:

- *Raspberry Pi Zero WH:* es el controlador que gestiona los datos de contaminación medioambiental [2]. Su reducido tamaño es una ventaja a la hora de minimizar las dimensiones totales del sensor. Se inserta en la parte superior de la placa de transformación. Se encarga además de transferir los datos vía Wi-Fi y vía Bluetooth.
- *Sensores de NO2 y O3 (con PT1000):* son los encargados de transformar la concentración ambiente de NO2 [3] y O3 [4] en una señal eléctrica que recoge una placa de eliminación de ruido y mejora de rendimiento [5]. Además, incluye una PT1000 que mide la temperatura del aire que llega al sensor de contaminación. Estos sensores necesitan una posterior calibración en laboratorio para mejorar la precisión del dispositivo.
- *Medidor de partículas PM2,5 y PM10:* es un sensor con láser que, utilizando la dispersión de la luz, es capaz de detectar y contar las partículas de materia en suspensión (tanto las de tipo PM2,5 como las de PM10) [6]. Además, cuenta con su propio ventilador para facilitar el flujo de aire a través del medidor.
- *GPS:* el módulo GPS que lleva incorporado el sensor de contaminación es un modelo "GPS NEO-6M" con una pequeña antena conectada [7]. Este módulo GPS proporciona tanto la posición geolocalizada como la velocidad a la que se está moviendo.
- *Reloj RTC:* es necesario incluir un reloj de tiempo real (RTC) para guardar la fecha y la hora cuando no exista conexión vía Internet (ya que la Raspberry Pi Zero WH no cuenta con esta función) [8]. De esta manera, se tiene la certeza de tener los datos con la fecha y hora correcta.
- *Ventilador:* es el encargado de facilitar el paso del flujo de aire por el sensor de NO2 y O3. Se trata de un ventilador de pequeño tamaño con un consumo reducido que se sitúa en la entrada de aire al sensor de contaminación [9].
- *LED:* se trata de un LED de 4 luces amarillas que indican el estado del sensor de contaminación [10]. Indican: funcionamiento, conexión bluetooth, conexión GPS y conexión WiFi.
- *Placa de transformación:* es una placa electrónica que hace de intermediario entre los sensores y el controlador. Su diseño se ha realizado a dos caras, e incluye tanto los componentes electrónicos necesarios para adaptar las señales de los sensores como los conectores para conectarlos.
- *Batería:* cuenta con una capacidad de carga de 10.000 (Amh), permitiendo que el sensor de contaminación sea portátil [11]. Se conecta con la electrónica mediante un cable USB y dos pines de la placa del controlador. Al tratarse de una powerbank, viene con el sistema de gestión de batería y de carga propio. Cuenta con un botón en la parte posterior que enciende el sistema e indica el porcentaje de carga mediante LED's indicadores.

4 Prototipo resultante

El sensor, debido a que va a estar expuesto a la intemperie, es necesario que cuente con el mayor grado de protección posible para no dañar la electrónica. Por esta razón, una vez ha finalizado el proceso de fabricación, hay que realizar un proceso de lijado y pintado de las superficies exteriores. Por último, cuando todas las piezas están encajadas mediante las guías y carriles que presenta el diseño, se fijan con elementos de unión normalizados de tipo roscado para aportar mayor fiabilidad (ver Fig.1).

Fig. 1. Aspecto final del sensor de contaminación medioambiental (izquierda) y desmontado (derecha).

5 Verificaciones de laboratorio

El sensor de contaminación se ha sometido a un proceso de calibrado en laboratorio para aumentar su precisión y su grado de fiabilidad. Con los resultados obtenidos, se modifican los parámetros de configuración para interpretar la señal eléctrica que proviene de los sensores internos.

5.1 Descripción del proceso de calibrado

Para calibrar los sensores, se han introducido en una cámara sellada donde se modifican las condiciones del interior de forma lenta y controlada, utilizando equipos de medida calibrados y verificados.

El proceso de calibrado se ha llevado a cabo para corregir dos medidas medioambientales: NO2 y O3. Esto se debe a que el sensor encargado de medir estos parámetros necesita que se lleve a cabo una calibración para mejorar sus prestaciones estándar.

- *Proceso de calibrado de NO2:* se introduce en la cámara climática un determinado flujo de NO2 (de forma lenta) procedente de una bombona comercial de características controladas. Mientras se introduce el NO2, el sensor de contaminación y el sensor verificado miden al mismo tiempo (ver gráfica Fig. 2). Es necesario asegurar lo máximo posible un llenado regular de la cámara, para ello es conveniente utilizar ventiladores en su interior. Una vez que la concentración de la cámara llega a un punto elevado, se ajusta la válvula de salida para disminuir esta concentración. Por último, se comparan las curvas y se ajusta la del sensor de contaminación para acercarlas lo máximo posible.

- *Proceso de calibrado de 03:* este proceso es el mismo que para el NO2, pero cambiando el agente que se introduce en la cámara climática. En este caso, se utiliza un generador que ioniza el aire que le llega por la válvula de entrada y, con el paso del tiempo, comienza a generar O3. Es necesario tener en cuenta que el sensor de O3 mide conjuntamente el valor del O3 y del NO2 del ambiente. Por lo tanto, a los resultados hay que eliminarles el valor de NO2 que registre el equipo.

Ambos procesos de calibrado son sensibles a los cambios de temperatura. Por esta razón, el dispositivo cuenta con un sensor de temperatura interno (PT1000) que mide la temperatura del aire de entrada.

5.2 Resultados obtenidos de los ensayos

Observando los resultados obtenidos en los ensayos de calibración (ver Fig.2) se ha llegado a las siguientes conclusiones:

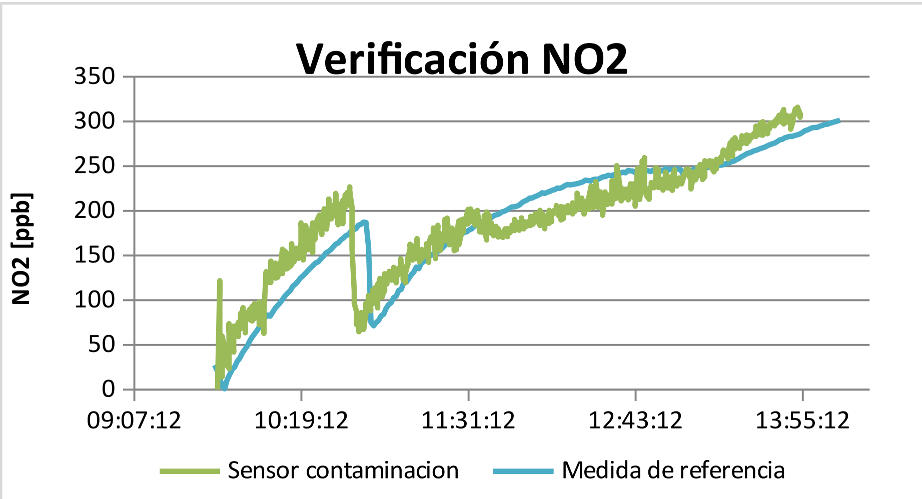


Fig. 2. Curvas de verificación y calibración del NO2 obtenidas en laboratorio.

El ensayo que se ha realizado tiene una duración de 5 horas, y se ha tenido en cuenta sólo el tramo de subida de concentración de NO2. La primera media hora de recogida de datos del sensor se descarta debido a que necesita un tiempo de calentamiento.

El sensor de contaminación sigue bien el comportamiento del equipo verificado. Además, es sensiblemente más rápido ante los cambios de las condiciones de la cámara climática (alrededor de 5 minutos más rápido).

Para realizar un calibrado correcto, es necesario realizar el mismo ensayo varias veces en las mismas circunstancias (en la misma cámara y a la misma temperatura).

6 Conclusiones

El uso de estos sensores presenta varias ventajas con respecto a sus competidores.

Una de las ventajas que presenta este tipo de sensores es su característica de portabilidad. Al distribuir una red de sensores móviles en una ciudad, es posible generar mapas de contaminación por las zonas por las que pasen.

En las pruebas de laboratorio se ha comprobado que la precisión que aportan los sensores es muy elevada con un tiempo de reacción bastante reducido (del orden de 5 minutos respecto a sensores de laboratorio de gran precisión).

Se trata de un sistema robusto que se puede utilizar en diversas aplicaciones industriales de medida, ya que se trata de un sistema calibrado.

Como líneas futuras de trabajo, se propone seguir avanzando con las funcionalidades de la plataforma IoT, así como minimizar el consumo de los sensores.

Agradecimientos

Este trabajo ha sido parcialmente financiado por el Fondo Europeo de Desarrollo Regional (FEDER) a través del Programa Interreg España-Portugal V-A (POCTEP) dentro del proyecto 0677_DISRUPTIVE_2_E (Dinamización de los Digital Innovation Hubs dentro de la región PocTep para el impulso de las TIC disruptivas y de última generación a través de la cooperación en la región transfronteriza).

Referencias

1. Mishra A., Singh A. K., Singh K. A., Pandey P., Yadav S., Khan A.H. and Barman S.C.: "Urban air pollution and their effects on rain water characteristics in Lucknow City, India", Journal of Environmental Research and Development, Vol 6 No.4, April-June 2012.
2. KUBII, "Raspberry Pi Zero WH", 2018.
3. Alphasense, "NO2-A43F Nitrogen Dioxide Sensor 4-Electrode", 2018.
4. Alphasense, "OX-A431 Oxidising Gas Sensor Ozone + Nitrogen Dioxide 4-Electrode", 2018.
5. Alphasense,"Analogue Front End (AFE) Alphasense A4 Air Quality Gas Sensors", 2018.
6. Honeywell, HPMA115S0-XXX,"Sensores de materia particulada Serie HPM PM2.5,tamaño estándar, Salida UART", 2018.
7. Sodial(R), GPS NEO-6M, "NEO-6M GY-GPS6MV2 GPS Modulo - SODIAL(R) Ublox NEO - 6M GPS Modulo Controlador de Vuelo de Aeronaves IMU SE04001 G21", 2018.
8. Keenso, RTC DS3231, "Módulo de memoria de reloj RTC de alta precisión, Módulo de reloj en tiempo real para Raspberry Pi 3.3V-5V", 2018.
9. Nidec Copal Electronics, F16EA-03LLC, "Brushless DC Fans", 2018.
10. BIVAR, Indicador LED para PCB, "Rectangular 2x3 mm 90º quad-level LED assembly", 2018.
11. ENJOYBOT, Power Bank - Quick Charge 3.0 PB100Q3, "PB100Q3 User guide", 2018.

HUB4AGRI – Digital Innovation Hub for Portuguese Agri-food Sector

José Manuel Medina[1], Pedro Miranda[1]

ISQ - Instituto de Soldadura e Qualidade, Oeiras – Taguspark, Portugal, +351.227471950,
email: {JMMedina, pfmiranda}@isq.pt

Abstract. Digital transformation could leverage the competitiveness of European Union companies while achieving the ambitious sustainability goals. To achieve this EC is launching a new framework called Digital Europe Programme (DEP) that aims to trigger investments by the EU, Member States and industry in digital solutions. DEP will develop a network of Digital Innovation HUBs which are one stop shop solution to support the digital transformation. To increase and accelerate the deployment of digital solution in the agri-food sector, the Portuguese Agriculture Digital Innovation HUB – HUB4AGRI was created to help the sector to become more sustainable and more competitive.

Keywords: Digital Innovation HUBs, Digital Europe Programme, Agri-food digital transformation.

1 Europe Digital Programme & European Digital HUBs

Europe is facing a lot of pressure to remain competitive at international level and one possible solution is to increase the digitalization level of EU companies specially SMEs. By adopting digital transformation solutions, the companies could benefit from the innovation and efficiency in their production process which could led to a reduction in the production costs. This also can contribute to the long-term sustainability of the three critical pillars: economic, social and environmental.

Currently the level of digitalization in EU is uneven and depends heavily on the sector, country and size of the company. There are large disparities between large companies and SME. The large majority of SME and midcaps are seriously lagging behind in embracing digital innovations. European industry risks falling behind when it comes to building the very foundations of its digital future [2].

To address this problem the European Commission proposes the launch of a new framework called Digital Europe Programme (DEP) expected to be launched on 2021 (Fig. 1). DEP is focused on building the strategic digital capacities of the EU and on facilitating the wide deployment of digital technologies, to be used by Europe's citizens and businesses. With a planned overall budget of €9.2 billion, it will shape and support the digital transformation of Europe's society and economy.

The programme will boost investments in supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society. Its goal is to improve Europe's competitiveness in the

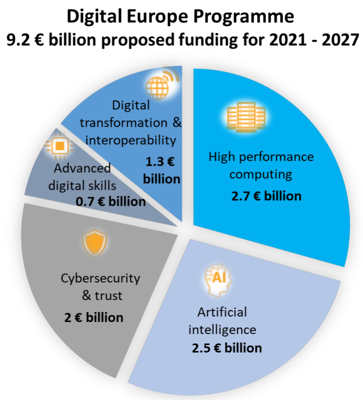


Fig. 1: Digital Europe Programme pillars and budget (adapted from [6]).

global digital economy and increase its technological autonomy. The pillar of digital transformation & interoperability (Fig. 2) has six areas of intervention, being one called *"Build up and strengthen the network of digital innovations hubs (DIHs)"*.

Fig. 2: Use of digital capacities & interoperability in DEP (adapted from [6]).

The commission defines a European Digital Innovation HUB (EDIH) as *"a single organisation or a coordinated group of organisations with complementary expertise, with a not-for-profit objective that support companies – especially SMEs and mid-caps – and/or the public sector in their digital transformation."* [5]. The major services that an EDIH should have are (see Fig. 3): 1) test before invest, 2) skills and training, 3) innovation ecosystem & networking, and 4) support to find investments.

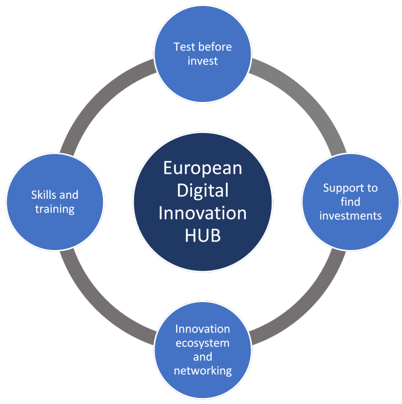


Fig. 3: Major services provided by an DIH (adapted from [5]).

The scope of an EDIH are open to be chosen by each entity, they could be focused in a sector ore more focused in a specific technology. They must have local presence, but they should aim at national, European or even world-wide customers.

2 Characterization of the Agri-food Sector

The agriculture sector is one of the least digitised sectors [3] and currently is facing lots of pressures, namely climate change, lack of water, new plagues and disease, public opinion and others. The urgent need to increase the sustainability of the sector is crucial and the digital transformation may have a critical role to achieve this goal. Currently there are quite a few tech companies working in the agri-food sector [4] and the venture capital funding in agri-food tech in 2018 was 16.9 billion dollars [7].

3 HUB4AGRI – The Digital Innovation Hub

In 2016, Portugal had 258 983 farms, covering 3 641 691 hectares of agricultural land which represents 39,5% of the Portuguese territory and almost 40 000 companies that works in the agri-food business [1]. Having in mind the importance of the agri-food sector in the Portuguese economy and the low level of digitisation, the Portuguese Digital innovation HUB was created to help the agri-food sector to became more sustainable and more competitive by offering solutions to enhance their digital transformation (see Fig. 4).

HUB4AGRI (http://hub4agri.com/) has a partnership agreement signed with 14 entities, as illustrated in Fig. 5, covering agricultural universities, RTOs, innovation consultants, spread across the Portugal territory.

Fig. 4: Vision of the HUB4AGRI (adapted from EIP-Agri infographics).

Fig. 5: HUB4AGRI partners.

The HUB4AGRI strategic objectives (SO) are the following:

- SO1: Support the digital transformation in agri-food value chain.
- SO2: Attract new ICT users in agriculture sector.
- SO3: Increase Competitiveness of Farming Community by improving their productivity and sustainability.
- SO4: Attract new ICT developers to provide digital solutions for farming sector.

– SO5: Support entrepreneurs and SMEs to be more competitive by understanding the real needs of the farmers who enable better product differentiation – market placement orientation.
– SO6: Create a collaborative self-sustainable network between relevant actors (European DIH), with unique competences, which allow digital transformation on agriculture sector (Competences centers, advisers/innovation brokers, start-ups, entrepreneurs, SMEs, public/private investors, regional/national authorities and the farming community) working as a one stop shop solution.
– SO7: Increase experiments that explore new ICT solutions in agriculture by DIH coverage.
– SO8: Support the implementation of Portuguese Digitization Strategy, "Indústria 4.0", related with agri-food sector.

The areas where the specific solutions/services are offered are illustrated in Fig. 6 and include the water, plant, soil, climate, energy efficiency, social & Economy, and Environmental Impact.

Fig. 6: Areas of services provided by the HUB4AGRI.

The technological solutions offered by HUB4AGRI, shown in Fig. 7, are IoT, AI & Modelling, Data & Security, Web, SAAS & Cloud, Sensing, Robotic & Electronic, VR, AR & Interaction Techs, and 3D tools, Photonic & Materials.

The services provided by the HUB4AGRI consortium are:

– Ecosystem building, scouting, brokerage, networking
– Visioning and Strategy Development for Businesses
– Collaborative Research
– Concept validation and prototyping
– Testing and validation
– Digital Maturity Assessment
– Incubator/accelerator support
– Voice of the customer, product consortia

Fig. 7: HUB4AGRI technological solutions portfolio.

– Access to Funding and Investor Readiness Services
– Mentoring
– Education and skills Development

In order to achieve the highlighted specific objectives HUB4AGRI operating model will be supported by a platform, currently in development, that will comprise a marketplace and a job dispatcher specific developed for expert consultancy. It will be divided in: 1) Well characterized services – micro-services (Chemical analysis; Humidity sensor; etc.); 2) Auctions for small to medium size projects (Irrigation project, Greenhouse sensorization, etc.); 3) Specific consultancy in the domains shown in figure 7, by experts from universities and RTOs. Several monetization models are being studied, namely commission per service sold, fee for posting services, fee to be able to apply for auctions and others. Some of the characteristics that differentiates HUB4AGRI services are: 1) the non-profit objective; 2) the know-how of the founding members; 3) the specific consultants form universities and RTO; 4) the payment for services and projects only being released after HUB4AGRI validation. These features could transmit confidence to the agri-food companies to use HUB4AGRI platform, solutions and services.

4 Conclusions

Digital transformation is the key to maintain the European competitiveness while achieving the sustainability goals. But to achieve that, it is necessary to have a strategy between all Members States and funding schemes available. The Digital Innovation HUBs will be the instrument to connect industry to the latest digital solutions and to give access to test these technologies before invest. This mechanism is crucial to the efficient deployment of the technologies. In the agri-food sector the possibility to test in real and large-scale environment, the available digital solutions are a critical aspect for their adoption. HUB4AGRI – The Agriculture Portuguese Digital Innovation HUB offers this opportunity and many services like training and access to funding to increase the digital transformation of the agri-food sector.

References

1. Agriculture Statistics. Tech. rep., National Statistics Institute (2016)
2. Digitising European Industry Reaping the full benefits of a Digital Single Market (2016), https://ec.europa.eu/digital-single-market/en/news/communication-digitising-european-industry-reaping-full-benefits-digital-single-market
3. Global Industry Digitisation Index. Tech. rep., McKinsey Global Institute (2016)
4. Ag Tech Market Map: 100+ Startups Powering The Future Of Farming And Agribusiness (2017), https://www.cbinsights.com/research/agriculture-tech-market-map-company-list/
5. Digital Europe Draft Orientations for the preparation of the work programme(s) 2021-2022 (2019), http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=61102
6. Digital Europe Programme Factsheet European Commission (2019), https://ec.europa.eu/digital-single-market/en/news/digital-europe-programme-proposed-eu92-billion-funding-2021-2027
7. Food & AgTech Investor Sentiment Report. Tech. rep., Idea2Scale and Ag Funder (2019)

An Edge-IoT Platform aimed at Smart Farming and Agro-industry scenarios

Ricardo S. Alonso[1 [0000−0002−6599−0186]], Inés Sittón-Candanedo[1 [0000−0001−8953−7848]], María E. Pérez-Pons[1 [0000−0002−2194−572X]], Óscar García[1 [0000−0002−8645−055X]], and Javier Prieto[1 [0000−0001−8175−2201]]

BISITE Research Group, University of Salamanca
Edificio Multiusos I+D+i, Calle Espejo 2, 37007 Salamanca, Spain
{ralorin,isittonc,eugenia.perez,oscgar,javierp}@usal.es
http://bisite.usal.es

Abstract. Currently the world market is globalized and highly competitive, broadening the spectrum of needs in all sectors of the agrifood industry. Technologies such as the Internet of Things (IoT), Distributed Ledger Technologies (DLT) and Edge Computing (EC) are crucial to meet these needs, because they allow all parts of the value chain to be digitized and secured, providing detailed information to the consumer about the final product and warranting its safety and quality. In Smart Farming and Agro-Industry environments, IoT and DLT enable resource monitoring and traceability in the value chain. Therefore, producers can optimize processes and guarantee the origin of their products to gain the trust of consumers. This work presents a platform oriented to the application of technologies such as IoT, Edge Computing, Artificial Intelligence and blockchain in Smart Farming scenarios. The platform is designed to monitor in real time the status of dairy cattle and feed grains and ensure traceability and sustainability of the different processes involved in production.

Keywords: Internet of Things · Edge Computing · Distributed Ledger Technologies · Smart Farming · Agro-Industry

1 Introduction

FAO estimates that approximately 750 million people worldwide are engaged in milk production [5]. However, there is a great contrast in the number of people engaged in this activity in developing countries because of limited access to new technologies. With the globalization of markets, it is intended that the differences between countries are increasingly smaller by providing them with technologies that increase their level of competitiveness, so the challenges faced by producers will be similar in any territory. Analyzing the FAO statistics, the milking yield data in the countries of the European Union are still considerably different, for example, while in Ireland the yield is 5,290 kg/head in Spain is 8,702 kg/head.

If production data are analyzed for animals other than cattle, the differences are even higher, with Spain standing out with 15.2% compared to 5.4% in Portugal and almost 0% in Ireland. In the milk production process, one of the most important industries is cheese, which is in continuous growth, in 1983 the milk used in cheese production represented 24% of total milk production, however in 2013 this value grew to 40% [2]. Although the figures support the growth of the dairy industry, there are a number of challenges faced by farmers in both the European Union, which apply to milk producers worldwide: achieve a more efficient and effective use of resources, respect the environment and integrate new technologies for traceability of the value chain, providing the consumer with all necessary product information from its origin to the point of final distribution.

Regardless of the type of farm, water is the most important resource in agriculture, and its use must be optimized and monitored. In 2016, according to Eurostat, the total irrigable area in the European Union-28 was around 15.5 Mha (8.9% of the total), but only 10.2 Mha (5.9% of the total) were irrigated. This is one of the problems faced by world-wide farmers and not only in Europe. Complete irrigation (i.e., applied in irrigated agriculture, as opposed to rain-fed or rain-fed crops) is necessary in different kinds of agriculture production in Southern European countries. Furthermore, in 2016, Italy and Spain were the countries that, in absolute terms, had the largest irrigable areas (4.1 and 3.6 Mha, respectively) [4]. Cyprus, Malta, Italy and Greece have the largest proportion of used agricultural area irrigated in 2016 (between 34.1% and 29.7%). In most of the 69 regions of the European Union, particularly the southern and eastern Member States, farms generated an average standard output worth less than €25,000 in 2016 [1]. Likewise, small and medium-sized farms in both developed and developing countries, such as Africa, would benefit from low-cost technologies for the monitoring and optimization of water and energy resources [19].

In this regard, technology has become much more accessible and low-cost than it has been before and the overall technological progress has favored the emergence of IoT and Cloud paradigms, leading to the emergence of different technology-related concepts such as *Precision Agriculture* and *Smart Farming* [38]. In Smart Farming, the *Internet of Things (IoT)* paradigm is essential in the monitoring of resources by connecting multiple and heterogeneous objects, such as buildings (e.g., barns), machinery and vehicles (e.g., milking machines or agricultural tractors) or even cattle [30]. Moreover, thanks to the *Edge Computing* paradigm [6], it is possible to reduce the costs associated with computing, storage and network resources in the Cloud by deploying services at the edge of the network, which reduce service response times and increase the *Quality of Service (QoS)* and the security of applications [29]. Furthermore, *Distributed Ledger Technologies*, such as *Blockchain*, can be used in smart farming scenarios as a mechanism by means of which final consumers can track the processes that the produce on sale has went through in the value chain of the agri-food industry, guaranteeing the integrity of the information [33].

This work presents a new agro-industrial platform that facilitates the application of Edge Computing, Artificial Intelligence and Blockchain techniques in Smart Farming and Agro-industry environments. The aim of the platform is monitoring, in real time, the state of livestock and forage cereals, at the same time ensuring traceability and sustainability of the various processes involved in the production. The platform is deployed and tested in a real-world scenario, to validate the benefits of integrating IoT with Edge Computing.

The rest of this paper is structured as follows: Section 2 present a review of Edge Computing and IoT, identifying the most important challenges and trends in the application of those paradigms in Smart Farming scenarios. The proposed intelligent Edge-IoT agro-industry platform for monitoring livestock and crops on mixed farms is described in Section 3. A real scenario in a mixed dairy farm is used to implement the platform, which is described in Section 4. Finally, conclusions and future work are included in Section 5.

2 Internet of Things and Edge Computing for Smart Farming and Agro-Industry

The emergence of the term *Internet of the Things (IoT)* and its recognition as a paradigm dates back to 2011-2012, when renowned companies and institutions such as *Gartner*, *Forbes* or *Wired* started using this term to refer to the emerging technology [8]. Formally speaking, the term *IoT* refers to connecting multiple heterogeneous objects, such as machinery, vehicles or buildings with electronic devices such as sensors and actuators, through different communication protocols, in order to gather and extract data [28]. Since then, the scope of IoT has spread throughout a great variety of environments and disciplines. Thus, the paradigm serves as the basis for the research and development of solutions in smart homes [22], smart cities [13], Industry 4.0 [36], logistics and transport [14], energy efficiency [20,7], health care [17] or agriculture [30].

In this sense, the ingestion of data from heterogeneous sources or the management of different wireless protocols becomes a key element that will require solid and stable solutions [9]. Layered IoT data ingestion solutions permit the ingestion of big data from multiple scenarios, giving rise to Big Data repositories where Data Analytics and Machine Learning techniques can be applied [11] to provide added value to work environments through real-time analysis and response, pattern recognition, forecasting, etc., [34]. According to the definition provided by [6], *Edge Computing* deals with the Big Data generated by IoT devices by processing them at the network *edge*. Thus, the services that are executed in the edge have a fast response time, with a higher *Quality of Service* (QoS) and security, compared with those executed in a centralized Cloud [34].

Thanks to technical and communication advances in technology, as well as ease of access, the number of sensors and devices that can be implemented in agricultural solutions has grown enormously. This growth and accessibility have favored the emergence of IoT and Cloud solutions, giving rise to a phenomenon known as *Smart Farming*. The concepts of *Precision Agriculture (PA)* and *Smart*

Farming may sometimes be confused, it is therefore important to distinguish between them. In [38], PA is said to only consider the variability in the field. On the contrary, Smart Farming provides a more exhaustive analysis, performs precise actions (e.g. decision support information, alerts notifications or task automation), taking into account, location of assets, cattle or humans, and other data enriched by the historical, real-time and forecast information and knowledge [38].

In this sense, irrigation is a main area of interest. Water is a key resource in agriculture so its management, both in quantity and quality, becomes crucial in all agricultural environments. A complex use case had been designed by Cambra et al. [12] to control bicarbonate irrigation for hydroponic precision farming. In this case, the combination of multiple sensors and pumps allows to take smart measurements of the pH, distilled water and the hydroponic facility.

Moreover, understanding the behavior of cattle and herds is important to improving animal welfare, which leads to better management, productivity and product quality. An example of this is the smart nest box management system that tracks the performance and behavior of individual hens designed by [15]. The system makes use of RFID sensors and egg detectors that gather information sent via Wi-Fi and processes it both locally and in the Cloud.

In addition, there are also solutions that help increase the quality of the produce. In this regard, controlling the quality of crops is important. [18] presented a phenotyping system which improves grain quality. The system receives data of multispectral images produced by different applications and then processes, reproduces and analyzes them.

Another solution associated with produce quality [24] proposes an electronic nose that detects apple mold. The system gathers information by means of multiple sensors and applies Artificial Intelligence techniques, such as BPNN and RBFNN (*Back Propagation* and *Radial Basis Function Neural Networks*, respectively), LDA (*Linear Discriminant Analysis*) and SVM (*Support Vector Machines*).

Jones et al. [25] analyzed the status of the agricultural and livestock systems. This analysis generates a framework with a minimum set of components required for the development of Smart Farming systems. Data ingestion, aggregation, analysis and management are the cornerstone of these type of system. The analysis is broad and covers multiple issues, however, it is not implemented nor does it describe any use case.

Another IoT platform is *SmartFarmNet*, developed in Australia by a multidisciplinary team, it is designed to provide Smart Farming solutions and applications [23]. The platform follows the *"bring-your-own IoT sensor"* principle, allowing for the integration of virtual and commercial IoT devices, different analytics tools for big data processing, including the customization of the analysis and their visualization. The system is mainly focused on the integration of multiple technologies and data analysis without a precise Edge Computing approach due to the limited functionalities of the IoT devices and the gateways.

Finally, another development worth mentioning is the IoT-enabled platform for agricultural environments defined by Popovic et al. [31]. The platform is formed in this case of five different layers: *Sensors* (create), *Network* (communicate), *Data Integration* (aggregate), *Augmented Intelligence* (analyze) and *Augmented Behavior* (act). The approach covers a wide scope of solutions and has been tested in multiple environments such a greenhouses or a marine mussel farms. However, it does not integrate open-source programming languages or support important IoT protocols, such as MQTT that enable an easy deployment of Edge Computing solutions.

3 SmartDairyTracer: Smart Monitoring, Sustainability and Traceability of Dairy Products by means of IoT, AI and Blockchain technologies

Nowadays, European dairy industry needs to address common challenges in all countries: to improve their efficiency in the use of resources, to be more environmentally friendly, to improve the digitization in all segments of the value chain and to improve their transparency and security providing detailed information to the consumer, ensuring the safety and quality of the final product [3].

To face these needs, researchers from the University of Salamanca (Spain) and the Digital Innovation Hub (Salamanca, Spain) are building a consortium gathering different profiles (livestock managers, farmers, dairy and cheese industries, IoT technology providers, ICT experts, energy engineers and scientific community researchers) with an extensive background in different activities/technologies (irrigation control, energy management/optimization, cattle welfare monitoring, pests and plague detection in crops) to involve the whole dairy value chain in the roll out of several use cases that, making use of currently available innovative technologies/solutions (IoT, Distributed Ledger Technologies and AI, among others), will provide an integral solution in the form of a smart platform based on FIWARE [32] for the improvement of the whole dairy industry, "from the grass to the glass": optimization of processes, reduction of water and energy consumption, reduction of pesticides in associated crops, promotion of a sustainable and environmental friendly production, monitoring of animal welfare and deployment of a reliable agri-food traceability system.

In this sense, the Global Edge Computing Architecture [35], designed as an Industry 4.0-oriented Edge Computing Reference Architecture, has been used to implement a new agro-industry platform. The GECA-based SmartDairyTracer platform, whose full architecture is illustrated in Figure 1, is focused on three main cornerstones: monitoring, through IoT technologies; sustainability, thanks to the application of AI algorithms; and traceability, achieved by means of innovative Distributed Ledger Technologies.

In the final version, SmartDairyTracer will include the following sources and IoT standards:

– *IoT in barns (ambient sensors inside barns in livestock farms)*: temperature and relative humidity -– to estimate stress -– and hazardous gas sensors

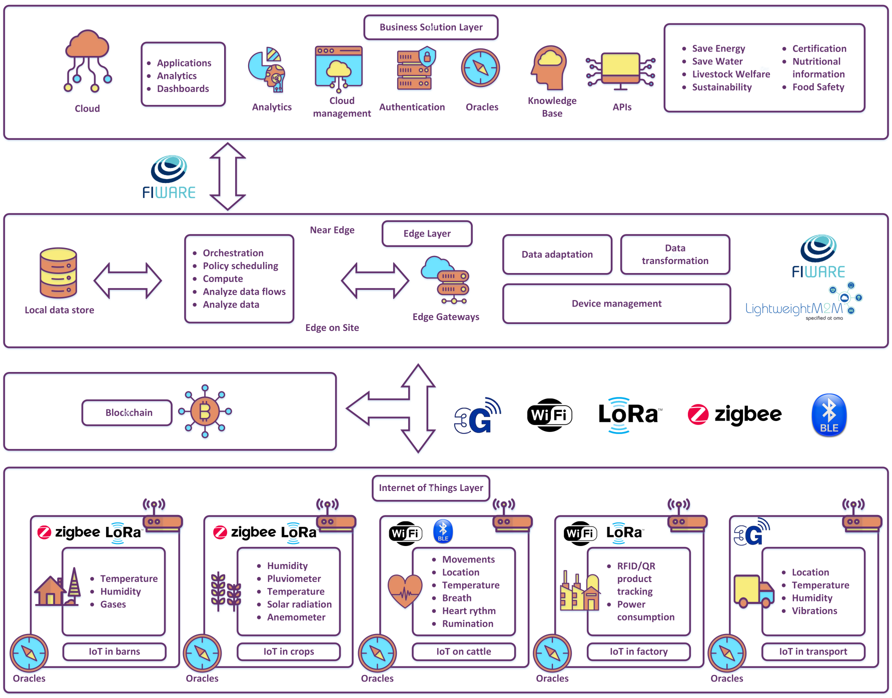


Fig. 1. Schema of the complete SmartDairyTracer platform based on the novel Edge Computing reference architecture (GECA).

(methane, hydrogen sulphide, ammonia and formaldehyde), using ZigBee and LoRa technologies; power consumption and solar production auditors, using 3G and Wi-Fi technologies.

– *IoT in crops (agro-meteo stations in crops)*: used to feed livestock, including rainfall, temperature, relative humidity, anemometer, soil humidity and temperature, and solar radiation, using 3G and LoRa technologies.
– *IoT on cattle (cattle bio-metric sensors):* including real-time location [16], using ZigBee and BLE (Bluetooth Low Energy); as well as livestock health conditions, including body temperature, breath, heart rhythm and rumination, using Wi-Fi technologies.
– *IoT in factory:* RFID tags and QR codes will be incorporated for the traceability of the different packaged products (milk, cheese, butter, etc.), as well as smart meters for monitoring energy consumption in the factories.
– *IoT in transport:* finally, the time and conditions of transport (temperature, humidity, vibrations, etc.) to the consumer will be controlled in order to guarantee the quality of the final product. If the agreed conditions are not met, the distributor will be penalized by means of *smart contracts.*

The values of the monitored parameters will be gathered through the above-mentioned wireless IoT technologies, managed by means of LightweightM2M and transferred using FIWARE [32] to IoT Service and Mediation layers, respectively.

AI techniques are used to process this information (ad-hoc ontologies for the implementation of Smart Data solutions in the dairy industry, Deep Learning to infer knowledge from the data and Decision Support Systems which facilitates the inclusion of extracted conclusions in the decision-making process) and to detect stress and illness in livestock (increasing production), prevent fungi and pests in crops (reduce the use of pesticides), optimize energy consumption (shifting some processes when it is possible to produce renewable energy) and reduce the consumption of resources (smart irrigation or smart waste management and circular economy), resulting in a more sustainable production.

Finally, to build a reliable system, innovative Distributed Ledger Technologies (DLT) have been used. They provide a tamper-proof framework which ensures the traceability of all the information in systems. This helps guarantee the safety and quality of the product by certifying its origin and giving detailed information of all the processes that the produce has undergone, from the farm to the table. Thus, DLT are an effective means of preventing food fraud and health risks.

4 Implementing the Intelligent Edge-IoT Platform for Monitoring Livestock and Crops in a Mixed Dairy Farm Scenario

The first version of the SmartDairyTracer platform has been deplyed in a real scenario in a mixed dairy farm located in Castrillo de la Guareña, in the province of Zamora (Castile and León, Spain). The farm has two barns of 1850 and 1650 m^2, respectively, which hold 180 dairy cows. This dairy farm also has 302 ha of associated crops, including corn and alfalfa used as fodder for the livestock. The main objective is to monitor all the resources used in milk production, the parameters related to the livestock, their environment and the associated crops (alfalfa, corn, fodder) used to feed the livestock. Monitoring has a twofold purpose; it allows to optimize the resources used in milk production, through Business Intelligence, Data Analytics and Machine Learning techniques. Moreover, monitoring makes it possible to track the produce in the milk value chain, from its origin to its retail location; this includes the daily conditions and the feed grain of the livestock, milking, the processes that the produce undergoes at the treatment and packaging plant, and its transport. Traceability is achieved by means of Distributed Ledger Technologies (blockchain). However, the transportation of the milk to the processing and packaging plant, as well as the final transport to the consumer, are issues that will be addressed in the future, in the second stage of development that will complete the implementation of the SmartDairyTracer platform.

Following the requirements of the first stage to be implemented within the SmartDairyTracer platform, as well as the design patterns of the Global Edge Computing Architecture, the following specifications were defined for each of the three layers of the architecture, which can be seen reflected in the platform in Fig. 1:

- *IoT Layer:* This layer includes all IoT devices designated for monitoring livestock-related parameters (location [16], activity patterns and health status through bio-metric sensors, such as temperature, pulsometer, respiration and accelerometers and gyroscopes to calculate the position and inclination of the animal's head, making it possible to estimate if the cattle is moving, eating, ruminating or just resting, also important to estimate dairy production levels [26]) and their environment (ambient conditions of the barns in order to detect potential stress in cattle based on temperature and humidity [27] and hazardous concentration of gases), as well as the feed grain (through agro-meteorological stations to monitor rain and irrigation, air temperature and humidity, wind conditions, soil humidity and temperature, as well as solar radiation, which can be utilized to estimate crop evapotranspiration levels. Therefore, by means of this layer, the agro-industry platform collects context information from a set of heterogeneous Wireless Sensor Networks [10].
- *Edge Layer:* collects all the information gathered by the IoT devices in the lower layer. It is in charge of preprocessing those data before they reach the Business Solution Layer which is deployed in the Cloud. In this layer, the Crypto IoT chips (designed by the blockchain and electronics teams from the BISITE Research Group of the University of Salamanca [35]) in the IoT devices (as *IoT oracles* at the IoT Layer) or IoT-Edge gateways, hash the information and it is stored in becoming part of the blockchain and maintaining the inviolability of the data to ensure traceability. On the one hand, all the information collected by the sensors becomes part of the distributed ledger from this point using the Crypto-IoT chips. On the other hand, the data are pre-processed and filtered by Data Analytics techniques, generating knowledge in the same Edge and reducing data traffic and transmission costs to the Cloud. In the described use case, the Edge node is formed by Raspberry Pi 3 Model B. This Raspberry Pi 3 Model B acts as an Edge node that filters and pre-processes IoT data with the assistance of TensorFlowLite libraries [37] using an ECMAScript run on a Node.js- and Express.js-based server.
- *Business Solution Layer:* is deployed in the agro-industry platform as a set of coordinated components. SQL and NoSQL databases, back-end Web Services are deployed through Serverless *Function as a Service*, as well as Artificial Intelligence algorithms of the Cloud Computing platform. In this layer a *Virtual Organization of agents* works as a social machine [21], which provides the Decision Support System (DSS) with decision-making features. The decisions are made on the basis of the physical quantities gathered by the different heterogeneous Wireless Sensor Networks at the IoT Layer. Moreover, the agro-industry platform includes additional features such as data visualization technologies and an alert management system which sends warning messages and corrective actions when the values obtained by heterogeneous

IoT networks indicate a hazardous situation. This layer is developed using .NET Core for the backend, and HTML5, Bootstrap 4 and Vue.js for the frontend. The platform relies on a MySQL (Google Cloud SQL) database for the relational part including configuration and the relationship of buildings, cattle, devices, sensors or stations, and Google BigQuery as database for storing massive sensor data coming from IoT and Edge Layers.

Fig. 2. The physical aspect of an agro-meteorological station in an alfalfa crop (left-hand side) and how one of the IoT biometric devices is worn by cattle (right-hand side) in the use case monitoring scenario.

Therefore, and by means of the tools provided through the graphical interfaces served from the Business Solution Layer of the platform, farmers can find out which cattle are suffering stress (which influence the level of milk production) or are ill based on the data collected by biometric sensors. Moreover, thanks to clustering algorithms and correlation with data from environmental sensors in the barns, it can be known whether this stress or disease affects a group of cattle and whether is related to environmental conditions in different areas of the barns.

5 Conclusions and Future Work

Globalization has made world trade in agriculture easier. The farmers and livestock producers should stand out for providing to consumers products of high quality, information about the origin of the product and the processes through which it has passed in the value chain, up to the point of sale. For this purpose, the agri-food industry needs to use technologies such as: the Internet of Things and distributed accounting technologies such as Blockchain, which offer monitoring and traceability functions. To make it possible, farmers and livestock breeders need access to these technologies. In this regard, the Edge Computing paradigm makes it possible to reduce the costs associated with computing, storage and network resources in the Cloud, through the implementation of services in low-cost Edge nodes.

As future lines of research, the authors propose the deployment of the platform in a set of dairy farms in the region in which the current study was developed. For this future scenario, the platform requires innovative consensus algorithms in research, designed to detect stress or possible health problems in cows, through the measurement of different parameters using biometric and environmental sensors. Simultaneous experiments will be conducted on several farms applying Machine Learning techniques to study the different conditions in which cows suffer stress or diseases that affect productivity. The IoT devices and methods used by SmartDairyTracer platform will transform it into an innovating agricultural product, in which all processes in the dairy chain are supervised and shown to the consumer, from feed grain to livestock and product packaging.

Acknowledgments This work has been partially supported by the European Regional Development Fund (ERDF) through the Interreg Spain-Portugal V-A Program (POCTEP) under grant 0677_DISRUPTIVE_2_E (Intensifying the activity of Digital Innovation Hubs within the PocTep region to boost the development of disruptive and last generation ICTs through cross-border cooperation). Inés Sittón-Candanedo has been supported by scholarship program: IFARHU-SENACYT (Government of Panama). Authors would like to give a special thanks to Rancho Guareña Hermanos Olea Losa, S.L. (Castrillo de la Guareña, Zamora, Spain) for their collaboration during the implementation and testing of the platform. Icons in Figure 1 have been designed by Icongeek26 and downloaded from Flaticon.

References

1. Agriculture statistics at regional level - Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agriculture_statistics_at_regional_level&oldid=431854 (2018)
2. Milk and milk product statistics - Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php/Milk_and_milk_product_statistics#Milk_products (2018)
3. REPORT on the future of food and farming. http://www.europarl.europa.eu/doceo/document/A-8-2018-0178_EN.html (2018)
4. Agri-environmental indicator - irrigation - Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_irrigation (2019)
5. Dairy production and products: Social and gender issues. http://www.fao.org/dairy-production-products/socio-economics/social-and-gender-issues/en/ (2019)
6. Ai, Y., Peng, M., Zhang, K.: Edge computing technologies for internet of things: a primer. Digital Communications and Networks **4**(2), 77–86 (2018)

7. Alonso, R.S., Prieto, J., García, Ó., Corchado, J.M.: Collaborative learning via social computing. Frontiers of Information Technology & Electronic Engineering **20**(2), 265–282 (2019)
8. Alonso, R.S., Sittón-Candanedo, I., Rodríguez-González, S., García, Ó., Prieto, J.: A survey on software-defined networks and edge computing over iot. In: International Conference on Practical Applications of Agents and Multi-Agent Systems. pp. 289–301. Springer (2019)
9. Alonso, R.S., Tapia, D.I., Bajo, J., García, Ó., de Paz, J.F., Corchado, J.M.: Implementing a hardware-embedded reactive agents platform based on a service-oriented architecture over heterogeneous wireless sensor networks. Ad Hoc Networks **11**(1), 151–166 (2013)
10. Alonso, R.S., Tapia, D.I., Bajo, J., García, O., de Paz, J.F., Corchado, J.M.: Implementing a hardware-embedded reactive agents platform based on a service-oriented architecture over heterogeneous wireless sensor networks. Ad Hoc Networks **11**(1), 151–166 (jan 2013)
11. Alvarado-Pérez, J., Peluffo-Ordóñez, D.H., Therón, R.: Bridging the gap between human knowledge and machine learning. ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal **4**(1) (2015)
12. Cambra, C., Sendra, S., Lloret, J., Lacuesta, R.: Smart system for bicarbonate control in irrigation for hydroponic precision farming. Sensors **18**(5), 1333 (2018)
13. Chamoso, P., González-Briones, A., Rodríguez, S., Corchado, J.M.: Tendencies of Technologies and Platforms in Smart Cities: A State-of-the-Art Review. Wireless Communications and Mobile Computing **2018** (2018)
14. Chamoso, P., Prieta, F.D.L.: Swarm-Based Smart City Platform: A Traffic Application. ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal **4**(2), 89–98–98 (may 2015)
15. Chien, Y.R., Chen, Y.X.: An rfid-based smart nest box: An experimental study of laying performance and behavior of individual hens. Sensors **18**(3), 859 (2018)
16. De Paz, J.F., Tapia, D.I., Alonso, R.S., Pinzón, C.I., Bajo, J., Corchado, J.M.: Mitigation of the ground reflection effect in real-time locating systems based on wireless sensor networks by using artificial neural networks. Knowledge and Information Systems **34**(1), 193–217 (Jan 2013)
17. Elhoseny, M., Ramírez-González, G., Abu-Elnasr, O.M., Shawkat, S.A., Arunkumar, N., Farouk, A.: Secure medical data transmission model for iot-based healthcare systems. IEEE Access **6**, 20596–20608 (2018)
18. ElMasry, G., Mandour, N., Al-Rejaie, S., Belin, E., Rousseau, D.: Recent applications of multispectral imaging in seed phenotyping and quality monitoring—an overview. Sensors **19**(5), 1090 (2019)
19. Fleming, K., Waweru, P., Wambua, M., Ondula, E., Samuel, L.: Toward quantified small-scale farms in africa. IEEE Internet Computing **20**(3), 63–67 (2016)
20. García, O., Alonso, R.S., Prieto, J., Corchado, J.M.: Energy Efficiency in Public Buildings through Context-Aware Social Computing. Sensors **17**(4), 826 (2017)
21. González-Briones, A., Chamoso, P., Rodríguez, S., Yoe, H., Corchado, J.M.: Reuse of waste energy from power plants in greenhouses through mas-based architecture. Wireless Communications and Mobile Computing **2018** (2018)
22. González-Briones, A., De La Prieta, F., Mohamad, M., Omatu, S., Corchado, J.: Multi-agent systems applications in energy optimization problems: A state-of-the-art review. Energies **11**(8), 1928 (2018)
23. Jayaraman, P., Yavari, A., Georgakopoulos, D., Morshed, A., Zaslavsky, A.: Internet of things platform for smart farming: Experiences and lessons learnt. Sensors **16**(11), 1884 (2016)

24. Jia, W., Liang, G., Tian, H., Sun, J., Wan, C.: Electronic nose-based technique for rapid detection and recognition of moldy apples. Sensors **19**(7), 1526 (2019)
25. Jones, J.W., Antle, J.M., Basso, B., Boote, K.J., Conant, R.T., Foster, I., Godfray, H.C.J., Herrero, M., Howitt, R.E., Janssen, S., et al.: Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science. Agricultural systems **155**, 269–288 (2017)
26. Kaufman, E., Asselstine, V., LeBlanc, S., Duffield, T., DeVries, T.: Association of rumination time and health status with milk yield and composition in early-lactation dairy cows. Journal of dairy science **101**(1), 462–471 (2018)
27. Kaufman, J., Saxton, A., Ríus, A.: Relationships among temperature-humidity index with rectal, udder surface, and vaginal temperatures in lactating dairy cows experiencing heat stress. Journal of dairy science (2018)
28. Kethareswaran, V., Ram, C.S.: An indian perspective on the adverse impact of internet of things (iot). ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal **6**(4), 35–40 (2017)
29. Lin, J., Yu, W., Zhang, N., Yang, X., Zhang, H., Zhao, W.: A survey on internet of things: Architecture, enabling technologies, security and privacy, and applications. IEEE Internet of Things Journal **4**(5), 1125–1142 (2017)
30. Patil, K.A., Kale, N.R.: A model for smart agriculture using iot. In: 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC). pp. 543–545 (Dec 2016)
31. Popović, T., Latinović, N., Pešić, A., Zečević, Ž., Krstajić, B., Djukanović, S.: Architecting an iot-enabled platform for precision agriculture and ecological monitoring: A case study. Computers and Electronics in Agriculture **140**, 255–265 (2017)
32. de la Prieta, F., Gil, A.B., Moreno, M., Muñoz, M.D.: Review of Technologies and Platforms for Smart Cities. In: Rodríguez, S., Prieto, J., Faria, P., Kłos, S., Fernández, A., Mazuelas, S., Jiménez-López, M.D., Moreno, M.N., Navarro, E.M. (eds.) Distributed Computing and Artificial Intelligence, Special Sessions, 15th International Conference. pp. 193–200. Advances in Intelligent Systems and Computing, Springer International Publishing (2019)
33. Reyna, A., Martín, C., Chen, J., Soler, E., Díaz, M.: On blockchain and its integration with IoT. Challenges and opportunities. Future Generation Computer Systems **88**, 173–190 (nov 2018)
34. Sittón, I., Rodríguez, S.: Pattern extraction for the design of predictive models in industry 4.0. In: International Conference on Practical Applications of Agents and Multi-Agent Systems. pp. 258–261. Springer (2017)
35. Sittón-Candanedo, I., Alonso, R.S., Corchado, J.M., Rodríguez-González, S., Casado-Vara, R.: A review of edge computing reference architectures and a new global edge proposal. Future Generation Computer Systems **99**, 278–294 (2019)
36. Sittón-Candanedo, I., Hernández-Nieves, E., Rodríguez-González, S., Santos-Martín, M.T., González-Briones, A.: Machine learning predictive model for industry 4.0. In: International Conference on Knowledge Management in Organizations. pp. 501–510. Springer (2018)
37. Tang, J.: Intelligent Mobile Projects with TensorFlow: Build 10+ Artificial Intelligence Apps Using TensorFlow Mobile and Lite for IOS, Android, and Raspberry Pi. Packt Publishing Ltd (2018)
38. Wolfert, S., Ge, L., Verdouw, C., Bogaardt, M.J.: Big data in smart farming–a review. Agricultural Systems **153**, 69–80 (2017)

Smart control system for zero-defect adhesive application using industrial robots*

João Cabrita[1,2], Fábio Miranda[1], and Magno Guedes[1]

[1] Introsys S.A., Av do Empresário 1, 6000-767 Castelo Branco, Portugal
{joao.cabrita, fabio.miranda, magno.guedes}@introsys.eu

[2] Instituto Superior Técnico, Av Rovisco Pais 1, 1049-001 Lisboa, Portugal
joao.miguel.cabrita@tecnico.ulisboa.pt

Abstract. Methods for joining car parts are becoming more complex. The use of adhesive beads in this industry is gaining more relevance to guarantee robustness, comfort, weathertightness and safety when welding is insufficient or not even possible. However, external factors from equipment, environment or process may influence the viscosity of the adhesive fluid and induce significant flaws that, if not detected and corrected beforehand, can provoke several problems during subsequent assembly procedures. The solution herein presented propose an integrated quality assurance system for the application of adhesive beads using industrial robots. The main objective is to contribute for the zero-defect paradigm in which waste should be reduced to a minimum. This goal is achieved by performing a visual inspection of the fluid application and introducing an additional system agnostic control stack to perform automatic and optimised corrections to the applied bead without hampering the throughput of the production line. The work was implemented and validated in two industrial demonstrators including a collaborative robot and legacy equipment, respectively. It was also integrated with the ROS *MoveIt!* framework,opening the possibility of extension to other robots. Results shown a success rate of 90% in a relevant industrial environment.

Keywords: Intelligent Manufacturing · Trajectory Optimization · Quality Inspection · Zero-defect

1 Introduction

Safety is a hot topic among car makers, not only to comply with strict legislation, but also to earn the trust of consumers. Thus, manufacturers have their quality assurance procedures regarded as top priority. This fact can cause negative side effects, as the production of unnecessary waste [9]. Current demand for efficiency and style requires vehicles to be more complex in terms of materials and assembly

* Supported by the European Regional Development Fund through the Portugal 2020 research and innovation programme under reference POCI-01-0247-FEDER-034072, project See-Q (Sistemas de Inspeção de Qualidade para a Indústria Automóvel).

techniques. Consequently, the use of industrial adhesives are gaining prominence as they guarantee robustness, comfort, weathertightness and safety when welding is insufficient or not possible [7]. However, this trend implies suitable quality control techniques to ensure compliance of joined parts. As external factors from equipment, environment or process may influence the viscosity of the adhesive fluid and induce significant flaws [6], this task is far from trivial and, if defects are not detected and corrected beforehand, several problems can occur during subsequent assembly procedures. Destructive testing techniques are still used to infer the characteristics of this process. It consists in separating a relevant sampling of joined parts and measuring the spreading, continuity and consistency of the adhesive along the joint. All parts used for this inspection are discarded, as well as the parts belonging to a batch where a sample revealed a defect. Consequently, this method can produce significant waste and, by not sampling all produced parts, full compliance can only be guaranteed to a certain extent.

The solution herein presented propose an integrated quality assurance system for the application of adhesive beads using industrial robots. The main objective is to contribute for zero-defect paradigm in which waste should be reduced to a minimum. This goal is achieved by (i) performing a visual inspection of the fluid application and (ii) introducing an additional system agnostic control stack to perform automatic and optimised corrections to the applied bead without interfering on the capacity of the production line. Industrial vision systems are appealing for quality assurance when is possible to observe the target object [10]. In part joining processes, this can only be achieved during, or immediately after the application of the adhesive bead, being the first less harmful to cycle time. In either case, they are able to continuous observe all processed parts, solving the sampling problem. Besides reveling problematic situations, it is important to correct them when possible in order to reduce waste and resources. The contribution of this paper is focused in the proposal of an automatic correction mechanism able to fill gaps in adhesive beads in an optimised manner, enabling its usage in high throughput production lines where, otherwise, discarding a defective part would be more cost-effective than correcting it. The solution was designed to be system agnostic, that is, it can be integrated with different industrial robots with minimum configuration and ramp-up effort. This is achieved by coding bridge modules able to interface and translate robot specific commands with the generic and widely used ROS *MoveIt!* [3]. Here, the solution can be developed and tested virtually in a ROS-Gazebo environment, using planning algorithms capable of computing free-collision trajectories, and then commissioned in the real world with minimum effort. To validate the solution, two industrial demonstrators were used, with a collaborative robot and legacy equipment, respectively. The heterogeneous machines used in the demonstrators show that the concept is general and can be reused for different setups. The rest of the paper is organized as follows. A related work overview is shown in Section 2, Section 3 describes the demonstrators and Section 4 details the implementation of the solution concept. Section 5 show the results obtained. Conclusions and further investigation steps are given in section 6.

2 Related work

To completely cover the related work regarding both identification and correction of defects in adhesive beads, this section is divided in three parts. The first one tackles the defect identification problem. The second one concerns robot interfacing and guidance with external control systems. Finally, the third one looks at path planning algorithms for optimal correction of gaps.

2.1 Adhesive bead defect identification

The topic of identifying defects in industrial adhesives has been under scrutiny for some time now. The traditional method consists in having an inspection station, after the application process, where the part is shown to a set of cameras in order to grab an image of the entire adhesive bead. This method can be seen in [12] and, while offering an opportunity to reveal defects with high level of definition, it adds time to the process, requires additional shopfloor space and optimal camera and lighting setups are hard to achieve when if different car parts must be considered or if their geometry is complex.

To suppress these limitations, another option is to attach the camera and lighting setup to the dispensing nozzle and perform the inspection during the application process [14]. By working closer to the target object, the inspection rig can be set up more easily and the lighting is more controllable. Also, inspection is synchronised with the application, not requiring additional time. Finally, defects are identified before the part being moved to the next workstation, allowing the introduction of corrective measures. To create an inspection rig for this purpose is, however, more difficult as the rig will be closed to hot surfaces, namely the dispensing nozzle and its dimension must be small enough not to collide with the part during handling.

Commercial solutions already exist in the market to perform inspection during the application process. In fact, the work herein presented builds on the technology already in use but extend it in a way that it can be seamless integrated with the overall production process. This aspect is the main limitation of current solutions, besides being a clear necessity for end-users. Even the cutting edge system offered by [5] with the ability to identify the position of gaps for further correction, does not integrate directly with control systems. Bearing this in mind, quality control is still decoupled from process control, requiring high programming, interfacing, configuration and ramp-up efforts.

2.2 Robot guidance

Robot guidance can be understood as the ability of an industrial robot to adapt its task according to the knowledge of the current state of its surroundings. This process can be divided in two main stages: perception and processing. When there is a need to collect information regarding the surroundings of the robot, the guidance system is called scene related and a given number of sensors, depending on the technology being used, are usually mounted on a robot or on a fixed structure. When there is a need to collect information regarding a more reduced region of interest (ROI), concerning the task to be performed (*e.g.*, to pick an object) the system is called object-related and the sensors are usually attached to the robot end-effector. This is called an eye-in-hand configuration [14]. Due to the fact that the inspection rig attached to the dispensing nozzle is the best option to enable both defect identification and correction, the later can be easily derived using the same inspection equipment for the perception stage. Regarding processing, one can typically use image or point cloud processing frameworks, such as OpenCV [1] or PCL [16]. However, industrial applications demand for highly robust sub-pixel processing, which can for instance be achieved with minimal effort using the Halcon library [4].

2.3 Motion Planning Problem

After the perception and processing, the motion planning problem arises. Currently, there are several approaches to solve this problem, such as Artificial Potential Fields, Cell Decomposition, Sampling-Based Motion Planning, Computational Intelligence or Grid Based algorithms [18]. [11] States that, in comparison to Computational Intelligence methods, Sampling-Based Motion planners are better to use in real production scenarios, because they generate smoother paths. Artificial Potential Fields algorithms have the drawback of getting stuck in local minima [18] and Grid Based algorithms become inefficient when it comes to planning on high DoF robots. Cell Decomposition entails complex implementation with poor time efficiency [18]. Recent studies focus on a Sampling-Based Motion planning approach, which provide large amounts of computational savings [8] and have been successfully implemented to solve difficult planning problems on robots of practical interest [17]. The OMPL includes several state of the art Sampling-Based Motion algorithms and it can be integrated with the platform *MoveIt!* in order to target those algorithms to solve path planning in the robotic field [17]. [15] and [2] Successfully implemented sampling-based motion planning algorithms for robotic arm trajectory planning performing benchmarking and concluding that the RRT family algorithms have the most suitable performance in terms of planning times and least failed planning attempts [15], particularly in tridimensional path planning for 6-DoF manipulators [2].

3 Running Example

The solution concept was tested and validated in two demonstrators comprised by certified automation equipment and compliant with industrial standards. The purpose of using 2 demonstrators was to assess the flexibility of the application in different production approaches: (i) highly customisable part assembly with frequent user changes and human-robot collaboration capability, and (ii) traditional mass production with less variants but low cycle time.

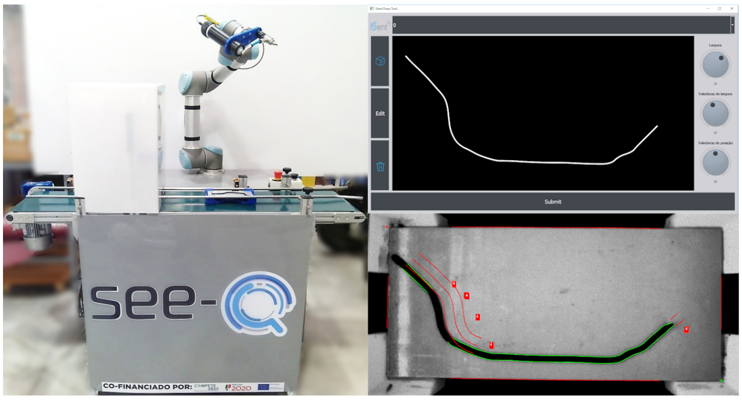


Fig. 1: Collaborative adhesive application demonstrator. Left: workstation. Top-right: interface for hand-drawing bead models. Bottom-right: inspection result showing a displacement error between the application and the original model.

3.1 Demonstrator 1

The first demonstrator tackles the emergent use of collaborative robots in the industry. This setup allows flexible production of new components as the user can, at any given time, change the bead model according to new workpieces without stopping the process. The workstation can also have a small footprint as there is no need for fences or complex safety equipment. The scene considered for the demonstrator (Fig. 1) consists of a single part resting on a pallet, a conveyor, a visual inspection setup, a station for applying and correcting the bead, composed by a UR5 robot model from Universal Robots, with an automatic bead dispenser mounted on the end-effector, one position sensor for each station and a start button. By activating the start button a main procedure starts, where the pallet transports the part to the applying station, the robot draws the bead model inserted by the user in the graphical interface and the pallet transports the part to the inspection station. If the inspection reveals no gaps, the process restarts and a new bead is drawn on a new part. If the inspection reveals gaps, a correction procedure starts where the pallet moves the part to the correction station and the bead is corrected. The part is inspected once again and, if it still presents gaps, the procedure repeats until they're eliminated or a stop command is actuated. Otherwise, the main procedure restarts with a new part. The use of a PLC was dismissed, being the robot responsible for controlling and orchestrating the equipment, such as conveyor, sensors and camera.

3.2 Demonstrator 2

The second demonstrator can be described as a high throughput production cell (Fig. 2). Besides being a testbed for research purposes only, it is prepared for real production, namely involving the application of adhesive beads. The cell is

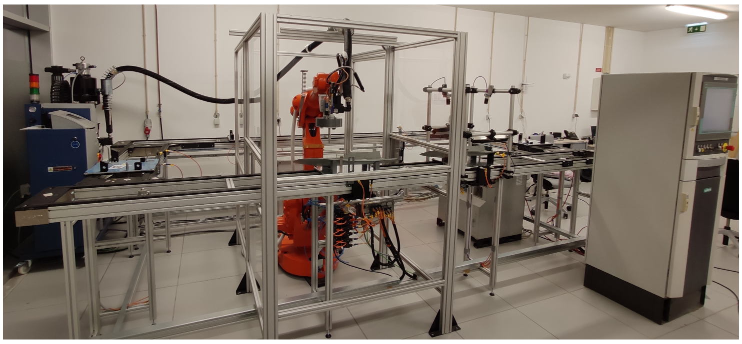


Fig. 2: Industrial adhesive application cell demonstrator.

comprised of an ABB IRB 2400 6-DoF industrial robot, a Nordson VersaPail bulk melter, a Nordson AG-930s dispensing gun, an in-process inspection ring with 3 IDS OEM cameras and built-in IR led lighting, developed by Introsys (not in use for the results herein presented), a post-process inspection setup with two Teledine cameras and IR lighting, a conveyor system and a Siemens Simatic S7-400 PLC. The cell is divided in six work stations: two idle stations; one for loading; one for unloading; one for post process inspection; and one for applying and correcting the adhesive bead. There is one sensor to detect the presence of a pallet and one sensor to detect the presence of a part for each station, as well as one clamp and two elevators for the applying/correcting and inspection stations. The conveyor system is able to transport up to five pallets. After a part has been loaded in the first station, it is transported to the applying/correcting station. Upon arrival on the applying/correcting station, the pallet is elevated, the robot draws the bead, the elevator descends and the part is transported to the post process inspection station, where is elevated once again and inspected. If the part has no gaps it is transported to the unloading station and unloaded by a worker. In this case, the pallet can only leave the unloading station if the sensor detects no part. It then passes through both idle stations and arrives on the loading station, thus repeating the cycle. If the inspection detects a gap, the part passes through the remaining stations and it's transported to the applying/correcting station, where the bead is corrected. After a new inspection, the part can either be transported directly to correction until it presents no defects or be unloaded on the next station, if the correction is successful or the worker stops the cycle.

4 Implementation

4.1 Main module

The main module has the responsibility of flowing the data coming from the vision system as well as translating it to trajectory planning commands,written in the robot's native language, and sending them to the robot controller. A sub module (listener) creates a server and receives data from the vision system through TCP/IP. It runs a thread which is always waiting for to receive an array of coordinates.The array has the following structure:

$$\{[x_0; y_0; z_0,\ x_1; y_1; z_1]gap_1\ ...\ [x_0; y_0; z_0,\ x_1; y_1; z_1]gap_n\} \quad (1)$$

On the main submodule (writer), the array is split and sent to another submodule (optimizer), which orders the gaps using a Dijkstra algorithm. A script is written in the robot's programming language, encapsulating the ordered targets in Move instructions, and a submodule (sender) sends it to the controller through FTP/SFTP.

4.2 Interfacing the module with the demonstrator 1

The UR5 can be controlled at three different levels: 1) graphically, using the PolyScope software; 2) via scripting; or 3) using a C language API. The URScript language is the programming language used to control the robot at the Script Level. To interface the developed module with the demonstrator's routine, two programs named 'Main' and 'Correct' were written in PolyScope, containing the main and correction procedure, respectively. When the main procedure starts, it sends a "don't correct" string to the main software module, while after the inspection it sends an "inspected" string. After the correction is performed on the correction procedure, PolyScope sends a "corrected" string to the module. These strings help an handshake between PolyScope and the main module, illustrated in algorithm 1, where the main module controls which procedure is being performed.

4.3 Interfacing the module with the demonstrator 2

The ABB IRB 2400 allows sending external motion commands through a high-level programming language named RAPID [13]. It runs on an hierarchical and modular program structure consisting on routines and was used to integrate with the developed solution. One particular aspect of this demonstrator is that there may be up to 5 parts in circulation, thus, there is a need to track the correction state of each part. Therefore, every part has a unique ID, printed on a qr-code, which is read on the inspection station and sent to the main module, which concatenates it on the correction information file. The main module sends the file to the controller through FTP, and deletes it when the inspection reveals no gaps, this procedure is illustrated in algorithm 2.

Two procedures called MoveGL_Start and MoveGL_Finish where created in RAPID to be used as a function that is executed with the same arguments as the MoveL instruction. MoveGL_Start sets the output to apply adhesive fluid at the beginning of the trajectory, MoveGL_Finish resets it at the end of the trajectory. For correction segments, MoveGL Start was used at the start of each gap, MoveL for the interpolation points contained in it and MoveGL Finish for the end of the gap. A camera mounted on the robot's end-effector reads the part

Algorithm 1 Interaction with the main software module

```
procedure MANAGING THE PSCOPE PROGRAMS
    string ← string received from PScope
    n_gaps ← number of gaps detected
    Main ← Main program
top:
    while string = "don't correct" do
        wait
        if string = inspected and n_gaps = 0 then
            goto top
        if string = inspected and n_gaps > 0 then
            stop Main
            load Correction
            play Correction
            goto top
        if string = corrected and n_gaps > 0 then
            goto top
        if string = corrected and n_gaps = 0 then
            stop Correction
            load Main
            play Main
            goto top
```

Algorithm 2 Interaction with the main software module

```
procedure MANAGING THE RAPID SCRIPTS IN THE VIRTUAL CONTROLLER
THROUGH THE MAIN MODULE
    path ← Path to the controller
    n_gaps ← number of gaps detected
    ID ← Part's ID received from the vision system
top:
    while ID = false do
        wait
    file = "Seeq" + "ID" + "prg"
    if n_gaps > 0 then
        send file
        goto top
    if n_gaps = 0 then
        if file exists in path then
            erase file
            goto top
        else
            goto top
```

ID, in order to choose which correction file should be loaded or if a new bead should be drawn. This decision, alongside with the management of the actuators and sensors, is performed by the PLC and will not be covered in this article.

4.4 Interfacing the module with the platform ROS *MoveIt!*

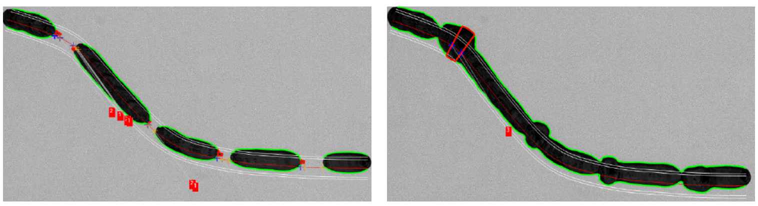
The software module was integrated in the platform ROS *MoveIt!* and tested using the Gazebo simulator.The integration was performed with the aim of proving the module's transversality to several frameworks. On simulation, the targets are received from the inspection and successfully reached by the robot while avoiding obstacles in the workspace, executing trajectories planned by the RRT's family algorithm RRTConnect. This builds the basis of a future work consisting of solving the adhesive quality control problem resorting to free-collision trajectories, therefore opening up the possibility of working on dynamic scenarios.

5 Results

For testing the concept, defects were induced by interrupting the air feed of the adhesive dispensing equipment at some intervals, creating gaps in the bead. The results are obtain by comparing the vision system performance on each inspection against the ground truth, that is, manually classified images.

5.1 Demonstrator 1: testing with the collaborative robot

Tests with the collaborative robot consisted on the application of five adhesive beads. Each bead was inspected and corrected up to two times or until no more gaps would be found (Fig. 3). Table 1 shows the correlation between inspection and presence of gaps in each bead. The occurrence of both false negatives and false positives is an exclusive consequence of lack of control of lightning conditions. Incident light on the bead formed shadows on gap segments, causing the vision system to interpret them as bead. On the other hand, light reflexes on bead segments were interpreted by the vision system as gaps.



(a) Before correction. (b) After correction.

Fig. 3: Visual inspection of the applied adhesive bead #4.

The Correction Success Rate (CSR) is calculated by dividing the number of successfully corrected beads by the total number of beads applied, resulting in a CSR of 80%

5.2 Demonstrator 2: testing with the industrial cell

Table 2 shows the results obtained with the demonstrator 2. From a total of 20 tests, that is, 20 bead applications, the first two could not correct the bead successfully due to the fact that tests were performed in a preliminary setup and without calibration. However it is possible to observe that the vision system detects the gaps in the correct location (Fig. 4). All the false negatives were originated by a vision system misclassification, categorizing inflection points on the edge of the bead as gaps.

		Inspection 1	Inspection 2	Inspection 3
Bead #1	TP	2	0	0
	FP	0	1	0
	FN	0	1	1
	Gaps	2	1	1
Bead #2	TP	3	0	-
	FP	1	1	-
	FN	0	0	-
	Gaps	3	0	-
Bead #3	TP	3	0	-
	FP	0	0	-
	FN	0	0	-
	Gaps	3	0	-
Bead #4	TP	4	0	-
	FP	1	0	-
	FN	0	0	-
	Gaps	4	0	-
Bead #5	TP	3	0	-
	FP	0	0	-
	FN	0	0	-
	Gaps	3	0	-

Table 1: Results obtained with demonstrator 1.

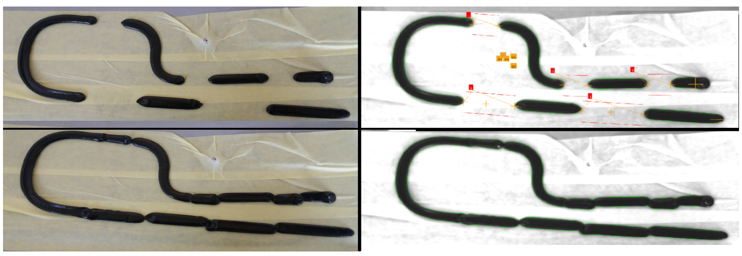


Fig. 4: Correction of the applied adhesive bead.

Test	Gaps	Nr. of Corrections	Final Status	TP	FP	FN	F.Status Class	Cycle Time (s)
1	4	1	NOK	4	0	0	TN	-
2	4	1	NOK	4	1	0	TN	-
3	5	1	OK	5	0	0	FN	19.02
4	4	1	OK	4	0	0	TP	18.09
5	4	1	OK	4	0	0	FN	16.97
6	5	2	OK	5	0	0	FN	-
7	4	2	OK	4	0	0	TP	-
8	5	1	OK	5	0	0	TP	18.78
9	5	1	OK	5	0	0	TP	19.29
10	4	1	OK	4	0	0	TP	17.01
11	4	1	OK	4	0	0	FN	22.08
12	4	1	OK	4	0	0	TP	19.73
13	6	1	OK	6	0	0	TP	21.04
14	6	1	OK	6	0	0	TP	21.46
15	5	1	OK	5	0	0	TP	20.30
16	5	1	OK	5	0	0	TP	20.57
17	4	1	OK	4	0	0	TP	18.04
18	4	1	OK	4	0	0	TP	17.93
19	4	1	OK	4	0	0	TP	17.12
20	5	1	OK	5	0	0	TP	21.79
Total	94	18 OK, 2 NOK	NOK	94	1	0	-	-

Table 2: Results obtained with demonstrator 2.

6 Conclusions

A control system was presented whose core is traversal to several robot programming languages and robot frameworks. This system operates independently from the inspection, therefore, it can be adapted to other vision systems, since it receives and deals with coordinate vectors. The system was validated in two relevant demonstrators, with a rate of success of 80% and 90% respectively. During the test, it was possible to observe that lighting and calibration of the camera rig has high impact on the success rate, it is expected that better calibration, to be performed in the future, shall produce better results.

An important subject for future work regards the further exploitation of in-process inspection. Despite the fact that the module is prepared to be used in that scene, the implementation on real environment would be the ultimate proof that the developed solution can compete on equal ground with the state of the art solutions. Aside from that, the inspection algorithm needs improvement to solve the problem of detecting false negatives on the inflection points.

The other prominent subject for future work is the adaptation of the integration with ROS *MoveIt!* to a real environment, where a perception and processing system have to be implemented to correctly monitor the robot's workspace and flow the information to the planners.

References

1. Bradski, G., Kaehler, A.: Learning OpenCV: Computer vision with the OpenCV library. " O'Reilly Media, Inc." (2008)
2. Nuno Gomes de Brito, J.: Manipulador robótico para poda automática (Projecto ROMOVI). Master's thesis, Faculdade de Engenharia da Universidade do Porto, Portugal (2018)
3. Chitta, S.: Moveit!: an introduction. In: Robot Operating System (ROS), pp. 3–27. Springer (2016)
4. Eckstein, W., Steger, C.: The halcon vision system: an example for flexible software architecture. In: Proceedings of 3rd Japanese Conference on Practical Applications of Real-Time Image Processing. pp. 18–23. Citeseer (1999)
5. Gruber, B.: Method for applying and monitoring an application structure comprising a repairing function and device therefore (Jan 25 2011), uS Patent 7,875,137
6. Hicks, C.R., Carlson, B.E., Mallick, P.: Rheological study of automotive adhesives: Influence of storage time, temperature and shear rate on viscosity at dispensing. International Journal of Adhesion and Adhesives **63**, 108–116 (2015)
7. James, S.: Machine vision helps adhesive trend stick in auto industry (September 2016), https://www.photonics.com/Article.aspx?AID=61129
8. Karaman, S., Frazzoli, E.: Sampling-based algorithms for optimal motion planning. The international journal of robotics research **30**(7), 846–894 (2011)
9. Klausing, M., Heuer, H.: An automated non-destructive testing system for seam bondings in automotive serial production. Applied Adhesion Science **5**(1), 21 (2017)
10. Labudzki, R., Legutko, S.: Applications of machine vision. Manufact Ind Eng **2**, 27–29 (2011)
11. Larsen, L., Kim, J., Kupke, M., Schuster, A.: Automatic path planning of industrial robots comparing sampling-based and computational intelligence methods. Procedia Manufacturing **11**, 241–248 (2017)
12. Lingier, E., Wilhelm, A.: Inspection device and method for inspecting an adhesive pattern on a substrate (Jan 4 2018), uS Patent App. 15/632,334
13. Mendoza, I.A.: Rapid programming of an assembly cell of lego cars and modelling the systems using sysml (2017)
14. Pérez, L., Rodríguez, Í., Rodríguez, N., Usamentiaga, R., García, D.F.: Robot guidance using machine vision techniques in industrial environments: A comparative review. Sensors **16**(3), 335 (2016)
15. Ragel, R., Maza, I., Caballero, F., Ollero, A.: Comparison of motion planning techniques for a multi-rotor uas equipped with a multi-joint manipulator arm. In: 2015 Workshop on Research, Education and Development of Unmanned Aerial Systems (RED-UAS). pp. 133–141. IEEE (2015)
16. Rusu, R.B., Cousins, S.: 3d is here: Point cloud library (pcl). In: 2011 IEEE international conference on robotics and automation. pp. 1–4. IEEE (2011)
17. Sucan, I.A., Moll, M., Kavraki, L.E.: The open motion planning library. IEEE Robotics & Automation Magazine **19**(4), 72–82 (2012)
18. Youakim, D., Ridao, P.: Motion planning survey for autonomous mobile manipulators underwater manipulator case study. Robotics and Autonomous Systems **107**, 20–44 (2018)

Author Index