Impact of Knowledge Exchange in Cross Regional Interdisciplinary Collaboration within a Robotic Development Project

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Abstract. Co-design and co-creation of robotic systems and supporting automated solutions for industrial applications have seen a rapid increase in development efforts in recent years. Research and development activities within collaborative and industrial robotic projects alongside implementations of technical solutions have also shown significant gains in offering small, medium and some large enterprises enough cost benefit justification and improved understanding of technical requirements to adopt them in the 'servitisation' of manufacturing and assembly operations. This paper reports findings related to the impact of generating and exchanging technical knowledge within a large multimillion euros project in France-England Channel region over a running duration of over 5 years and the mutual benefits it had on the research institutes, industrial partners and collaborative network established from the project. The results indicated an increase in knowledge acquisition and exchange amongst individuals, that can be used to gain significant advantages and a steppingstone in improving new product development activities, speed to market, as well as enhancing methods to establish long term collaborative efforts within industry-academia and improve innovation output.

Keywords. Knowledge Management, Cyber Physical Systems, Industrial Robotics, Smart Manufacturing, Interdisciplinary Collaboration.

1. Introduction

The UK government is investing £725m in addressing industrial strategy challenges to improve innovation throughput [1]. A total of 12.5bn had been invested in research and development (R&D) activities in 2021/2022 alone, with an annual growth of 40% per annum projected between 2020 and 2030 in the areas of robotics (currently at £400m). The UK is perceived to be in the top three funding environments in the world, and first in the world for venture capital investment in technology companies, though other European countries are leading in implementation of advanced robotics [2].

Brexit made it much more difficult for the UK to recruit staff from overseas, and thus the focus of UK's industrial strategy saw an increase in reliance on IT infrastructure and its growth to match the increasing demand in local and regional innovation [3]. The UK's loss of eligibility to some EU regional funding programmes (except Horizon Europe) saw the government's wider uptake of 'leveling up' types of approaches across the region [4]. In many ways, this loss of eligibility translates to loss of productivity of future R&D activities that pan into the European region. Meaning, new establishment of alternative methods of knowledge exchange programmes with European partners, industry and others will need to suffice. Key impact reports have to be considered with completed and ongoing projects to understand effective approaches to future collaborations. This paper reports significant key benefits attained from a large interdisciplinary project to improve the design of flexible robots and the impact it had on knowledge acquisition. Discussions of how these methods can be used to develop alternative avenues with regional partners or strengthen local demands for industrial development requiring collaboration are introduced.

2. Overview of Related Research

There are a vast number of European projects in the area of robotics and autonomous systems development (e.g., Robot Union, euRobotics, EURON and IM- CleVer). Often knowledge of impact of completed projects remains tacit and will remain so until research is published which is not always exploited enough within research focusing on technological advancement in academic-industry collaboration [5]. Critical Success Factors Framework for Collaborative Product Development requires that extra effort is exhorted on communication protocols and upheld for measuring success [6].

The CoRoT Project (Improving the design of flexible and responsive manufacturing systems involving autonomous Collaborative Robots) is an Interreg France England Channel collaboration with almost 4m euros granted between 2016 and 2022 across 8 partners (3 UK, 5 French) from academic institutes and small to medium enterprises (SMEs). Major funding from European Commission - European Regional Development Fund was attained. Over the project duration, typically the work packages are split by aligning the outputs needed with the areas of skills and expertise for each partner. Each partner then met on a regular basis to discuss common themes and technical overlaps and gaps that then formed key parts of activities and requirements for each research and development direction in meeting the project aim.

The University of Greenwich undertook work packages related to the development of web-based data, information and communication management systems for a number of use case studies within the aerospace [5], automation [6] and civil infrastructure [7] domains. CESI LINEACT worked on process modeling and optimization used for the manufacturing system deployed within enterprise resource planning (ERP) of the CoRoT Project [8]. As well as the task allocation model for sharing resources in ROS to implement motion planning [9] and so on.

Exeter University developed a multi-project planning algorithm delving into multiagent services to improve concurrent decision making in limited resource allocation context [10]. Autofina developed a low-costing high fidelity collaborative arm and concepts for gripper. BA Systems developed high performance mobile base with onboard programmable logic controller (PLC) capabilities to deal with local algorithm and interfacing with scheduler and task planning comms as well as manage Internet of Things (IoT) supervision protocols. Collaborative efforts with Le Havre University, ESIGELEC and CERI who developed programs and applications of cyber-physical communications in ROS, RobotStudio and provided concepts for further scoping in the Digital Twin domain.

3. Analysis of Findings

The leadership members of the team were contacted via a multitude of qualitative data collection attained from interviews. Early career researchers (ECRs) were contacted to summarize findings from firsthand experiences and collated via email. Quantitative impacts were reviewed and interpreted from technical publications with the team with variable inputs in tabulated form capture. A cross-horizontal study of the survey data from industrial contacts and SMEs were reviewed, as well as vertical study of seed projects and activities from the collaboration network. The reported findings from the research have been analysed and distinguished into four main themes. Several of them, reported impact gone far beyond the immediate objectives and more toward generating groundworks for sustainable futures in the area of flexible cost-effective systems in robotic and automated manufacturing.

3.1 Capital Acquisitions

Acquisition of capital equipment leading to industrial growth and awareness in the South-East England area were seen as a result of the collaboration. Information transfer from industry partners short tracked market scoping of capital equipment to seed fund research and teaching lab-based resources including multimedia and video content, research informed teaching programmes, undergraduate and postgraduate projects as well as direct discussions with Chamber of Commerce in both UK and French regions. Estimates of 6 figure budgets were further spent for increasing purchases in physical equipment like robotic, gripper and maneuverable robots, including installation of enabling mechatronics, and other acquisitions of automation technologies within a large UK medical manufacturer were also reported. An establishment of open-source physical platform with technology readiness level of two and above; for reconfigurable manufacturing systems was reported and saw a rise in contact hours between academic members and SME’s specifically addressing labor intensive assembly challenges for example in road traffic infrastructural manufacturing, scoping exercises for Virtual and Augmented Reality in consumer healthcare and training and others. On the French side, attainment of sensor and image processing capabilities for academic institutes grew to establish three major laboratories spread across the northern France region, some match funded with internal capital investment to develop major milestone demonstrators: thus, both regional developments contributing to improving eco systems of manufacturing in industry 4.0 context and capability knowledge.

3.2 Advancement of Technology

Integration technology addressing interoperability between physical and software systems controlling completely different types of systems and synchronization capabilities in real time via middleware was achieved by the Normandie Universite team through cross functional efforts. Advances in managing Protocols of Communications and Networking infrastructure via central processing using Gazebo/ROS took a principle of theory to novel contributions to applications within the given timeframe of the project, although some non-critical limitations reported. Robot-machine and machine-product precision was achieved with novel applications of compliance of robot platforms within advanced light processing in image recognition technology equipped with Lidar for maneuverability; that was addressed with a significant degree of precision in collaborative flexible-environment context. Algorithmic frameworks were implemented to improve capability of Autofina Arm and Gripper and develop the interface with Le Havre saw a rise in process capability and cost engineering seed projects within the French partners.

3.3 Problem-based Learning

Significant contributions were a result of four internship programmes offered to French students over periods between two and four months each. The first developed scenario modeling for the use cases deployed with the UoG partners, resulting in addressing complexities found in industry-collaborative robot-human work settings, and was fruitful with regional SMEs designing second generation grippers. The second intern was able to design complex secure fixture mechanisms for environmental testing procedures, and the third took way in strengthening collaboration with Cummins power generation on improving Quality of PLM activities related to automation. The fourth, currently ongoing, is looking at improving safety operations of dock and go activities of maneuverable robots – all valuable progressions in the individuals career projection in this area as several publications of these works were disseminated. Furthermore, work in the area of mobile robotics was improved in its pedagogy as assumptions were reported to have been minimized, and requirements capture of effective and ineffective scientific experimentation was fruitful in setting up benchmarks. A strengthened understanding of complexity of implementation, maturity level, and use case scenarios related to robotic equipment behavior were much more feasible, viable and real. All of which allowed researchers to discover change making industrial advances and make them much easier to identify and manage. Professional attributions of French researchers on the project were reported to have been improved in the area of presentations, impact articulation, and English language communications all together.

3.4 Industrial Steering

A number of companies in the UK were reported to have formed alignment of strategic vision via engagement with industrial workshops and potential formation of industry steering committee as a direct result to outreach, and network development. Further numbers from SMEs were reported to have been encouraged into early adoption of technologies, by ongoing conversations happening with large enterprises like BAE Systems, Cummins Power, Atlas Copco, Linde Fenwick and others. Thematic issues arose in relation to aging workforce, knowledge and skill retention and upskilling towards industry 4.0 especially in the areas of cost benefit analytics, installation tactics, fleet management, and commercialization of proof of concepts deployed within high tech context. The advent of online social media platforms saw a notable following of online workshops, discussion forums, and exploratory project steering in the areas of technology integration into product lifecycle management (PLM), ERP, and manufacturing execution system (MES) systems. Interest in revenue generation were highlighted in multiple areas of two significant surveys sent out to a large database of contacts generated via research and development team within sections related to immediate and strategic benefit of investment highlighting a strong orientation towards supporting flexible manufacturing systems, quality control, and human safety of operations, due to flourish in due time.

The resulting work of the collaboration was deemed excellent by the funders and facilitators, in addition, a rise of public awareness is reported to be a key outcome of the project as it led to further strengthening collaboration seeding within SME's and industry although many of the elements are challenging to quantify at this stage. The discussions section next, summarizes the above four themes and presents key implications within the areas of impact due to cross regional collaboration efforts of knowledge exchange and its further work.

4. Discussions, Conclusions and Further Work

This research mainly contributes to understanding the successes profound and output through collaborations especially in multiregional context and with exchange of knowledge between academic researchers, industries, and SMEs. The UK is perceived to be in the top three funding environments in the world, and first in the world for venture capital investment in technology companies but lacks confident perception of foreseeable future to sustain growth within robotic and automation technologies, as leveling up may not keep up enough pace with key industrial players around the regional and international drivers. The global challenges on the horizon in shortage of skills and global technology security presents a significant opportunity for UK to collaborate for the sake of knowledge scaling up and understanding of socio-economic benefit of such projects. The analysis of the reported findings shedding more light on the common building blocks of interdisciplinary collaborative effects learned from the CoRoT project.

Shared Perception, Values and Modality of Working Activities: The most highlighted area of thriving in innovating and exchange of knowledge is due to a common understanding of the project aim, objectives, and deliverables. Certain technological outcomes were still not ready for deployment, but this does not underwhelm the fact that more effective attainment of knowledge that goes beyond the strategic vision of the project scope had been successful. The same applies to values behind the shared vision and drive for addressing real problems from the real world that had been effective due to ongoing engagement with the public, the research community, industrialists, subject matter experts, and experienced professors pushing through to meet the deadlines. With the ongoing challenges of the COVID19 pandemic, risk was managed and mitigated, and realistic outlines of works to be done were under constant review and adjustment which in effect, made a smoother interactive function amongst the community of the project, and externals involved. Modality of work saw, constant and innovative solutions being deployed to ensure running of the project and on time delivery of results amongst the partnership.

Growth, Personal Development, and Sustainable Networks: The other key points of interest common across all analysis areas were the provision and catalytic power of interdisciplinary collaboration in growing the next generation of innovators, technologists and academic think tanks. The results are too early to report, but already formations of networks can be seen evolving on profound professional ethics and problem-solving skills in the technical areas of robotic and automation development especially in addressing complex environmental and business-oriented challenges in engineering. Every single reported finding was based on personal and intellectual investment in such a large project, each developing key personal development attributes and efficiency in style of working, that if used to steer setting up the future of collaborative projects to have familiar features of the ones reported in this paper.

An expectation of final publications in high impacting journals and publishers are planned to conclude scientific exploration and novel contributions in the area of manufacturing engineering, innovation design, computer science, systems and electronic engineering, telecommunications, and industry-academic progression. Works from the other direct resulting works will be published accordingly with their own project direction.

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