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Solderbot: Automated Soldering using Robot Arm

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Abstract: ***The last few decades have seen technological advancements in the field of modeling, simulation, manufacturing, assembly and prototyping such as CNC (Computer Numerical Control) machining, milling etc. Such technological advancements have now become widely adopted to meet the needs of today's economy. There is also a growing culture of hobbyists, makers and tinkerers finding innovative ways to lower the costs of such technology. It has enabled the invention of low-cost manufacturing and assembly machines such as 3D printers, desktop PCB (Printed Circuit Boards) millers, fabricators etc. The automated soldering of fabricated PCBs still remains a costly ordeal where the market is dominated by expensive and sophisticated vision-enabled soldering systems. Here, we propose an automated soldering technique with a low-cost robot arm that traverses planned soldering motion paths. The soldering iron heats an appropriate amount of solder/filler metal from a spool attached to a shaft that is turned by a servo. OpenCV library is used to analyze the images to position the solder iron and solder on top of the surface to be soldered. Finally, the robot arm is moved after trajectory planning in RoboDK simulation environment.***

Keywords: Soldering, Automation, OpenCV, Simulation, Robot Arm

1. Introduction

The rate at which automation is being employed for repetitive as well as complex industrial tasks has grown in the last few decades. This integration of automation comes from the fact that a lot of manpower goes untapped as it is channeled to just mundane tasks. Therefore, automation helps divert this manpower to tasks that require a human's insight and critical thinking abilities. This employs people in more skilled labor and leaves the repetitive and often hazardous and intensive tasks to equipped machinery and robots. Further, intelligent robots equipped with computer vision and artificial intelligence make this automation process more versatile so as to incorporate deviation from the original training data. A new scenario can be mapped to a corresponding action by the learning model of the robotic system.

2. Literature Survey

The growth of startups, hobbyist groups and academic tinkerers as a community has enabled the making of small-scale and cost effective solutions to equivalent processes in the industry. 3D printing has been hailed as a revolution in rapid prototyping as well as manufacturing. Wohlers, Campbell and Diegal, et al. [1] estimates that a total of more than 140,000 industrial 3D printers and 2 million consumer 3D printers have been sold worldwide, as of 2013. [1] also reports that most of these machines are being sold to hobbyists, do-it-yourselfers, engineering students, and educational institutions. A survey of existing robotic arm applications and automated manufacturing was done as part of the literature survey for this paper. Xiang Li et al. in [2] and [3] proposed methods for automated soldering of flexible PCBs. The method employs an assistive end effector for the proper deformation and positioning of the flexible PCB for soldering. It is also a vision guided system where the camera images are processed to take decisions regarding manipulating the end effector and positioning the soldering iron. Such complicated computations restrict the method to the niche domain of flexible PCBs & expensive automated soldering and cannot be exploited for hobbyist soldering automation. Xie Zhen et al. have explored the use of point cloud algorithm in [4], whereby a set of Cartesian data points in space represent the shape of the 3D object. The point cloud data is used to generate the robot arm's motion plan and can be employed for any range of end effector tasks such as welding, painting etc. This does put a computational load on the device generating the motion plan from the point cloud data. Vipul Garg et al. have proposed a robotic manipulator prosthesis that works as an arm actuated with a laser and camera based object detection system[5]. This faces the same problem as [2] and [3] as they may not be economically feasible at smaller scales. In [6], Hyeonchul Jung et al. have employed a deep-learning based object detector to control a robot arm in a simulated environment. The automated soldering application may not require intensive algorithms as in deep learning as most electrical contacts and soldering surfaces can be recognized via a lighter framework such as OpenCV. Zexin Huang et al. have simulated a robotic arm with 6 degrees of freedom(DOF) in Gazebo[7]. As only Cartesian points in space have to be accessed by a linear structure end effector, i.e, the soldering iron, 6 DOF robot would not be needed for an automated soldering application. Wenbin Zhang et al. have proposed a picking robot with object detection and sorting capabilities by using OpenCV library[8]. In [9], Chulhee Yun et al. have proposed a visual programming technique that uses drag-and-drop modules, connectors, commands etc. to instruct edutainment robots. Such hand-taught and icon-based programming methods would make it easier to program repetitive solder jobs, instead of the traditional coding and testing approach. Li Jian et al. have proposed a positioning technique based on a recognizable marker planted on the object and subsequent training of OpenCV models to recognize the marker[10]. As metal contacts of electrical contacts on components are quite small in size, such marker-based recognition would not be suitable for automated soldering application. P. M. Khiabani et al. have implemented visual servoing in a simulator for a robotic arm, where the robot's motion is in accordance with the vision sensor[11]. An automated soldering application would require such visual servoing to bring the exact area into particular frame within the real-time image so as to start soldering process. The exact frame in the real-world application of the same would have to be obtained heuristically. U. Meshram et al. have proposed an FPGA based robot arm controller for positional control in [12]. The use of FPGAs in the control circuitry would drive up the costs for a low-cost robot arm application.

3. Problem Definition

This paper proposes the design of a low-cost robot arm being used in an automated soldering application. The camera from the top view of the surface to be soldered provides the images that can be processed with OpenCV library so as to enable solder targets to be set. Once the soldering motion path is generated, the soldering iron end effector is traversed through the path to get the soldering iron in the right position to dispense the adequate amount of solder from a spool.

4. Methodology / Approach

RoboDK is offline programming and simulation software for industrial robots. The simulation software can be used for many manufacturing projects including milling, welding, pick and place, packaging and labelling, palletizing, painting, robot calibration and more. The simulation consists of the Robodk visualisation part and the OpenCV image analysis part. Fig. 1 shows the block diagram of the proposed workflow.

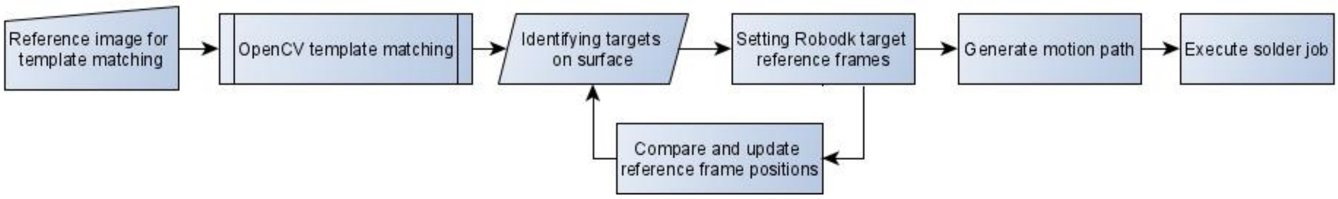

Figure 1: Block diagram

4.1. Robot Arm

Fig.2 shows the robot arm, capable of manipulating the end effector soldering iron in a 3D Cartesian space.

Figure 2: Robot Arm

4.2. Soldering Iron and Spool End Effector

Fig.3 shows the end effector soldering iron and spool. The spool is attached to the shaft of a servo motor with 360^{O} motor control. This helps dispense the solder in the right amount. The right number of rotations of the spool servo motor in a real-word scenario would have to be determined heuristically for optimum performance.

Figure 3: Soldering Iron And Spool End Effector

4.3. PCB Surface for Simulation

Fig.4 shows the test PCB surface with 4 connector pins in a row of the vias slots. This PCB component is used for simulation and gathering the image data from the camera module.

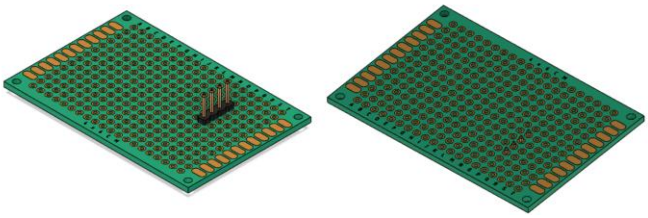

Figure 4: PCB Surface for Simulation

The user is first prompted to select a reference image on the surface to be soldered. This reference image of a vias, component lead etc. is used in a template matching algorithm to find the targets to be soldered on the surface. The target point reference frames for soldering in the RoboDK simulation software are placed at the detected positions. Once the RoboDK target reference frame are positioned on the surface, a solder job motion path is generated. The robot arm end effector traversing the motion path is properly positioned to heat an appropriate amount of solder/filler metal from a spool attached to a shaft that is turned by a servo. The simulation environment visualizes the soldered job as a deposit of the grey solder material at the base.

5. Results & Discussion

The simulation environment shown in Fig.5 shows the robot arm with the custom end effector tool, a camera system that gives image data of the PCB surface underneath. The robot arm, capable of manipulating the end effector soldering iron in a 3D Cartesian space, is

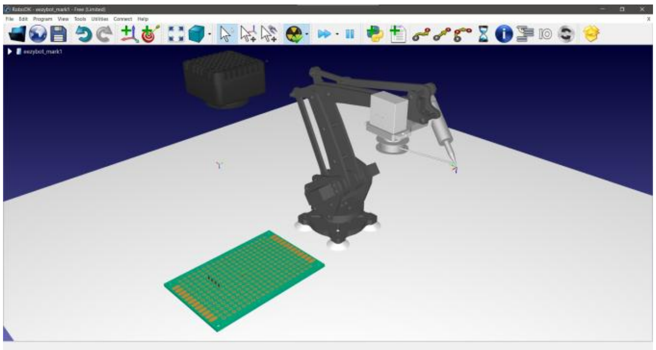

Figure 5: Simulation workspace

coupled with a soldering iron and a spool of solder material. The spool is attached to the shaft of a servo motor with 360° motor control. This helps dispense the solder in the right amount. In an actual model, the right number of rotations of the spool servo motor would have to be determined heuristically for optimum performance.

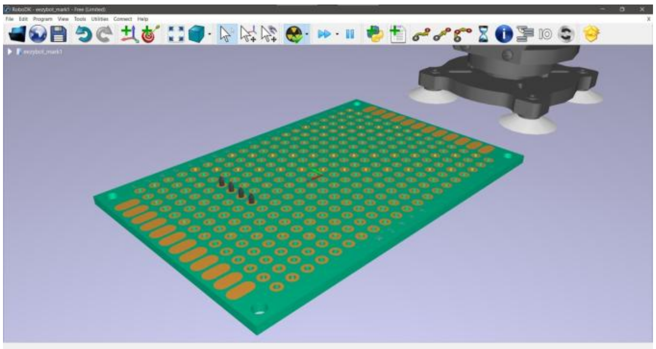

Figure 6: PCB with 4 connector pins to be soldered

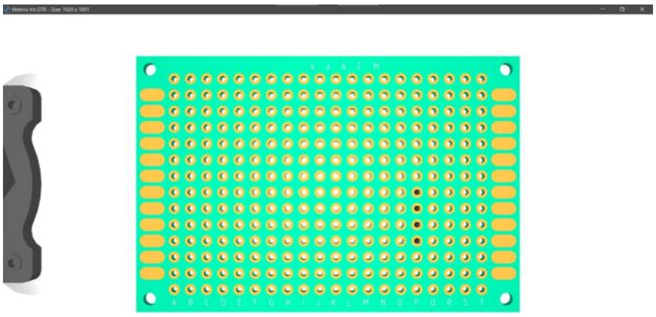

Figure 7: Camera view of the PCB surface

Fig. 9 shows the result of the template matching algorithm in OpenCV, with the image on Fig. 8 as the reference, on the image data gathered by the camera on top of the PCB surface.

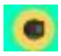

Figure 8: Reference image

Figure 9: Target detection on PCB surface

Once the targets are detected, Robodk target reference frames, as seen in Fig. 10, are set at the positions of the targets detected. These reference frames are used for the motion planning and generation of a traversal solder job path seen in Fig.11.

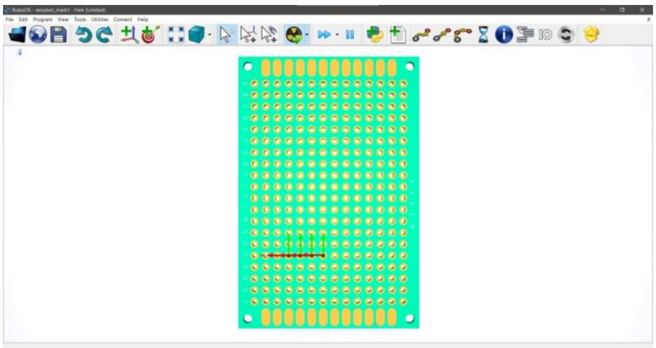

Figure 10: Robodk target reference frames set on PCB surface

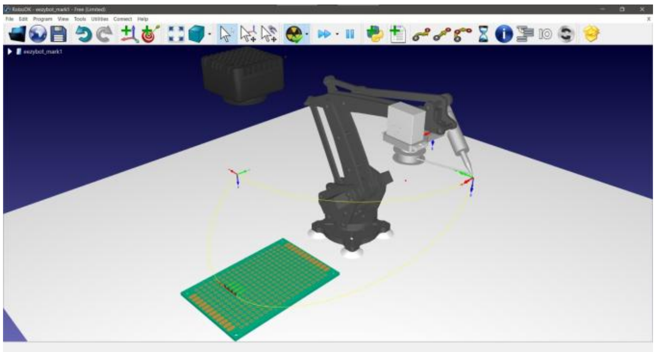

Figure 11: Solder job motion path generation

After the solder job motion path is generated, the robot arm end effector traverse its motion path. The arm end effector moves sequentially towards each of the target and deposits the adequate amount of solder from the spool as shown in Fig..12. The arm moves to the initial position after the solder job is complete as seen in Fig. 14.

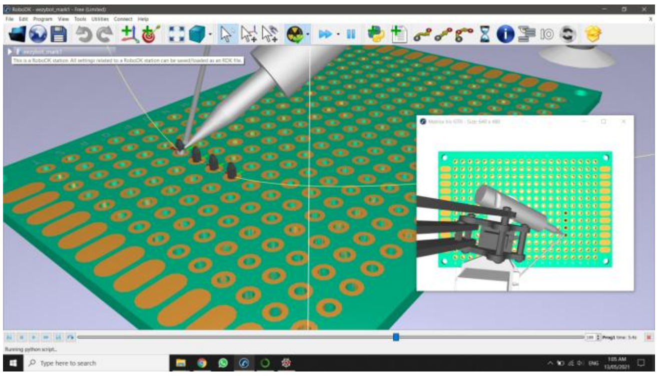

Figure 12: Soldering first target

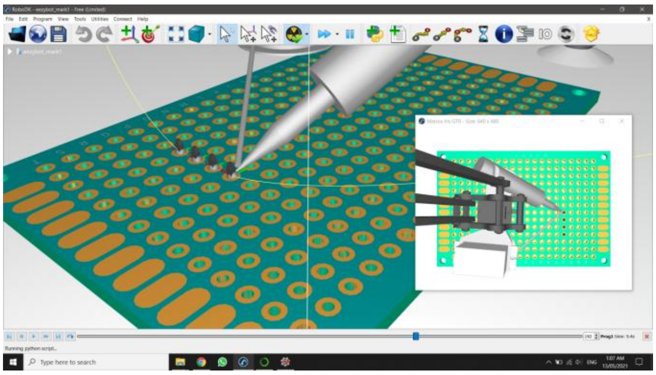

Figure 13: Soldering final target

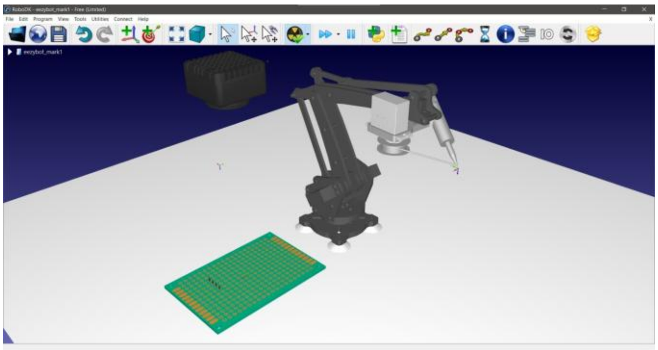

Figure 14: Solder job complete

6. Conclusion

Through this project, the system level design and simulation of an automated soldering technique with a robot arm has been proposed. A camera module on top of the surface to be soldered gathers the required image data to position targets to be soldered upon. With the template matching algorithm in OpenCV library, RoboDK target reference frames are positioned on the surface and a solder job motion path is generated. The robot arm end effector traversing the motion path, is properly positioned to heat an appropriate amount of solder/filler metal from a spool attached to a shaft that is turned by a servo.

7. Future Scope

Future work could include a "Hand-Teach" mode in the GUI where the position sensors on the robot arm's motors would record the different user configured positions. This would enable hand-teaching the solder paths of repetitive solder jobs. This would require no pre-requisite programming knowledge and would provide a seamless operating process. Further, PCB design files in gerber format could be uploaded in the GUI to enable automated soldering along the PCB circuit lines, pads etc. according to the user input.

References

[1] Terry Wohlers, Ian Campbell, and Olaf Diegel, et al., Wohlers Report 2019 (Fort Collins, CO: Wohlers Associates, Inc., 2019), pp. 173, 175.

[2] X. Li, X. Su and Y. Liu, "Adaptive region control for robotic soldering of flexible PCBs," 2017 18th International Conference on Advanced Robotics (ICAR), Hong Kong, 2017, pp. 216-221, doi: 10.1109/ICAR.2017.8023521.

[3] X. Li, X. Su and Y. Liu, "Cooperative robotic soldering of flexible PCBs," 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Vancouver, BC, Canada, 2017, pp. 1651-1656, doi: 10.1109/IROS.2017.8205975.

[4] X. Zhen, J. C. Y. Seng and N. Somani, "Adaptive Automatic Robot Tool Path Generation Based on Point Cloud Projection Algorithm," 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), Zaragoza, Spain, 2019, pp. 341-347, doi: 10.1109/ETFA.2019.8869301.

[5] V. Garg, T. Sharma, A. Kumar and V. Rastogi, "HandAid: A Seven DoF Semi-Autonomous Robotic Manipulator," 2020 5th International Conference on Control and Robotics Engineering (ICCRE), Osaka, Japan, 2020, pp. 37-41, doi: 10.1109/ICCRE49379.2020.9096262.

[6] H. Jung, M. Kim, Y. Chen, H. G. Min and T. Park, "Implementation of a unified simulation for robot arm control with object detection based on ROS and Gazebo," 2020 17th International Conference on Ubiquitous Robots (UR), Kyoto, Japan, 2020, pp. 368-372, doi: 10.1109/UR49135.2020.9144984.

[7] Z. Huang, F. Li and L. Xu, "Modeling and Simulation of 6 DOF Robotic Arm Based on Gazebo," 2020 6th

International Conference on Control, Automation and Robotics (ICCAR), Singapore, 2020, pp. 319-323, doi: 10.1109/ICCAR49639.2020.9107989.
[8] W. Zhang, C. Zhang, C. Li and H. Zhang, "Object color recognition and sorting robot based on OpenCV and machine vision," 2020 IEEE 11th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT), Cape town, South Africa, 2020, pp. 125-129, doi: 10.1109/ICMIMT49010.2020.9041220.
[9] Chulhee Yun, Jaegon Ahn and Yeon-Ho Kim, "A fusion of computer vision technique and a visual programming language for edutainment robots," IEEE ISR 2013, Seoul, Korea (South), 2013, pp. 1-5, doi: 10.1109/ISR.2013.6695728.
[10] L. Jian, Z. Chengyan and C. Shujuan, "Positioning Technology of Apple-Picking Robot Based on OpenCV," 2012 Third International Conference on Digital Manufacturing & Automation, Guilin, China, 2012, pp. 618-621, doi: 10.1109/ICDMA.2012.146.
[11] P. M. Khiabani, B. S. Aghdam, J. Ramezanzadeh and H. D. Taghirad, "Visual servoing simulator by using ROS and Gazebo," 2016 4th International Conference on Robotics and Mechatronics (ICROM), Tehran, Iran, 2016, pp. 308-312, doi: 10.1109/ICRoM.2016.7886865.
[12] U. Meshram, P. Bande, P. A. Dwaramwar and R. R. Harkare, "Robot arm controller using FPGA," 2009 International Multimedia, Signal Processing and Communication Technologies, Aligarh, India, 2009, pp. 8-11, doi: 10.1109/MSPCT.2009.5164161.

Author Profile

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