11-2022

A Smart Parallel Gripper Industrial Automation System for Measurement of Gripped Work Piece Thickness

Erik Kocher
Michigan Technological University, ehkocher@mtu.edu

Chukwuemeka George Ochieze
Michigan Technological University, cochieze@mtu.edu

Ahmat Oumar
Michigan Technological University, aooumar@mtu.edu

Travis Winter
Donald Engineering

Aleksandr Sergeyev
Michigan Technological University, avsergue@mtu.edu

See next page for additional authors

Recommended Citation

E. Kocher, C. G. Ochieze, A. Oumar, T. Winter, A. Sergeyev, M. Gauthier, N. Rawashdeh, "A Smart Parallel Gripper Industrial Automation System for Measurement of Gripped Work Piece Thickness", 2022 American Society for Engineering Education (ASEE) Conference for Industry and Education Collaboration (CIEC), Tempe, AZ Feb. 4-11 2022, ASEE. Retrieved from: https://digitalcommons.mtu.edu/michigantech-p/16519

Follow this and additional works at: https://digitalcommons.mtu.edu/michigantech-p

Part of the Computer Engineering Commons, Computer Sciences Commons, and the Electrical and Computer Engineering Commons

Authors

Erik Kocher, Chukwuemeka George Ochieze, Ahmat Oumar, Travis Winter, Aleksandr Sergeyev, Mark Gauthier, and Nathir Rawashdeh

A Smart Parallel Gripper Industrial Automation System for Measurement of Gripped Work Piece Thickness

Erik Kocher[a], Chukwuemeka George Ochieze[a], Ahmat Oumar[a], Travis Winter[b], Aleksandre Sergeyev[a], Mark Gauthier[b], Nathir Rawashdeh[a]

[a] Michigan Technological University, [b] Donald Engineering

Abstract

As part of the advanced programmable logic controllers (PLC) course at Michigan Tech, this class project is performed on a mechatronics system gifted by Donald Engineering, a Michigan-based supplier of industrial automation systems and components. This paper explores the functionality and ladder programming of the smart parallel gripper system to measure the width of components grasped with the gripper. In addition, details of the system's components, operation, more advanced uses are discussed. On the automation line, this smart gripper can be used to measure the thickness of work pieces while handling them and classifying these as either acceptable, too large or too small. In addition, the pneumatic power supply and safety measures are discussed, along with the human machine interface (HMI).

Introduction

Pneumatically actuated grippers are widely used in industry and academia to carry out tasks varying from workpiece handling to component quality checks and material characterization. Schunk grippers are widely used in industry, and in research for advancing robotics technology. Drimus *et al.* utilizes a Schunk PG70 parallel gripper that has been equipped with custom tactile sensors that are the object of study for the paper [1]. Using these custom sensors with the gripper, the robot is able to identify different objects based on rigidity and deformation characteristics.

Due to the excellent quality of the Schunk grippers and the versatility of parallel gripper systems, they are commonly used for testing new gripper technologies as previously mentioned. A team of researchers currently exploring self-aligning grippers that use electrostatic/gecko-like adhesive to pick flat surface parts [2]. The team is showing very promising results and is even able to pick parts of non-smooth surfaces, like fabrics. This team uses a Schunk EGP 40-N-N-B two-finger parallel gripper, which is very similar to the gripper used in the system presented here.

Hardware for Industrial Gripping at SCHUNK GmbH & Co. KG details how and when Schunk grippers are used in industrial settings and how they are advancing [3]. Discussed topics include topics as why automated gripping machines are often overlooked, but really play a vital role in countless manufacturing processes. The author says that because humans by nature have one of the most advanced gripping systems ever created, blended with superior sensors and data processing capabilities that tasks such as simple gripping often seem trivial. The authors go into detail about how handling material does not add value to a particular part, but still does play a crucial role that cannot be overlooked. In addition, recently published works on gripper design and applications include soft grippers for handling of food items and agricultural produce [4, 5], as well as force-controlled grippers for handling of fragile workpieces [6, 8].

The pneumatically actuated parallel gripper system explored in this paper was donated to Michigan Technological University Applied Computing Department by Donald Engineering to help provide a hands-on learning experience for students in the electrical engineering technology and mechatronics programs. The parallel gripper system presented in this work can grasp objects and simultaneously measure its width. System functionality, components, safety, and an example of how the technology could be used in an industrial application are discussed.

System Description

The system described in this paper is designed around a gripper than can grasp objects and simultaneously measure their widths. It has the capability to have three different measurements programmed/taught into it, so that when a part is gripped and measured, if it matches one of the preprogrammed measurements, the corresponding light will be lit signaling that the part matches the preprogrammed size. The station is shown in Fig 1.

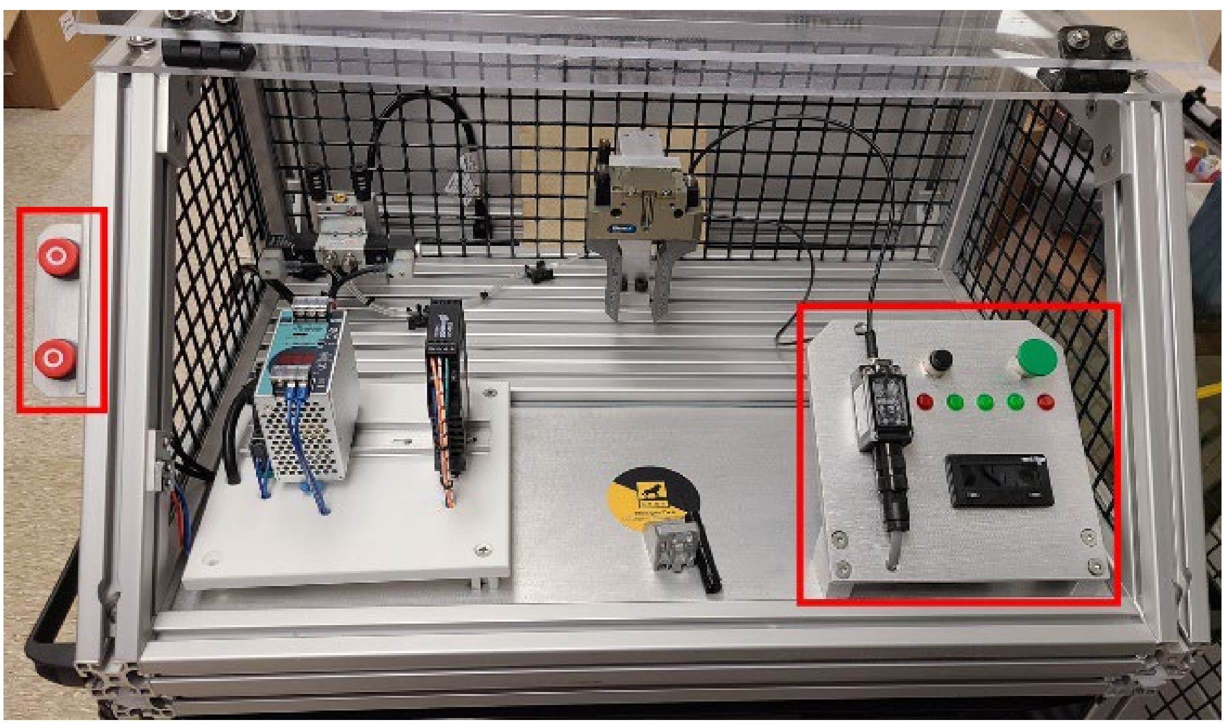
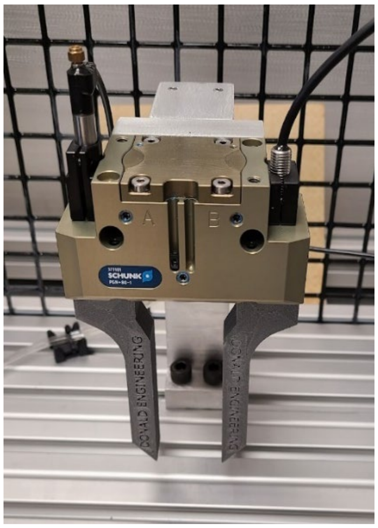


Figure 1: Smart gripper system with highlighted HMI

Human Machine Interface

The HMI of the system allows for easy system operation by the user. The HMI has external controllers, on the left side, which are used when the safety cover is closed, and components are moving. The internal HMI with the display is used for programming and setup when the system is not in motion and the cover is open. The internal HMI is not accessible while components are moving but can be seen through the clear cover. The HMI components are labeled with red boxes in Fig. 1.



(a) gripper

(b) measurement unit

(c) power supply

(d) pneumatic valves

Figure 2: Main components of the gripper system.

Controller

The system is controlled by a *Clippard Cordis* closed loop regulator, which monitors and creates system inputs and outputs. This controller enables the operator to measure, set, monitor, adjust, and record the dimension of the object placed between the gripper fingers. The Cordis controller features include smooth linear control, real time adjustable PID control, multiple flow configurations, static or dynamic applications with the same proportional regulation, no integral bleed required, customizable pressure ranges and mounting options. The controller is mounted with the HMI shown in Fig. 1.

Gripper - 371101 Schunk PGN + 80-1

This is a universal 2 finger parallel gripper that is pneumatically actuated and capable of high gripping force since it is equipped with a multi tooth guidance system. It has a base jaw so that custom fingers can be used, and has built in bracketry so that sensors, such as proximity switches and control cams can be directly mounted and utilized. This particular gripper is equipped with custom fingers from Donald Engineering. The gripper is shown in Fig. 2(a).

Measurement Unit

The Schunk APS-M1E is a mechanical analog sensor that is capable of accurately recording gripper jaw position when used in conjunction with specific gripper systems. This module allows the gripper to measure the width of grasped parts. The measurement unit is shown in Fig. 2(b).

Power Supply

The power supply system takes 100-240VAC power with a maximum current of 2A at 50-60 Hz. A selector switch must be set to the appropriate input voltage level. The unit converts the AC power to DC for use in the system. The DC power is output at 24V with a maximum of 4.2A. It has a built-in display to show the current voltage output. The power supply is shown in Fig. 2(c).

Valving

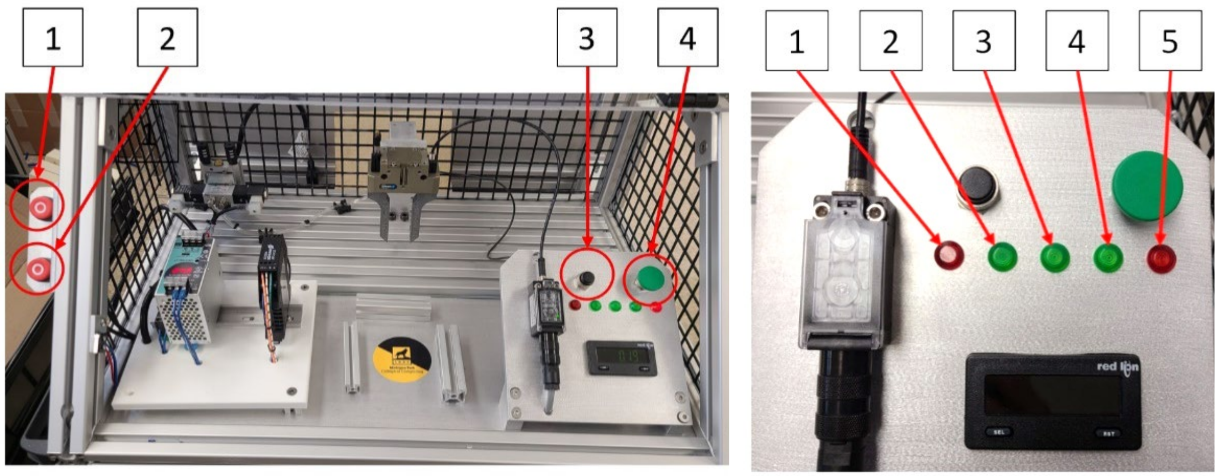
To actuate the gripper system, air pressure must be precisely applied to the proper cylinders to open and close the fingers. Clippard valves actuated with 24 volts of DC power are used for this purpose. The pneumatic pressure is delivered from an external source connected via a charged airline. The valving is shown in Fig. 2(d).

System Operation

To operate the parallel gripper system, the unit must first be connected to a compressed air source via the yellow air hose on the side of the unit, and the black power cord coming out of the power supply on the station must be plugged into a 110-volt outlet. The station can be programmed to measure three different part widths, assuming the red HMI lights are used to represent the fully closed and fully opened gripper states. Figure 3, shows the button definition and the display light definitions along with the HMI, the controller, and the programming buttons. To operate the gripper system the following steps are recommended:

- Ensure the system is connected to a compressed air source and the power cord is plugged in.

- Pressing the upper red button (button 1) will close the gripper, pressing the lower red button (button 2) will open the gripper. The gripper will not actuate if the safety shield is not in the closed position.
- When the gripper is at any position - whether completely open, closed, or at any of the three preprogrammed part widths, the corresponding light will illuminate on the HMI. Typically, the left red light (light 1) will indicate the gripper is completely closed and if no part is detected. The right red light (light 5) indicates the gripper is completely open. These settings can be changed in the programming, but it is recommended to use the red lights for this purpose.



(a) buttons (b) indicator lights

Figure 3. Locations of the HMI's user buttons and indicator lights.

Operation Example

For this example, we will show the functionality of the gripper system by measuring three different width parts. The system has been programmed so that: light 1 will illuminate when the gripper is completely closed; light 2 will illuminate when the gripper grasps part 1; light 3 will illuminate when the gripper grasps part 2; light 4 will illuminate when the gripper grasps part 3; light 5 will illuminate when the gripper is completely open.

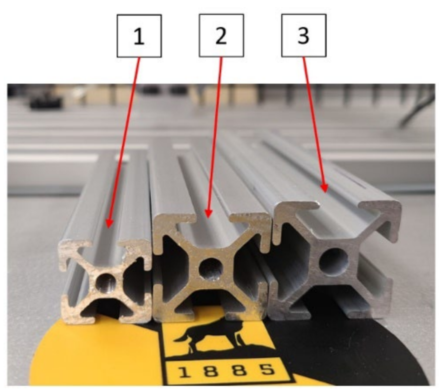
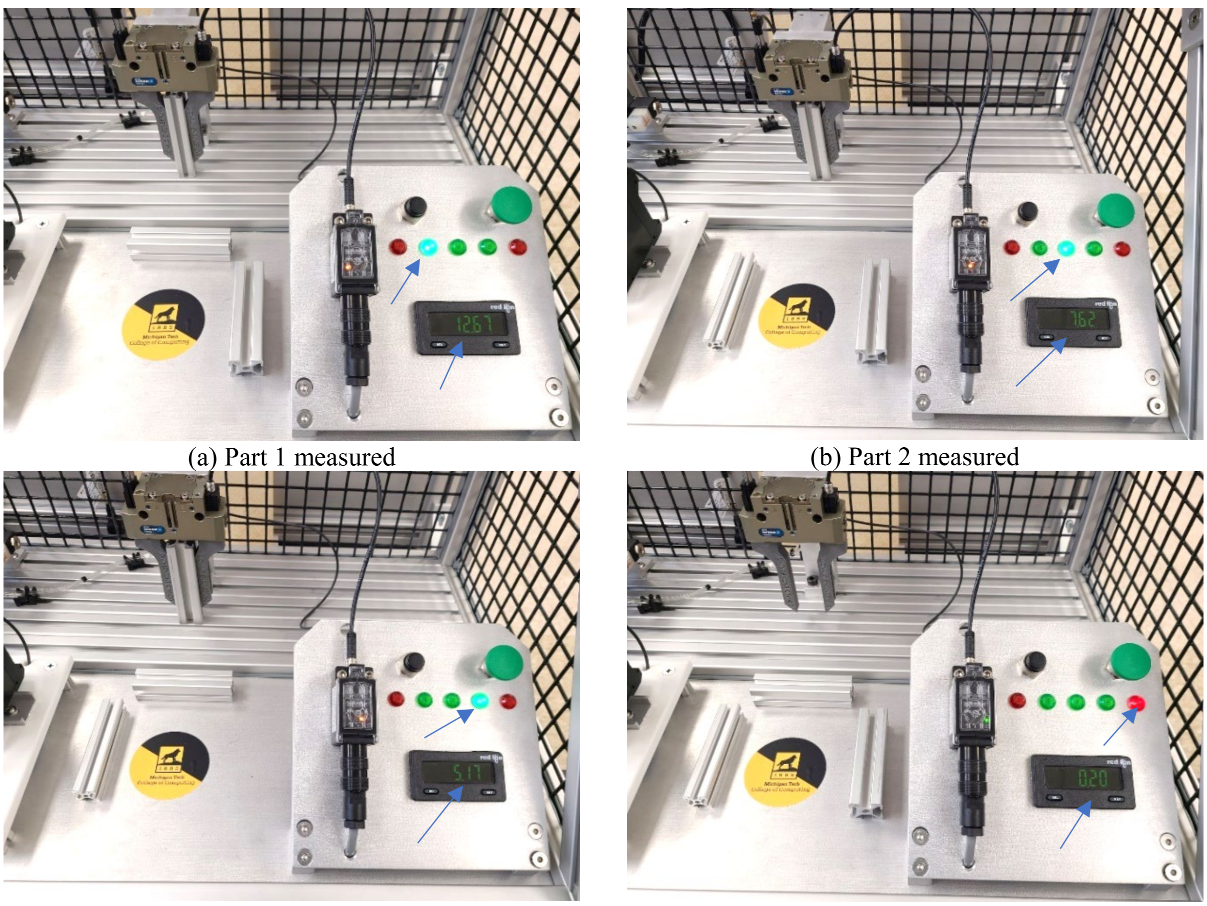


Figure 4. Gripper test work pieces.

For this example, the 3 different parts, 1-3, are shown in Fig. 4. The parts are each a different standard size of 80/20 aluminum extrusion that we will measure the width of. Figure 5 shows the four different gripper states represented by the four lights on the HMI. The fifth state of the gripper close without a work piece is not shown; however, it illuminates the left red light as discussed earlier. Parts 1-3 are stored in a clockwise pattern around the MTU College of Computing logo as shown, each part is stored in the same location when not being measured by the gripper. Each of the five potential states that can excite a light are shown in the images. Take note to which part is in the gripper while each of the green lights is lit up. The display shows the total distance the gripper fingers closed compared to the open position. To determine part width, we must know the open distance between gripper fingers (35 mm), we can then calculate part size. For example, the large part in Fig. 5(c), the width is 35 mm - 5.17 mm + 0.20 mm (open offset) = 30.03 mm, the actual part width is 30.0 mm.



(a) Part 1 measured

(b) Part 2 measured

(c) Part 3 measured

(d) Open grippers

Figure 5. Griper states with work piece measurement shown od the display.

To program the part widths, the following steps are used. This process is also shown in a flowchart in Fig. 6:

- Ensure the system is connected to a compressed air source and the power outlet.
- Pressing the upper red button (button 1) will close the gripper.
- Pressing the lower red button (button 2) will open the gripper.

- Press the black button (button 3).
- Wait until the far-left red light starts to blink (light 5).
- There are two options:
    - pressing the green button (button 4) will program the current gripper width into the blinking light
    - pressing the black button (button 3) will skip the programming of this light, leaving the current stored value.
- Once advanced to the next step, the next light to the left will start to blink, at this stage, the black or green button can again be used to program or skip this measurement setting.

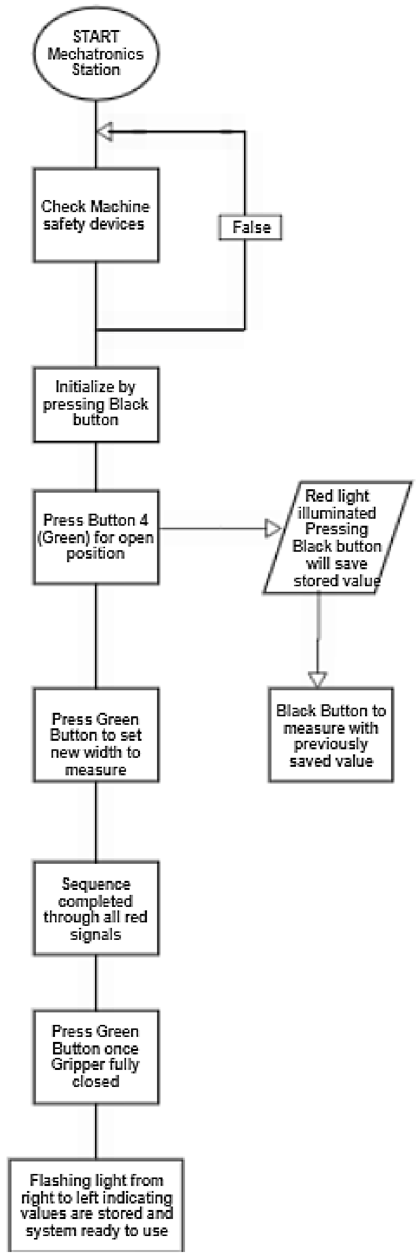


Figure 6: Part Programming/learning Flow diagram

- Repeat this process until all lights have been satisfactorily programmed or skipped.
- Once the left red light (light 1) has been programmed, the system is fully programmed, this will be indicated by all 5 lights illuminating briefly from right to left.

Following this procedure, the system will be ready for use with the newly "learned" measurement settings. These steps can be revisited at any time to change any of the preset widths.

Safety Features

The mechatronics station is equipped with three notable safety features: the fencing/cage around the entire system visible inFig. 1; a limit switch that will not allow operation without the clear shielding in the closed position; a Ross Controls air entry assembly for pneumatic control and air dump/release system shown in Fig. 7. The fencing/cage around the system is meant to protect the operator from the moving components, while the interior is the system is accessible via a clear shield on the front that can be lifted. The contact switch ensures that the system will not operate when the shield is open.

The ROSS Control air safety system is a panel-mounted unit that is for pneumatic conditioning and air dump release. Figure 7 shows the assembly. The air safety system has an air entry system via a drip leg with an energy isolation lockout L-O-X valve, a filter and regulator, and a control reliable safe exhaust double vent. The system is designed to supply air to the system until signaled to shut off and exhaust residual downstream pneumatic energy from the machine. This reduces the hazards associated with the presence of residual energy during employee access and/or minor servicing.

Figure 7: Pneumatics supply regulator.

Advanced PLC Programming

The fictitious system described here is meant to illustrate how this technology could be implemented in an industrial setting for production use. The system consists of a conveyor belt which is manually fed parts, as parts are transferred down line.

Inputs	Type of Input
Start Process	Push Button
Stop Process	Push Button
Part Detected	Proximity Sensor
Gripper in Place	Contact Sensor
Gripper Closed	Pressure Sensor
Gripper Open	Pressure Sensor
Gripper Home	Contact Sensor
Small Part	Potentiomter
Large Part	Potentiomter

(a) PLC inputs

Outputs	Type of Output
Red Light	Small LED Light
Orange Light	Small LED Light
Green Light	Small LED Light
Run Conveyor	Electric motor
Extend Solenoid	Electric Solenoid
Close Gripper	Pnuematic Valve
Open Gripper	Pnuematic Valve
Retract Solenoid	Electric Solenoid
Small Part Sort	Electric Solenoid
Large Part Sort	Electric Solenoid

(b) PLC outputs

Figure 8: PLC ladder logic input/output definitions

Figure 9: PLC ladder logic Program for example application

The parallel gripper system grasps each part to measure the width, then parts are sorted accordingly. The system is started with a push button that starts the conveyor, then parts moving down the line must be sorted into small part (3 cm) and large part (5 cm) storage areas. As a part reaches a particular spot (signaled by a proximity sensor), the conveyor will temporarily stop. A cylinder will be actuated that moves the parallel gripper system so that the part is in the gripper fingers. The gripper will then measure the part width, then release the part - the cylinder will retract. Once the gripper cylinder is retracted, the conveyor will restart. The measurement from the gripper will either indicate a small or large part, and an appropriate solenoid will be triggered that will cause a sorting gate to either move it right into the large part storage bin or left into the small part storage bin. Pushing the stop button at any time would stop the conveyor. There is a green light on while the conveyor is moving, an orange light on while a part is in measurement process, and a red light on while the system is turned off. An example of how the ladder logic for this process could be programmed is shown in Fig. 8. Finally, the definition of inputs and outputs used in the program are shown in Fig. 9.

Conclusions

The Donald Engineering parallel gripper system with measurement capabilities provides a unique learning opportunity to study the setup, function, and application of components and systems that span multiple engineering disciplines - which truly highlights the nature of the mechatronics program at Michigan Tech. Students studied each component to learn how it works and what function it provided to the station. In addition to learning about the physical setup, their research capabilities were expanded by performing a literature review of similar systems, and programmable logic controller programming skills were exercised and tested by creating the ladder logic program that would control the simulated application. Future research could include incorporating this station with other systems. The project has a companion video on YouTube.

References

[1] Alin Drimus, Gert Kootstra, Arne Bilberg, Danica Kragic, “Design of a flexible tactile sensor for classification of rigid and deformable objects” Robotics and Autonomous Systems, Volume 62, Issue 1,2014,Pages 3-15, SSN 0921-8890

[2] M. Dadkhah, Z. Zhao, N. Wettels and M. Spenko, "A self-aligning gripper using an electrostatic/gecko-like adhesive," 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, Korea (South), 2016, pp. 1006-1011, doi: 10.1109/IROS.2016.7759172.

[3] Parlitz C. (2013) “Hardware for Industrial Gripping at SCHUNK GmbH & Co. KG”. In: Carbone G. (eds) Grasping in Robotics. Mechanisms and Machine Science, vol 10. Springer, London. https://doi.org/10.1007/978-1-4471-4664-3_14

[4] Terrile, S., Argüelles, M., & Barrientos, A. (2021). Comparison of Different Technologies for Soft Robotics Grippers. *Sensors*, *21*(9), 3253.

[5] Zhang, B., Xie, Y., Zhou, J., Wang, K., & Zhang, Z. (2020). State-of-the-art robotic grippers, grasping and control strategies, as well as their applications in agricultural robots: A review. *Computers and Electronics in Agriculture*, *177*, 105694.

[6] Romeo, R. A., Fiorio, L., L’Erario, G., Maggiali, M., Metta, G., & Pucci, D. (2020). Dynamic control of a rigid pneumatic gripper. *IEEE Robotics and Automation Letters*, *5*(2), 2793-2800.

[7] Mitsuda, T., & Otsuka, S. (2021). Active bending mechanism employing granular jamming and vacuum-controlled adaptable gripper. *IEEE Robotics and Automation Letters*, *6*(2), 3041-3048.

[8] Zuo, W., Song, G., & Chen, Z. (2021). Grasping Force Control of Robotic Gripper with High Stiffness. *IEEE/ASME Transactions on Mechatronics*.

Biographies

ERIK KOCHER has a bachelor's degree in Mechanical Engineering with a minor in manufacturing from Michigan Technological University and in Dec. 2021 will graduate with his master's degree in Mechatronics from Michigan Tech. He has over four years of experience as a mechanical/mechatronics engineer working primarily in the defense industrial base specializing in electro-mechanical naval system test and design, vibro-acoustics, and CAE analysis. He worked as an engineer at GLSV Inc. starting in 2017 and in the summer of 2021 transitioned to the position of Research Engineer at Michigan Tech's Great Lakes Research Center. He has experience in the areas of product development, NVH & end user product testing, manufacturing, and intake/exhaust system development. He brings an interdisciplinary skill set spanning mechanical engineering, electrical engineering, and robotics with a focus on research and development.

CHUKWUEMEKA GEORGE OCHIEZE is a PhD student at the department of mechanical and aerospace engineering in the University of Virginia. He earned his master's degree from Michigan Technological University in the department of Mechatronics. During his master's degree program, Ochieze was a mechatronics instructor in the 2020-21 academic year for the Career Technical Education (CTE) program in Mechatronics, which was recently launched by Michigan Tech and the Copper Country Intermediate School District (CCSID). Prior his master's program he worked with Lafarge Africa PLC as a mechanical design engineer and Instructor.

AHMAT OUMAR has a Master in Mechatronics from Michigan Technological University. Prior to pursuing a Master of Science degree at Michigan Tech, he has worked at Intel Corporation's technology manufacturing group as a manufacturing engineer. During his time at Intel, Ahmat played a critical role in meeting Intel's goal across several technology platforms by making process improvement for photomasks. While pursuing his master's degree in Mechatronics, Ahmat worked as an intern for Veo Robotics as an application engineer intern developing complex robotics vision system that will allow robots to work side by side without hurting them.

TRAVIS WINTER is the engineering manager at Donald Engineering. He was instrumental in building and commissioning the advanced programmable logic controller systems installed at Michigan Technological University's Mechatronics Playground.

ALEKSANDR SERGEYEV is a Professor of Mechatronics, Electrical, and Robotics Engineering Technology in the Department of Applied Computing at Michigan Tech. He is a Director of FANUC Authorized Certified Robotic Training Center, and a Director for Master of Science in Mechatronics degree program at Michigan Tech. Dr. Sergeyev is a member of SPIE, ATMAE, IEEE, and ASEE professional organizations, and has mentored numerous undergraduate senior design projects and student publications.

MARK GAUTHIER is the President and Owner of Donald Engineering Co., Inc (DE). located in Western Michigan. After Graduating from Michigan Technological University in 1985, he worked as a technical designer at SDRC in Farmington Hills, Michigan in statistical analysis and assembly review for the automotive industry. In 1988, he joined the family business at Donald Engineering and became power specialist and automation designer. He became president of DE in 1996. In 2019, he consulted and assisted with starting up the Mechatronics program at Michigan Technological University to further education in Automation, Fluid Power, Motion Control, PLCs and Machine safety.

NATHIR RAWASHDEH is an assistant professor at the department of applied computing at Michigan Tech. since August 2019. He instructs introductory and advanced programmable logic controller courses. Prior to this appointment, he was an associate professor in the Mechatronics Engineering Department at the German Jordanian University, where he spent 10 years. His industrial experience includes 5 years with Lexmark International, Inc. Lexington-Kentucky and MathWorks, Inc. in Natick-Massachusetts. Dr. Rawashdeh is a Senior Member of the IEEE and has experience with European-funded research capacity building projects. His research interests include mobile robots, autonomous driving, image processing and sensor fusion.