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Modular, Mobile and Autonomous Robotics for Manufacturing SMEs

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Abstract. The CoRoT project is a collaboration of French and UK partners funded by the EU Interreg Programme. The CoRoT research group has developed a mobile robot demonstrating autonomous operations particularly aiming for applications within flexible manufacturing factories of small to medium enterprises (SMEs). The robot's capability of full separation classifies it as a modular robotic system. Although the separation is possible, it introduces challenges in the areas of staff training, physical labour and workshop planning. This paper introduces a new method resolving the overt issues of lifting the robot, storing the robot and making use of the two systems as well as highlighting emergency stop regulations and maintaining the warranty of the equipment. By using a steel framed pneumatic lift, the top module can be removed and held in place, anchoring the arm for full operations whilst freeing the base to perform delivery tasks enabling seamless separation of modular robotic systems.

Keywords. Autonomous and Mobile Robots, Collaborative Robotics, Modular robotics, Industry 4.0, Flexible Automation, Health and Safety, SME

1. Introduction

This paper presents research carried out in the CoRoT project funded by the European Interreg France Chanel England (FCE) program, which aims to ease the adoption of collaborative robotics by small to medium enterprises (SMEs) whilst developing innovative technologies. These technologies are integrated into the industrial partners' IT systems and have been demonstrated on a prototype mobile manipulator to determine its full capabilities. The CoRoT Autonomous Industrial Mobile Manipulator (AIMM) is a combination of a UK robotic arm by Autofina and a French Autonomous Mobile Robot (AMR) by Alstef Group (formerly known as BA Systémes). Additionally,the robot uses an integration platform and gripper module built by French partner CERI.

In a questionnaire conducted to 35 SMEs, it was determined that a modular robotic solution could be beneficial to many companies within the manufacturing industry looking to maximise the benefits of investing in collaborative robots. The survey also helped to highlight concerns from the SMEs regarding the cost and training involved with purchasing such technologies.

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Several issues present themselves when designing a modular solution ranging from the training required for staff to successfully separate the two robots (a robotic arm and a mobile base), the labour involved in separating the two robots (weight and geometry being key factors) and lastly the effective use of the individual robots, ensuring the separation process and storage does not detract from the benefits. The designed solution was made by research engineers and used by local Kent fabrication engineers from G.Brightling Fabrication & Development to build a working solution. It was then tested on the Enabled Robotics (ER) Flex mobile manipulator and a framework was developed to be implementable across all major platforms as well as the CoRoT prototype.

2. Literature Review

Research, development and applications of AIMM robots have been within the Industry 4.0 trend with European robotic advancement almost doubling between 2004 and 2016 [1]. Being the combination of two collaborative technologies, it was set out as early as 2011 in the “Little Helper” project that an AIMM robot could provide Flexible Manufacturing Systems (FMS) workshops with transportation, pick-and-place, quality control, classification, process control and dangerous/inaccessible task assistance [2]. The technology is not limited to FMS workshops though, as it has been seen through the CoRoT Project that larger companies using more assembly lines also benefit from AIMM robots [3]. As the technology has matured and low-cost solutions are becoming available, research is being carried out into Enterprise Resource Planning (ERP) systems integration for task allocation for greater efficiency at scale.

Despite a long standing within the Industry 4.0 area of interest, separating AIMM robots is rarely discussed despite the many discussions of each robots independent benefits [4][5]. In a 2022 paper, researchers explored using a dedicated separation system for removing a collaborative robot arm from an AMR, however, it was also determined that the arm would not be secure for independent operations [6]. As the arm is not anchored, this can lead to calibration issues caused by instability making it inoperable. The system proposed used the docking tolerances of the AMR in combination with a vision system and docking marker which can also involve additional steps in the set up rather than solely relying on the docking system and working within the tolerances provided.

3. Separation Method and Reasoning

As part of the CoRoT Work Package 3, an industrial survey, was distributed in late 2018 to over 1500 registered companies within the FCE area. With 35 eligible companies responding, a report was made in March 2019. The data captured showed industrial requirements, challenges, key technologies, and the expertise in the whole FCE area. Information was also gathered on potential collaborating companies and their interest in implementing the CoRoT projects emerging technologies to improve their manufacturing processes.

A key consideration when separating the AMR from the robotic arm is maintaining the warranty of the individual components. Warranty of the goods will typically be violated by moving outside of the manufactures recommended ranges of weight, operation angle/incline and any notable impact damage. From Figure 1 it can be seen that the cab is made of a continuous sheet metal casing with two detachable panels on either side of the robot. These panels will allow access to the steel frame that supports the UW control box, but do not allow access to the router and power adapter which are placed in the tower directly below the arm and accessed through a locked door. It is recommended by the manufacturer that lifting the robot should be performed via the frame, however the centre of gravity of the robot is closest to the rear creating unbalance. A non-destructive method of industrial suction pads was used, having 100kg pads affixed to either side of the robots metal panelling whilst gripping onto the inner frame. It is recommended that a specification be provided to the supplier prior to purchase so that a means of accessing the frame from the front and rear is viable.

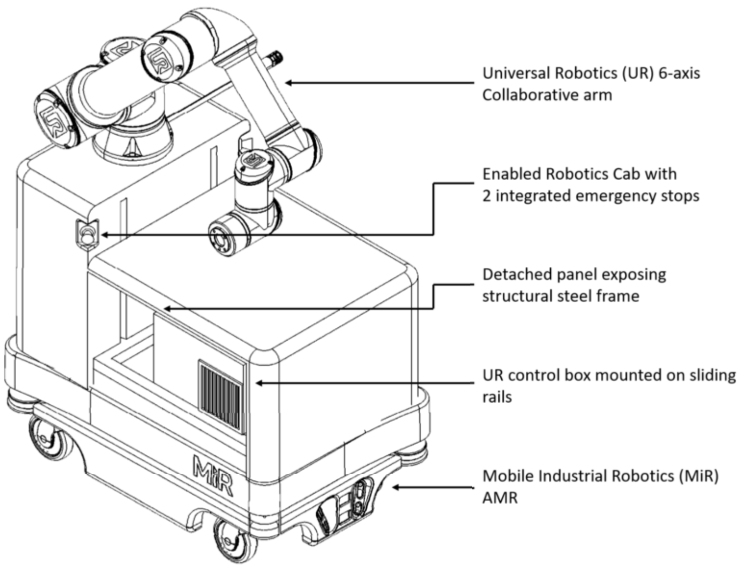

Figure 1. The University of Greenwich ER-Flex modular robot configuration

3.1. Plug and play hardware set-up

In May 2021, the University of Greenwich hosted a Webinar for the CoRoT project entitled: *Robot readiness - How SME's can train staff and integrate robots to take on simple tasks in the workplace* [7]. With over 30 unique guests in attendance, it was determined that staff training can be a barrier to robotics as programming and electrical principles are not always core skills for manufacturing technicians. Market solutions are available where the connections between a mobile manipulator can be consolidated to a single cable which mixes both power and data. It should be noted that this does not make separation as simple as "plug and play", as a robotic arm and a mobile base will share emergency stop functions whilst together but will be disabled once separated. As per the EU Machinery Directive "machinery must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted" [8]. Alterations to the wiring specifically in the robot arm are required post separation. The joint emergency stop circuit should be replaced with a high signal disabling the joint stop and allowing the operations pendant can become the primary emergency stop.

It is also important to specify with the supplier that the robotic arm now separated from its power supply be fitted with a transformer for a mains connection. Without this the robot would need a second battery supply to replace the one that would typically be embedded into the AMR. The added benefit of this is that the AMR when separated will now be fed by a larger or dual battery system increasing its range, but the arm will be limited by its need of a mains power supply.

3.2. Labour consolidation

Robotic arms and their ancillaries will typically weigh between 30-45kg. As per Health and Safety England guidelines, this means that lifting the robotic arm from the AMR will require two or more workers [9]. In the Manual Handling Operations Regulations this weight limit varies between a lifting limit of 25kg and 17kg. To safely lift and separate a mobile manipulator, a minimum of 3 staff members are required, at least two to perform the lift and one to turn off the fuse for the robot's power and disconnect the power and data cables. For SMEs using a small workforce or operating on a skeleton crew this can mean that hiring can become less inclusive as male candidates are required to consolidate these types of labour-intensive tasks. It also means that staff resource is stretched when the robot needs separation. Using the pneumatic lift not only consolidates the task from a minimum of two workers, it also reduces the risk of accident and injury.

Figure 2 shows a general set up for the lift that should be replicable for any mobile manipulator that uses a top loaded AMR. The apparatus should be bolted to the floor with an opening set to width of the robot with a tolerance in line with the manufactures recommended docking limits. There should be a minimum of 4 contact points on the robot holding it from the front and rear.

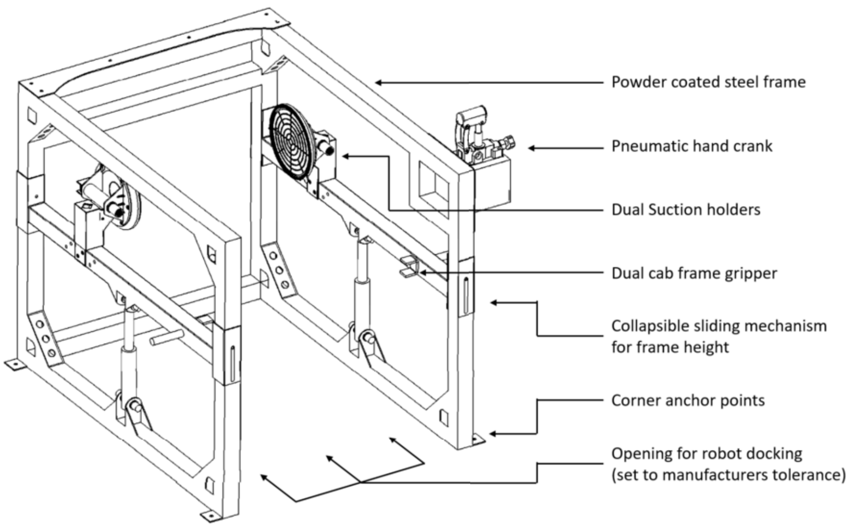

Figure 2. Robot Separation shelf designed by UoG, modelled by Antoine Sarrazin

3.3. Standalone systems

When properly separated the division of a mobile manipulator can allow for simultaneous use of the robot arm and mobile base. This opens up the ability for the AMR to perform material handling tasks or attach new modules for tasks such as disinfection, telepresence, or surveillance [4]. The collaborative arm can become available for pick and place, independent/assisted assembly tasks or inspection tasks [5]. Understanding where a business will get the highest benefit from this separation requires an in depth look into their ERP system. Knowing all the tasks that occur in the workshop/factory and the schedule in which the business works to, the ERP system will be capable of adding planned separations for the business to take the most benefits from the mobile manipulator package.

It can also be seen that custom modules for AMRs are becoming more common, with cost effectiveness being highest when a business already has an AMR, collaborative arm, or both. Where AMRs can cost greater than £20,000 and a collaborative robotic arms can cost greater than £30,000. Modules such as UV lights for sterilisation, rollers for automated pick up and drop off tasks and intelligent towing bars can cost £7000 - £17,000. This can be unjustifiable for a single use case, but when the base is available, and the workshop is capable of allowing quick changeovers it can be a viable option.

4. Conclusion and Further Work

The design and build of the separation shelf was successful in addressing the challenges of using modular robots in an efficient manner. The solution is applicable across multiple platforms, addressing the issues of staff specialism and labour intensity. A Photo can be seen of the separation shelf in operation in Figure 3. Improvements in the equipment such as automatic lifting rather than a manual crank, blind cable connectors for engaging/disengaging of the top module and integrated power cabling to consolidate the arms power supply would all provide greater convenience to workers. This level of refinement would typically be in a commercial product.

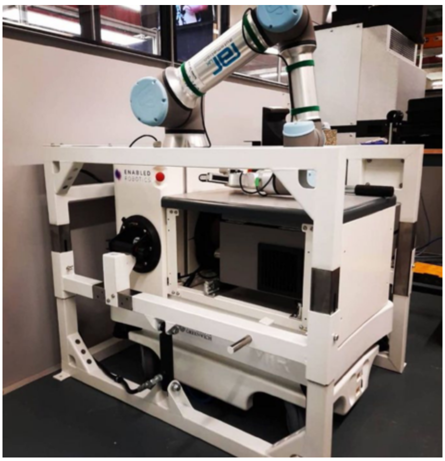

Figure 3. Photo of the Separation shelf manufactured by G.Brightling Fabrication & Development

Further work in this area would involve expanding the scope outside of mobile manipulators, working on quick change apparatus for other modules that can be mounted onto an AMR. These modules would include UV sterilisation which has grown in interest since the COVID-19 pandemic [10] and can be used for quick change operations and hook systems for where towing applications are required for their superior weight capacity. Detailed testing of an ERP integrated job list would also be of great interest as this would demonstrate how docking can be added to the job list and separation procedures can be added, providing accurate times.

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