sl.no	Title of the paper
1	CAD-Based Off-Line Robot Programming
2	Automated Offline Programming for Robotic Welding System with High Degree of Freedoms
3	Automated Programming for Robotic Welding
4	Off-line Programming and Simulation from CAD Drawings: Robot-Assisted Sheet Metal Bending
	A Novel Trajectory Planning Scheme for Spray Painting Robot with Bézier Curves

5	
6	Offline programming of an ABB robot using imported CAD models in robotstudio
7	CAD-based robot path planning and simulation using OPEN CASCADE

8	Robotic Welding of Ship-Subassemblies with fully automatic Offline-Programming
9	Automatic robot path integration using three-dimensional vision and offline programming
10	3D Mapping using a ToF Camera for Self Programming an Industrial Robot*

11	Offline CAD-based robot programming and welding parametrization of a flexible and adaptive robotic cell using enriched CAD/CAM system for shipbuilding
12	Recent progress on programming methods for industrial robots
13	CAD-based automated robot trajectory planning for spray painting of free-form surfaces
14	An Optimal Motion Planning Method of 7-DOF Robotic Arm for Upper Limb Movement Assistance

15	Trajectory Planning for Reconfigurable Industrial Robots Designed to Operate in a High Precision Manufacturing Industry

short description(methodology and algorithms used)
The CAD based positional information is extracted from **Autodesk Inventor API**. The tranformation matrices are computed usign **MATLAB**, **Quaternions calculations** are used for orientation positioning of tool(end effector & robotic arm) Path generation, trajectory generation, motion planning are not discussed but necessary input parameters were mentioned. Obstacle are not considered. The conversion of positional data to robot command is **not generalized in nature**
Using VB scripting and manual selection, **key-points** or **work points** in the CAD, robot, tooling, are selected to generate surfaces and paths using **DELMIA** OLP package. Path planning is broken down to multiple stages of the 13 dof robot for efficient calculation through configuration space. **simplified bounding volume**(sphere) method is used for efficient collision checking **Probalistic Roadmap algorithm** used for computing weldpath transition A post processor to convert generated motion into robot language
Automated weld path generation: Weld paths are defined at the stage of meshing based on mesh alignments between two individual parts. The search space of the possible welding configurations are discretized. Weld positioning and end effector configuration is planned using **A* search algorithm .** **Trajectory planning: Probablistic Roadmap Method (PRM)** is used for searching through the configuration space for obstacle free configuration. Touch sensing and laser profilometry techniques are used for **online calibration** Post processing involved optimization of generated motion and conversion iinto robot code
CAD packages used for reconstruction of the robotic production cell Robot motion data is extracted from CAD using Autodesk Inventor APIs. Arm movement simulation is performed recurring to the **Robotics Toolbox for MATLAB** Autodesk Inventor API is used for simulating the generated programs **MATLAB** robotics tool box is used for path/trajectory generation which is then simulated in Inventor using API. Conversion of program into robot codes is done using pre existing OLP packages
The target surface and trajectory planning path are both represented in Bezier curves

Path and orientation of the paint gun are designed first to reduce the complexity of the problem
New T-Bazier basis is presented in tool trajectory optimization problem of spray painting robot.

uses offline programming(OLP) to integrate virtual CAD model into programming environment.it is primary contained the setting up creation of the virtual workplaces for offline programming and simulation by using CAD models imported to the RobotStudio programming environment.
OLP starts from 3D CAD model (Catia, Solid Works etc.) what is primary start of the creation workstation and workpieces then it is possible to insert modeled parts into Robot Studio.
steps involved in this are 3D CAD model genereation,Tag creation,Trajectory planning,process planning followed by simulation and if simulation is good then the program is calibrated and loaded into Robot controller.
the robot trajectory creation invloves sequential steps which follow as obtain workpiece' form from 3D CAD file-->select operating parameters -->Analyze workpiece->Generate curves on surface->Generate robot path->process simulation(if this is selected)->Robot program->calibration->robot controller->test and application.

A CAD-based off-line programming (OLP) platform is developed based on OPEN CASCADE (OCC) open source libraries instead of buying a license of OLP platforms like CATIA or KUKA Sim Pro or ABB Robotics.

In this CAD-based OLP platform is developed using OCC libraries with Microsoft VisualStudio. proposed platform
provides several features such as loading of the CAD model for task defination,generating a robotpath,manipulator's accessibility verification, simulation to check and prevent a collision before converting into robot program and allows a user to define and generate a path using the CAD features (face,wire,edges,etc.)and simulate a given industrial task(like glue dispensing)in the virtual environment.

OCC CAD kernels are used to extract the position information from CAD--> Different classes are used to extract the position information from a CAD model-->
orientation of the workpiece with respect to the a given frame from the end-effector is defined by a transformation matrix--> These positions and orientations are input into the robot inverse kinematics for transforming the joint coordinates-->As a result, individual angles for each joint
of the manipulator are obtained to perform the simulation.

First, The standard-program is made using the off-line programming. Second, using the CAD interface,
the job program which contains real size of a workpiece is made. Third, the job-program is transfered to robot controller.
Finally, the robot controller execute the job-program line by line and controls welding robot.

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robot body and workpiece modelling is done using VRML(virtual reality modeling language)
3D geometric models of robot simulations are acquired from a TRIBON CAD interface--> this 3D model is converted into VRML-->
here the genetic algorithm (GA) is used for our robot system (Davidor, 1991; Fonseca & Flemming, 1995; Munasinghe et al, 2003).
Travel length minimization is more efficient than working time

Pose estimation using 3 dimensional vision system

After pose estimation offline programming is used for path generation
Existing Automatic OLP systesm reply on CAD hence prone to error & provides non flexible solutions

Depth sensor Kinect is used for estimation of pose of the workpiece

The sensor information is given to OCC based OLP platform for automatic path generation based on CAD information

Reliance on CAD data is reduced by using a asensor called ToF camera

Robotic collision occurs due to incorrect CAD information.

The C matrix corresponding to 6 degrees of freedom was altered by adding a new state called C-unknown in the algorithm
Along with C-free , C-forbidden a new state C-unkown is introduced which represents configuration space that is not yet mapped

Robotic paths must not intersect with C-forbidden & C-Unknown

Robotic cell with 9 degrees ofbfreedom (6 dof & 3 axis XYZ gantry)

Machine vision is used to find the position and orientation

In the image processing gantry is moved in X direction when the vision system scans the workspace giving an image for movement of 350mm
The same is performed in Y direction and a total of 16 images obtained(8 in X direction & 8 in Y direction) then the images are combined for overlapping to produce high resolution image
Using SBM shape based matchng algorithm pose and orientation are obtained
Free CAD is used to perform the trajectory planning automatically

This is a review in the trends and progress on the programming methods for industrial robots

There are 2 main categories of robotic programming online programming & offline programming
Offline programming method shifts the burden from the shopfloor to the software developer,it also does all the testing and development in simulated environment
During the online programming the robot cannot be used while in the teaching period
In OLP the fine tune of parameters is done in the simulation environment and tested . Finally program is generated and fed to the robot.
The new approach is Augmented Reality it will be interactively overlaying the real environment with virtual spatial information

trajectory for each patch, including the gun path and direction and velocity, will be generated based on the thickness requirements, the gun model and assumptions.

The generated spray gun trajectories were also exported to ROBCAD2/Paint to simulate the painting process

This article is about aiding the upperlimb with an assistive robotic arm using Rapidly exploring random tree algorithm.

Sampling based motion planng algorithms are designed for faster path planning out of them PRM & RRT are most widely used

Transition based RRT considers the cost while planning the path

RRT can find the optimal path only after various iterations which consumes memory and time

Potentials Guide Sampling based-on Rapidly-exploring Random Tree Star (PGS-RRT) is the proposed approach

The closer the sample to goal, the force smaller. That also ensures that if the goal is at far away then the force is large which will reduce the scatter in space of the sample point

presents an algorithm for an automated planning of time-jerk optimal trajectories on a ReRobI(reconfigurable industrial robot)

position and orientation of the end effector in the Cartesian space is dynamically generated through a reconfigurable forward kinematics module

through an iterative inverse kinematic method, the robot configuration space for the start and goal destinations and the geometric path for every motion tasks are generated.

results

Time and complexity Comparison between 'offline robot programming using cad' vs 'robot teach pendant'

An automated offline programmable for 13 dof robot based on CAD

improving commercial viability of robotic manufacturing systems, by reducing programming overhead significantly.

A automated cad based offline programmable robot system is designed specifically for Gas Metal Arc Welding operation purpose.

An Cad based Offline programming and simulation system in which the CAD package used for cell design, OLP, and robot simulation.

A new trajectory planning scheme based on Bexier curves is developed and implemented

Proper function program created by offline method programming will allow us prior to implementation in the real production better debugging, optimize the overall layout of the workplace, improve work efficiency, eliminate collision states etc. The program, which is ultimately created is more-less usable in the real environment using a minimum of interference

Link to the paper:https://www.researchgate.net/publication/286778192_Offline_Programming_of_an_ABB_Robot_Using_Imported_CAD_Models_in_the_RobotStudio_Software_Environment

OLP platform according to their application requirements with low investment together irrespective of the training level of their operators.

Developed off-line programming is very easy for operators to use and maximizes the operating efficiency of
welding robot systems of the shipbuilding industry. In the future, due to intelligent robotic techniques such as
PC-based OLP, painstaking human labor will be reduced and manufacturing productivity in shipyards will be increased

1.Realative error while moving the robot in X,Y &Z direction

2.Absolute error against human defined ground truth
3.&4. are to define the robustness of system for various illumination & object materials.
The overall performance was considered as good since the error was 2mm and it was attributed to the camera to robot caliberation.

The performance on testing was similar to the standard model untill 40 iterations

After the 40th iteration performance of this model increased gradually while it was almost the same for the standard model

This better performace is attributed to two factors

One was the freedom of the motion planar to plan paths aroound the environment
Second one was the introduction of Mscore encourages the mapping in the space C-unknown to maximize the motion paths available.

Welding operation gave a precision of ± 3 mm

Inaccuracies are adjusted using the wire tip as a sensor to determine initial and final point
Trajectory deviations are corrected using seam gtracker and weave function

Resultant is the reduced deformations in welding which inturn redcuced the re-work

Optimization of time & workforce has happened using this system model

Drawbacks of online programming are intuitiveness, low programming skill requirement, and low
initial cost

Though OLP has many advantages based on the fact of costs SME prefer online programming over it.

Program genertaed by online programming lacks the flexibility and reusability

The most difficult part of OLP is system integration and compatability between the robot manufacturers
Current developments is to make olp more flexible and interactive using machine vision and sensors

A new CAD-based paint gun trajectory
generation system for free-form surfaces has
been developed.

PRM considers many paths and optimize best out of them however RRT is a sinngle path algorithm so it cannot guarantee an optimized path

PRM makes complex road maps

The proposed algorithm will reduce the memory and time consumption by reducing the iterations

Greater reduction in the average time is seen when usinmg thePGS-RRT
This approach can be a effecient method in most of the pick and place applications

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The approach results in being enabler towards a fully reconfigurable control

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link
https://www.researchgate.net/publication/224157445_CAD-based_off-line_robot_programming
https://www.researchgate.net/publication/287470724_Automated_Offline_Programming_for_Robotic_Welding_System_with_High_Degree_of_Freedoms
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