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Proceedings TEEM 2022: Tenth International Conference on Technological Ecosystems for Enhancing Multiculturality

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TEEM 2022 Preface

We celebrated the tenth edition of the Technological Ecosystems for Enhancing Multiculturality (TEEM) International Conference in the University of Salamanca, the institution in which it was born. Nine years ago, this academic conference project started. We had the goal to create a new interdisciplinary event in which the new advances in technology would be reflected in the resolution of the problems of Education and the Knowledge Society. We pursued the establishment of a new research community with a strong aim to help Ph.D. students to have opportunities to know and collaborate with consolidated researchers worldwide.

Looking back, we are very satisfied with the obtained results. We are a consolidated research community that has grown, many research projects were born in the previous editions, many collaborative papers in prestigious books and journals have been published, many international internships have occurred, but we are very proud because tens of new Ph.D. participated in the previous editions of TEEM Doctoral Consortium track and contribute to help the future Ph.D. to be part of the TEEM family.

This edition is a reunion event, fully face-to-face, after two editions in virtual and hybrid mode due to COVID-19. More than one hundred and ninety researchers shared their scientific advances in this tenth edition. Some of them were new, but most of them were regular participants in this conference, which reinforces the original idea of forming a solid scientific community.

It is also important to say that this TEEM tenth edition was within the European Campus of City-Universities (EC2U) Alliance (https://ec2u.eu/), co-funded by the Erasmus+ Programme of the European Union. The EC2U is a multi-cultural and multilingual Alliance consisting of seven long-standing, education- and research-led, locally and globally engaged universities from four diverse regions of the European Union: the University of Coimbra, the University of Iași, the University of Jena, the University of Pavia, the University of Poitiers (Coordinator), the University of Salamanca and the University of Turku.

TEEM 2022 has had 210 submissions from which 145 full papers were accepted; that is, there is a 30% rejection rate. These papers have involved 424 authors from 26 countries.

The TEEM 2022 was organized in 16 thematic tracks that covers research areas such as Educational Assessment and Orientation, Human–Computer Interaction, Computers in Education, Communication Media and Education, Medicine and Education, Learning Analytics, Engineering Education, Robotics in Education, Diversity in Education, Gamification and Games for Learning, Smart Learning and Laboratory-Based Education.

In addition to the regular sessions, the TEEM 2022 edition featured three prestigious guest speakers. Firstly, Gema Parreño Piqueras, Developer Advocate at Iterative, gave the inaugural keynote entitled "Alignment of language agents in video games." Dr. Oriol Borrás Gené, Professor at Universidad Rey Juan Carlos (Spain), gave a keynote entitled

"3 years escaping from a room, learned lessons." The closing lecture was given by Dr. Ricardo Colomo-Palacios, Full Professor at the Østfold University College (Norway), with the title "Academia-Industry collaboration: a view from IT."

We would like to thank the members of the Steering Committee for their counsel and the International Scientific Committee for their accurate and timely reviewing. We would also like to thank the Track Chairs for their efforts in organizing the academic issues related to each track and the Organizing Committee for their huge effort in all the associated tasks that an international conference involves. We would like to do a special mention for the Editors-in-Chief of the linked journals that have offered special issues or slots in their regular issues for those selected and extended papers of TEEM 2022 conference that will have another in-depth review following the guidelines of each journal. Last, but not least, we would like to thank the participating organizations: University of Salamanca, Research Institute for Educational Sciences at the University of Salamanca, GRIAL Research Group and European Campus of City-Universities (EC2U) Alliance for their support.

Next year, we will continue with eleventh edition of TEEM Conference that will be held at Bragança, Portugal, organized by Instituto Politécnico de Bragança.

October 2022

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Automated Ceramics Tableware Finishing: A Laboratory Prototype for Concept Validation

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Abstract. In this paper, it is presented an integration between a finishing device and a collaborative robot in order to automate the sanding process of a ceramic industry in Portugal. The finishing device and the collaborative robot are described as well as the communication between the devices. It was used a computer responsible for decision making and control of all the system. The system was able to control the position of the finishing device according to the force done in the sponge by the ceramic. The final system behavior was presented and discussed, which was satisfactory and performed well. The presented experimental setup is not intended for industrial use, but it is suitable for concept prove, in laboratory. The outputs that will emerge here will be applied in a future industrial application, with requisites compatible with the application environment, regarding robustness and repeatability.

1 Introduction

The ceramic products industry has a long tradition in Portugal, where there are currently more than 300 active companies [1]. One of this companies is GRESTEL - Produtos Cerâmicos, S.A. Founded in 1998, and is dedicated to the production of tableware, oven and serving accessories in fine stoneware, in an original concept of quality, durability and exclusive design [2].

Modern ceramics is under constant pressure to manufacture ever more complex products with more rigorous standards. This is why companies are forced to develop alternative processes and techniques to improve manufacturing and quality control chains. In addition to these advances, industries must increase automation levels and replace human operators in repetitive tasks, such as the

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elimination of excess material derived from the molding process. However, due to the fragile nature of the produced ceramics, replacing human labour by robots is a very complex task. Specially in activities that deals with soft materials with irregular shapes. In this context, tactile and force feedback actuation must be included in any robotic manipulator in order to control the amount of pressure exerted in the material while adapting to disturbances produced by slight differences in the production batch due to random changes in the operating conditions.

In the market there are some commercial solutions that seek to solve these series of problems, such as the finishing of cups and bowls [3], or for ceramic pieces with irregular shapes through manipulation with collaborative robots [4]. In addition, there are different articles related to the problem, such as, the control of the applied force and prediction of deformation [5], or the calculation of the trajectory in the manipulation of objects through simulation [6]. However, in these examples the reader can see partial solutions or related to other applications. It is for this reason that this work seeks to find a solution to the finishing of ceramic pieces together with the STC 4.0 HP project.

This project continues the work done in a previous version, already described in an article in the framework of the STC 4.0 HP project [7] which consists of a device designed to remove excess material from ceramic pieces. With the addition of a collaborative robot that will be in charge of manipulating the ceramic piece, and a computer that directs the states that the process goes through.

At this stage of the project, the prototype is a laboratory device, where materials and devices not suitable for the industrial environment were used, however, as part of future work, it is planned to implement it at an industrial level.

This paper is structured as follows. The Sect. 2 describes the finishing device created. The Sect. 3 presents the collaborative robot and its communication with the computer. Section 4 describes details about the integration between the finishing device and the robot. Section 5 presents and discuss the results of the integration. Lastly, conclusion and future work are presented.

2 Finishing Device

With this prototype [7], it been sought to solve the problem of finishing irregular pieces made in the ceramic products company GRESTEL, which until then had been done by hand. In order to try to solve this problem, the idea of controlling the force with which the sponge is pressed on the ceramic piece was proposed. This control has been carried out thanks to the implementation of a closed-loop control of the position and the speed of rotation of the sponge.

As can be seen in the Fig. 1, the device consists of a structure that supports a sponge mounted on a shaft, which by means of a DC motor rotates at a constant speed, this structure is mounted on a base with a pair of rails, the position of the structure can be adjusted thanks to a stepper motor that is coupled to a lead screw. Another approach could have been the use of a pneumatic system

Fig. 1. Laboratory prototype. Source: Author

to control the position of the sponge, as in various works [8–10], however this idea has a better result when using a tool that needs a greater degree of control in different axes, and entails a higher degree of complexity. For the case of this work, control is only necessary in a single axis.

The initial prototype is a laboratory device, which was used to test and analyze different hypotheses to perform force control. At this stage, the speed and position control was carried out only by means of an Arduino UNO microcontroller.

In the speed control (Fig. 2), an encoder is used to take the readings of the rotational speed, then the control is carried out through a PI controller implemented in the Arduino and then send the signal to the DC motor driver. On the other hand, for position control (Fig. 3), a sensor integrated with an LVDT is used, which measures the current position of the structure and sends this data to the microcontroller. Simultaneously, the current consumed by the DC motor is measured, which is proportional to the force applied to the ceramic piece. With these two variables, the microcontroller is able to calculate the necessary displacement to keep the applied force constant.

3 Collaborative Robot

This section aims to describe the collaborative robot that was integrated in the final system, which is better described in Sect. 4. The Kassow Robots' collaborative robot (KR810), presented in Fig. 4, is a robot arm with 7 axes, whit a joint speed of 3.92 rad/s, it has a payload of 10 kg and a reach of 850 mm. It is included a controller and a tablet, where it is done all the robot programming. The collaborative robot's development environment is high level, simple and has a intuitive interface for the user, composed by block programming [11].

The collaborative robot includes several digital and analog inputs/outputs, Ethernet tool and another communications like RS232, RS485 and modbus [12].

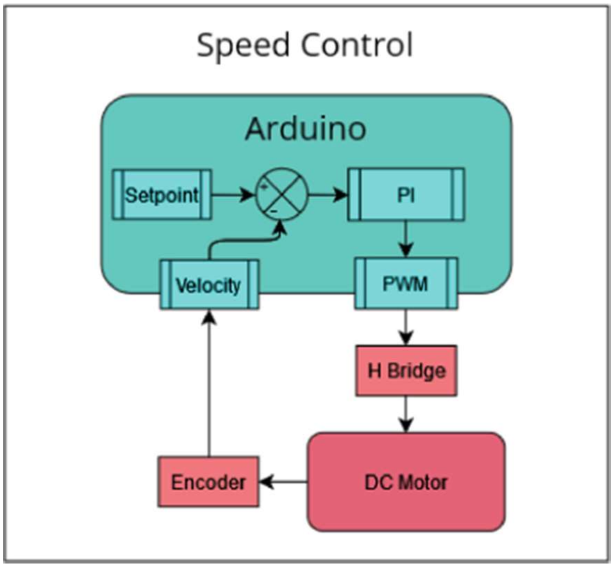

Fig. 2. Speed control block diagram. Source: Author

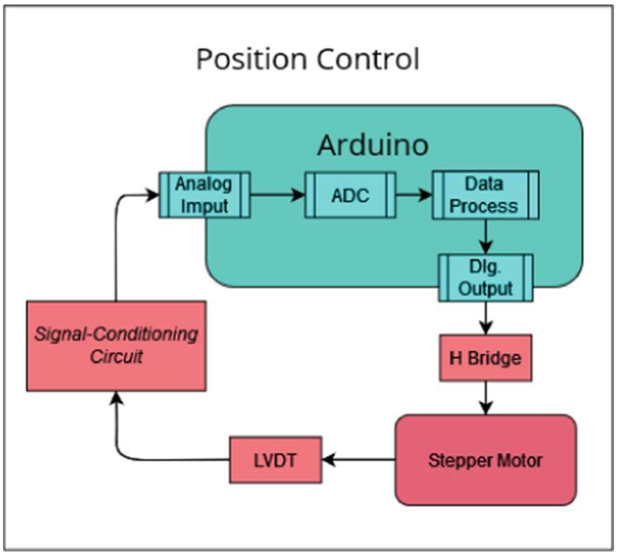

Fig. 3. Position control block diagram. Source: Author

In this paper, it was applied a computer to control the system, therefore, in order to allow the use of own libraries that already exists and a communication protocol that the robot includes, it was chosen the modbus TCP communication through Ethernet to communicate the collaborative robot and the computer.

Modbus is a data communication protocol very common and used in industrial automation establishing a common language to information exchange between electronic devices. The modbus works in two ways, modbus serial based in master/slave architecture and modbus TCP based on server/client architecture. It is encompasses various physical configuration like RS-232, RS-485, Ethernet, among others [13].

Fig. 4. Collaborative robot KR810. Source: Author

Decision making on the computer is done through the Lazarus software, an open source development tool, which used the Free Pascal compiler and Pascal programming language. Lazarus is a programming environment which presents a great performance and response time, besides to allow the creation of graphic application for user interaction [14].

4 Integration

For this article, we seek to perform an integration between the finishing device and the collaborative robot. The main objective is to create a first instance of communication to use as a starting point for future versions, where the robot will receive and send signals to the PC, and the microcontroller will send the variables obtained by the sensors and will receive the orders from the PC. The computer will be in charge of controlling and governing the states that the process goes through.

At this stage, the function of the collaborative robot is to manipulate the ceramic piece, taking it from an initial point to a target point, once this point is reached, it rotates the piece 360 degrees about its center, once the trajectory ends, it returns to the initial position. On the other hand, the objective of the finishing device is still to control the position and speed, only that it will be the computer that indicates when to perform each control.

Figure 5 illustrates the system data flow. Decision making is controlled by the computer, which receives all the relevant information about the system and sends messages to microcontroller, via serial, and collaborative robot, via modbus, related to actions that must be taken. These actions are based on the data received by the microcontroller, like the current, position and speed, and the data received by the robot, related to finishing moves. Microcontroller reads the current and the position through the analogs inputs, and controls the position of the finishing device and the rotation speed of the sponge sending signal through the digital outputs.

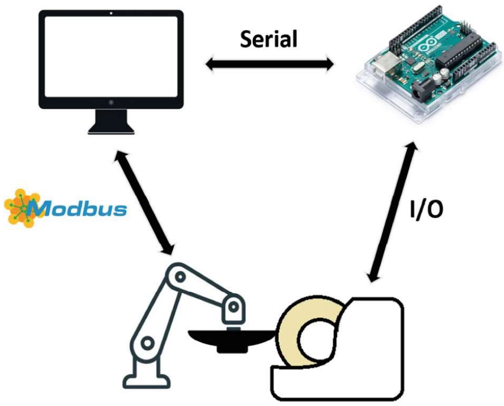

Fig. 5. System devices communication. Source: Author

For this first version, it was printed a circular plate, to perform tests, using a 3D printer and it was attached to the robot flange in order to keep it fixed. Then, based on the plate radius, the robot can reach the target point next to the sponge. The completed system is showed in Fig. 6, where it is possible to visualize the collaborative robot with the 3D plate attached and touching the sponge.

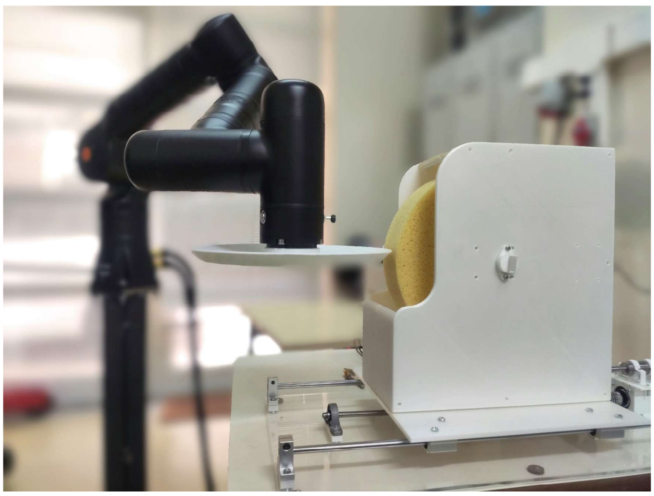

Fig. 6. Integrated system. Source: Author

The control of the system is based on a state machine composed by 6 stages illustrated in Fig. 7. The state machine controls the change of states and the actions that must be done based in a frequency 30 Hz. At state S0, the system is waiting the user starts the process of sanding through a button that exists in the Lazarus graphical application in the computer.

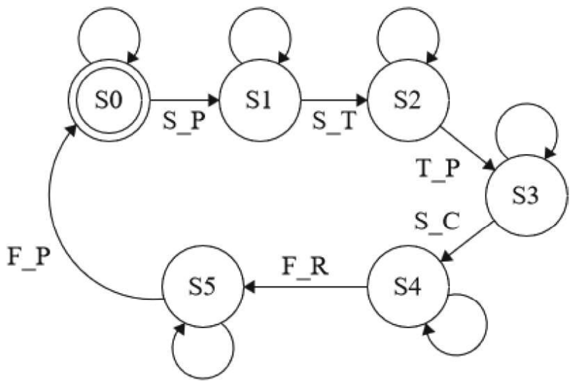

Fig. 7. Control state machine of the system. Source: Author

When the user starts the process, the flag S_P is activated, then the state changes to S1 and the sponge starts to rotate. The system will remain in S1 until the sponge speed reach the stationary state, when it happens the flag S_T is activated and the state changes to S2. At state S2, a message is sent to the robot to move to the target point and when this movement is finished, flag T_P is triggered and the system changes for the next state.

At state S3, the finishing device will move until the sponge touch the 3D plate and then the system is ready to start the control, activating the flag S_C and changing to state S4. The state S4 represents the moment when the robot is rotating the 3D plate around its center, while the finishing device is performing the control, adjusting the position according to the current that is proportional to the force.

When the robot already turned the 3D plate for all its trajectory, the flag F_R is triggered and the system changes the state to S5. At this state, the robot perform a movement, reorganizing the joints, to return to the start point. After that, state S5 is finished, flag F_P is activated and the system is ready to restart the process again.

5 Results

Once the software was implemented in the computer and interconnected with the robot and the finishing device, a test was carried out obtaining the data of the current, position and speed of the sponge, together with the state in which the process is, in function of the time, and the graph of the Fig. 8 was obtained.

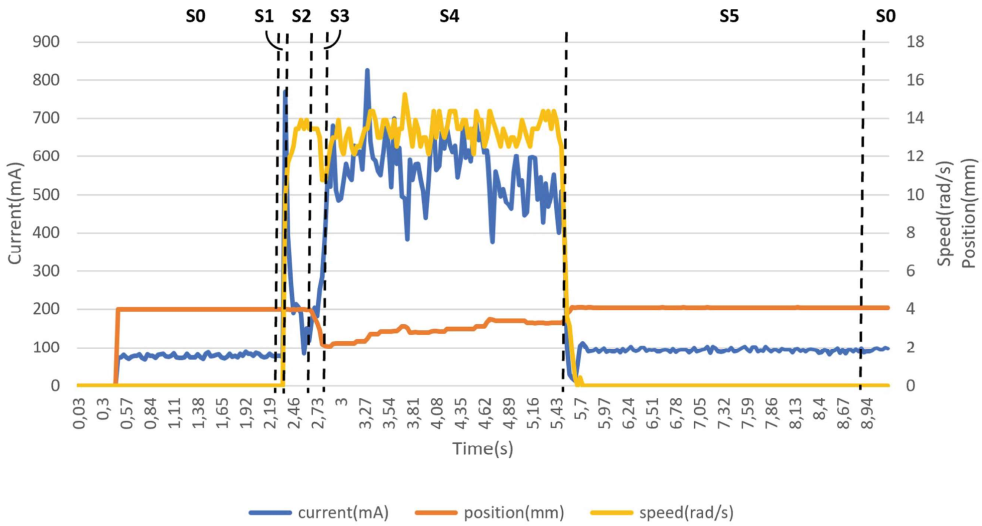

Fig. 8. System behavior. Current, position and speed of the sponge in function of the time.

In the first 0.4 s the system still does not read the data of the variables. Once the data capture begins it can be seen that the rest position of the device is 4 mm, and that the nominal current is less than 100 mA. At this moment the system is in the S0 state, so it is waiting for the user to press the button to start the process.

Once the button is pressed, the system goes to state S1 and the sponge begins to rotate, it remains in this state for an instant until the speed of rotation is close to that of the steady state, this takes about 100 ms. Once this speed is reached, the system changes to state S2, where the computer sends a signal to the robot to move the plate from the initial point to the target point, this process takes about 300 ms. Once it reaches this point, it sends a new signal to the computer and it changes to next state.

In state S3, the device approaches the plate until the pressure exerted is the desired one, this occurs when the current consumed by the DC motor is greater than 400 mA. The graph shows how the current increases as the distance decreases. Once this point is reached, state S4 is passed, where is in which the robot performs a trajectory that rotates the plate on its axis, making the sponge cover its entire perimeter. This state is where the control of the position by the device begins. Pushing the sponge in or out as needed to keep the force constant.

Once the trajectory of the plate is finished, the system goes to state S5. In which the position control is stopped and the device returns to the home position, and the spinning of the sponge stops. In turn, the robot returns to the initial position. Once everything is at its starting point, the system returns to state S0.

6 Conclusions and Future Work

It can be concluded that an integration between a finishing device and a collaborative robot was performed in order to automate a sanding process of a ceramic industry. And it can serve as a starting point to continue with new approaches. The communication between the devices at a frequency 30 Hz was enough for this application.

It was possible to include a computer responsible for decision making and control of the actions through the creation of a state machine. Besides that, the software Lazarus used allowed the creation of a graphical interface for user interaction and visualization of the data in real time.

The integration complied with the expected behavior, being able to control the position according to the sensor current, which is proportional with the force that is done on the sponge by the ceramic. And the collaborative robot was able to move the 3D plate according to its radius and rotate around its center.

As future work, it is proposed that the position control is performed by the collaborative robot, allowing a high precision and a better control face different shapes of plates, such as ovals, in which the trajectory is not symmetrical.

It is also proposed the use of a force sensor on the robot instead of the sensor that is being used now in the finishing device. Besides that, it is expected the use of a suction claw to hold the ceramic, taking into account a cloud of points of the piece, making it possible to calculate the center and radius. Lastly, it is expected that the system could be applied within the industry, once improvements in robustness are made.

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References

1. da Cerâmica, P.: Portal da cerâmica (2012). http://www.ceramica.pt/setor.php. Accessed 26 Jan 2022
2. Grestel homepage (2022). https://grestel.pt/perfil-da-empresa. Accessed 14 July 2022
3. Auto finishing machine for ceramic cups and bowls (2022). https://www.ceramicmachine.com/product-details/auto-finishing-machine-for-ceramic-cups-and-bowls/. Accessed 14 July 2022
4. CERINNOV, "Robotised finishing unit (2020)." https://www.cerinnov.com/wp-content/uploads/2020/04/finition.pdf. Accessed 3 Mar 2022
5. Kuhlenkotter, B., Zhang, X.: A robot system for high quality belt grinding and polishing processes (2005)
6. Wang, W., Liu, F., Liu, Z.: Prediction of depth of cut for robotic belt grinding (2017)

7. Alvarez, M.: Prototyping and control of an automatic ceramic tableware finishing device. In: Brito Palma, L., Neves-Silva, R., Gomes, L. (eds.) CONTROLO 2022, pp. 167–178. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10047-5_15
8. Roswell, A., Xi, F.J., Liu, G.: Modelling and analysis of contact stress for automated polishing. Int. J. Mach. Tools Manuf. **46**(3), 424–435 (2006)
9. Zhang, X., Chen, H., Yang, N., Lin, H., He, K.: A structure and control design of constant force polishing end actuator based on polishing robot. In: 2017 IEEE International Conference on Information and Automation (ICIA), pp. 764–768 (2017)
10. Liao, L., Xi, F.J., Liu, K.: Modeling and control of automated polishing/deburring process using a dual-purpose compliant toolhead. Int. J. Mach. Tools Manuf. **48**(12), 1454–1463 (2008)
11. Kassow robots - kr810. https://www.kassowrobots.com/products/kr810/. Accessed 1 June 2022
12. Kassow robots: software manual. https://www.rd-as.com/app/uploads/2019/02/Software-manual-Kassow_Robots_V1.0.0_UPDATED-FONTS.pdf. Accessed 1 June 2022
13. Protocolo modbus: Fundamentos e aplicações. https://www.embarcados.com.br/protocolo-modbus/. Accessed 1 June 2022
14. Lazarus homepage. https://www.lazarus-ide.org/. Accessed 1 June 2022