Abstract

Jobs performed by small to medium enterprises (SMEs) are infrequently automated due to high setup costs and lack of technical expertise needed for robot training, however productivity and worker safety can be improved in SMEs with the use automated tooling. In a traditional automated manufacturing environment, tasks such a welding or painting are accomplished through execution of pre-programmed tool motions which rely on the location and orientation of the workpiece to be fixed and known. The lack of this spatial information is typically treated through positioning of the workpiece with respect to the robot arm using jigs or fixtures which are costly in initial setup and not easily modified. Further, the resulting toolpath associated with a desired task is typically defined through manual teaching resulting in a path appropriate for an individual job. For this reason, SMEs requiring variation in part geometry or arrangement are not commonly automated. This work presents a method for automated weld path generation for a 6DOF co-bot arm using random sample consensus (RANSAC) and iterative closest point (ICP) workpiece localization from LiDAR pointclouds. Scans from a low cost 2D LiDAR mounted to the co-bot arm are used to generate 3D pointclouds of the workspace scene with the Robot Operating System (ROS). The Point Cloud Library (PCL) is used to compare the generated pointcloud with a CAD model to produce a rigid transformation to localize the workpiece. The estimated pose of the workpiece with respect to a fixed frame is used offline to generate a weld path as series of tool poses. Two example welding processes in which a cylinder or rectangular tube is joined to a flat plate and two square tubes are joined through weldment are investigated and a physical implementation of the method is demonstrated using a 2D LiDAR mounted to a 6DOF co-bot carrying a MIG welding torch.

1. INTRODUCTION

Small to medium enterprises perform manufacturing tasks associated with relatively low part volume and increased variation in assembly geometry as compared to jobs performed in large scale manufacturing environments. This type of manufacturing operation is infrequently automated due to high setup costs. However, productivity and worker safety can be improved in small to medium enterprises with automation such as robotic tooling.

In a traditional automated manufacturing environment, a task such a welding or painting is accomplished through the execution of pre-programmed tool motions which rely on the location and orientation of the workpiece to be fixed and known with respect to a global coordinate system. The need for spatial information is typically treated through positioning of the workpiece with respect to the robot arm using jigs or fixtures which are costly in initial setup and are not easily modified. In large scale production environments, this can be accomplished with dedicated infrastructure built into the environment such as moving jigs on assembly lines and other features available in a highly structured environment. Further, the resulting toolpath associated with a desired task is typically defined through manual teaching resulting in a path appropriate for an individual job. For this reason, SMEs requiring lower volume manufacturing with variation in part geometry or arrangement are not commonly automated.

A method is presented in this paper is for automated weld path generation with a 6DOF co-bot arm using random sample consensus (RANSAC) and iterative closest point (ICP) workpiece localization implemented using the Robot Operating System (ROS) and the Point Cloud Library (PCL). Point Cloud Library provides an open-source C++ implementation of several 3D point cloud and image processing algorithms including: object recognition, filtering, feature estimation, surface reconstruction, registration, model fitting, and segmentation [5]. This library is an attractive research tool due to its stability, integration with ROS, and standard data sets that can be used for comparison repeatability in research.

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A collection of these algorithms is used to locate, or register, a point cloud representing the workpiece in a point cloud of the working environment collected by a LiDAR scanner located on the robot. Once the known part is located with respect to a fixed frame, an automated weld path generation routine is used to plan a weld tool-path offline. Two example welding applications are presented. In the first, a square tube is joined to a flat plate through weldment. In the second, two square tubes are joined orthogonally to each other to form a tee. Simulations of both applications are investigated and a physical implementation of the method is demonstrated using a 2D LIDAR mounted to a 6DOF co-bot carrying a MIG welding torch which can be seen below in Figure 1.

A picture containing wall, indoor

Description automatically generated

Figure 1

Environment sensing devices which generate 3D points are frequently used in the robotics industry, and improved sensors are being developed with the increased demand [5] for automation in manufacturing and transportation. A pointcloud is a list of points in 3D space representing a physical object or collection of objects [6][8], and this data is generated through measurements from a sensing device such as a LiDAR or 3D camera. Widespread applications and research involving spatial data has led to the development of standard file types, storage containers, and libraries for efficiently processing of pointclouds [5]. Common programming languages (C++, Python, MATLAB) support integration of pointcloud data with various libraries (PCL, OpenCV) and software frameworks (ROS).

The geometrical data, or features, stored in a pointcloud (typically) contain the locations of the boundaries of a solid object. Features may also include point normals which can be measured or inferred from the feature locations. Non-geometrical data such as color or other surface properties that are independent of the transformations between features are known as descriptors [13]. Descriptors are also used in feature based registration methods, which primarily depend on unique, descriptive features in order to obtain a match between pointclouds [6]. These two types of data contained in a pointcloud are stored separate because they are different in nature and are processed differently in algorithms such as segmentation or registration.