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Design And Analysis Of A Mobile Modular Fixture Robot Using Image Processing

Jinju Joseph[1] and S.Prabhu[2],

[1] Student, Robotics, Department of Mechanical engineering, SRM University, Chennai 603 203, India
[2]Professor, Department of Mechanical Engineering, SRM University, Chennai 603 203, India
E-mail:j.jinju007@gmail.com, prabhume@yahoo.co.in
[2]Corresponding author

Abstract

The Mobile Modular Fixture (M^2F) is act as a mobile robot for the purpose of holding the work piece with irregular shapes .The main reason for going to this design is the flexibility of the design, reduced fixturing downtime, decreased cost and many shape of objects can be clamped without any manual adjustments. The fixture contains eight clamps they are arranged radial around the work space and all are independently controlled by lead screw mechanisms powered by dc motors. The M^2F algorithm has been developed for the automation of the fixture with the help of image processing technique using MATLAB platform. The final fixtured simulation is graphically represented as solid models on the screen of a CAD system. The micro controller is programmed in such a way that the whole process includes capturing the object and DC motor actuation simultaneously leads the development and implementation of an automated fixture-design system. Locomotion capability reduces the cycle time and increase the machining capability. User friendly and smooth operation leads the system to a good multi tasking expert system.

Keywords: Mobile modular fixture, Image processing, Robot, MATLAB

1. Introduction

Modular fixturing uses a number of simple locators and clamps to that plug into a lattice of holes to hold the part. This work has developed to analyze the automated modular fixture robot using image processing algorithms implementing in MATLAB and gives mobility to the whole system. Before that the user should know more about fixtures and modular fixtures. One of the primitive modular fixtures is as shown in Fig.1.

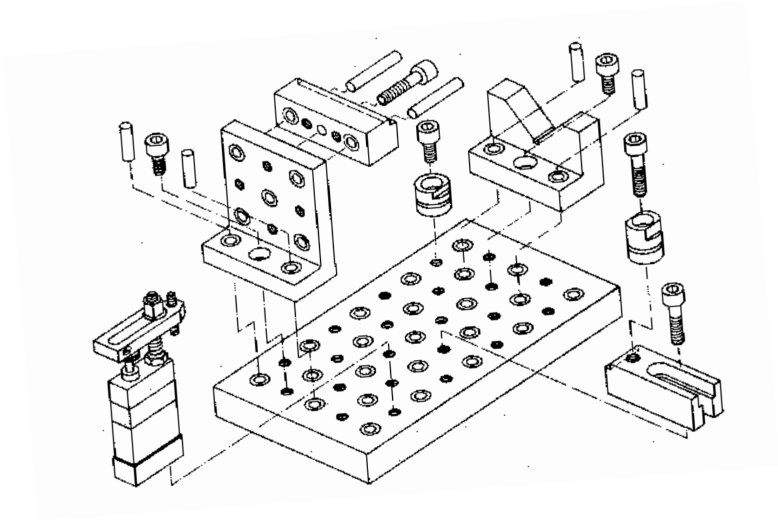

Fig.1. Components of a modular fixture.

Many approaches for computer assisted fixture planning have been developed over the last two decades to address different types of process constraints; comprehensive reviews can be found. Most automated solutions for modular fixture synthesis are restricted to planar shapes where it is assumed that three locators and a clamp are sufficient to immobilize the shape. The assumption is valid for two dimensional fixture synthesis because it has been shown that four fixture locations are necessary and sufficient to guarantee complete part immobility for planar degrees of freedom. Stability analysis to restrict planar motions relies on reasoning about a three dimensional configuration space of forces and moments. For three dimensional motions (i.e. six degrees of freedom) the problem requires stability analysis in six dimensional spaces which is substantially more challenging.

One of the main reasons for going to the mobile modular fixture robot is the flexibility of the design which means, many type of objects can be clamped using this fixture without manual adjustments. To clarify, it is an automated process carried out by taking input as the image of the object and output as the electrical signals to the clamps to fix the object. The clamp is arranged radially around the work volume with a different design and it is manipulated by lead screw mechanism with each one having 1 d.o.f. Above the work volume one camera is placed to capture the object image and the whole system is controlled by microcontrollers. One specialty of this design is movable fixture by providing wheels into it.

The mobile modular fixture is act as mobile robot, modular robot and fixture robot. The fixture contains eight clamps they are arranged radial around the work space and all are independently controlled by lead screw mechanisms powered by dc motors. One vision sensor is placed above the workspace, while placing a work piece in the work volume; the sensor will take the image of the particular object and give signals to the clamps. After image processing the profile of the object will find out and comparing with the workspace coordinates where clamps taught all the coordinates in that work space, so according to the profile/edges coordinates the clamps will form the shape of the particular work piece to clamp it properly. Any irregular shape can be clamped using this fixture. At the time of machining the whole system moves from one location to another for multi tasking. The clamps act as modules in a modular robot and mobility is given by placing wheels. Finding the work piece properties are future tasks. Fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run.

To reduce the manpower, automate fixturing techniques, image processing techniques, development of M2F algorithm, converting M2F into a program and implement it in mat lab to automate the whole system are the main objective of this work. In phase one, mainly concentrating design, algorithm and program part of the system and in phase two the concentration is on manufacturing and automate the whole system including interface with MATLAB. This is a type of new technique in fixturing and applying these concepts into grippers and other systems are the future tasks. The ultimate aim of this work is to implement the concept of image processing techniques into fixture for grasping the object.

Previous Work

Saigopal et al.,[1] addressed the problem of rapidly synthesizing a realistic fixture that will guarantee stability and immobility of a specified polyhedral work-part.The problem of automated fixture layout may be approached in two distinct stages. First, determine the spatial locations of clamping points on the work piece boundary using the principles of force and form closure, to ensure immobility of the fixtured part under external perturbation. When clamps are allowed to exert arbitrarily high reaction forces on the part, the spatial arrangement of the clamping locations ensures the part is in form closure. On generating force/form closure configurations, the chosen locations are matched against a user-specified library of reconfigurable clamps to synthesize a valid fixture layout comprising clamps that are accessible and collision free with each other and the part. Senthil et al.,[2] has developed the design task relating to the development and implementation of an automated fixture-design system. An automated fixture-design system requires an intelligent feature recognizer, a sophisticated design system, a good knowledge-representation scheme, and sound interfacing of these modules. A CAD model is used as an input to the system. A feature recognizer is developed to recognize the machining features represented in the cad model. Rule/object-based approach is used to group the machining features into appropriate fixture setups, and to recommend suitable clamping, locating and supporting points.

Bartholomew et al. [3] has proposed the automatic layout of fixture models on a CAD/CAM system for given applications through an interactive process. The final fixtured simulation is graphically represented as solid models on the screen of a computer-aided design system. This focuses on the fixturing of planar polyhedral work pieces for face-milling operations and predicts the feasibility of a generalized expert fixturing strategy on CAD systems. The software developed as a result of this research has decreased fixturing costs by a substantial amount and has successfully reduced fixturing down-time to a mere fraction. Gandhi et al.,[4] proposed for the automated design and robotic assembly of these modular fixturing systems based on the integration of state-of-the-art methodologies from several distinctly different disciplines. The complexity of this challenging frontier problem is discussed and the interdisciplinary nature of the solution philosophy is emphasized. Peng et al,[5] has introduced a novel virtual reality-based system for interactive modular fixture configuration design is presented. Here used a multi-view based modular fixture assembly model to assist information representation and management. In addition, the suggested strategy is compatible with the principles of virtual environment and it is easy to reutilize the element model. Based on geometric constraints, proposed a precise 3D manipulation approach to improve intuitive interaction and accurate 3D positioning of fixture components in virtual space. Thus, the modular fixture configuration design task can precisely be performed in virtual space.

Fleischer et al,[6] has developed to required accuracies regarding the alignment of the joining partners, a new approach based on component-inherent markings. Different tests have already been conducted in order to validate the approach. The test results demonstrate that the approach is suitable for the spatial alignment of components. James et al,[7] mentioned that applying Design For Manufacturability (DFM) can reduce manufacturing costs and increase quality. This complete, hands-on DFM resource helps partner product design with better, simpler manufacturing operations and updates new materials and processes, such as metal injection molding, laser machining, wire EDM machining, abrasive water jet machining, gas counter pressure and co injection molding, and more. Described are each DFM adapted process and the characteristics of the parts turned out, design and tolerance recommendations, and potential improvements to the bottom line. Yuguang et al,[8] presented a new approach to automated modular fixture planning. The approach identifies all the location plan candidates of a work piece using linkage mechanism theory and excludes the infeasible location plan candidates by evaluating their accessibility and fixturability. The algorithms for analyzing accessibility and fixturability and generating feasible clamp positions of a fixture plan are developed based on several new concepts including IRC triangle, locator visible cone, etc. The approach is capable of handling the work piece whose side clamping faces consist of planar faces. Rong et al,[9] suggested the processes such as fixture and die design are often a necessary but time-consuming and expensive component of a production cycle. Coupling such attendant processes to product design via feature-based CAD will lead to more responsive and affordable product design and redesign. In the context of on-going research in automating fixture configuration design, which presents a fundamental study of automated fixture planning with a focus on geometric analysis. The initial conditions for modular fixture assembly are established together with geometric relationships between fixture components and the work piece to be analyzed.

Djordje et al,[10] proposed system provides new fixture layout design on the basis of previously designed solutions. The case-based reasoning technique was used for this system development. Additionally, the system provides optimization of fixture layout. Productivity, accuracy and production costs were used as criteria for optimization. It describes basic steps of applied methodology, description of particular system segments and system implementation in production industry. John et al,[11] developed a kinematic method to analyze the work holding condition by evaluating the "motion stops" corresponding to the reciprocal screw motions within a given fixture configuration. More significantly, the method may be used to compare the relative quality of two or more configurations in terms of the overall kinematic constraint. Graphically based methods are then developed which can be used to synthesize a fixture layout configuration for a given 3-D work part geometric model. A CAD system is used to demonstrate the techniques for automated fixture layout planning, and the results of this work have been applied directly to a set of modular fixture elements for sheet metal work parts. Bryan et al, [12] developed the design and construction of fixtures is a major hindrance to the reconfigurability of flexible manufacturing systems. A promising method is to use a modular fixturing system. There remains, however, a considerable problem in the design of appropriate assemblies of such fixturing elements. Its input is a description of the work piece geometry, the machining envelope and the fixturing points. Its output is an automatically generated fixture design.

Isabelle et al, [13] presents a modular Mat lab tool, namely MORPHEO, devoted to the study of particle morphology by Fourier analysis. A benchmark made of four sample images with different features is then proposed to assess the abilities of the software. Attention is brought to the Weibull distribution introduced to enhance fine variations of particle morphology. Finally, as an example, samples pertaining to a lahar deposit located in La Lumbre ravine (Colima Volcano, Mexico) are analyzed. MORPHEO and the benchmark are freely available for research purposes. Anders et al,[14] GPUs are in some cases crucial for enabling practical use of computationally demanding algorithms. This review presents the past and present work on GPU accelerated medical image processing, and is meant to serve as an overview and introduction to existing GPU implementations. The review covers GPU acceleration of basic image processing operations (filtering, interpolation, histogram estimation and distance transforms), the most commonly used algorithms in medical imaging (image registration, image segmentation and image denoising) and algorithms that are specific to individual modalities). Xiaoming et al, [15] proposed a nose tip detection method that has the following three characteristics. First, it does not require training and does not rely on any particular model. Second, it can deal with both frontal and non-frontal poses .Finally, it is quite fast, requiring only seconds to process an image of 100–200 pixels(in both x and y dimensions) with a MATLAB implementation.

Based on the above literature survey, an overall idea regarding the initial design and the available fixtures in market has been obtained. Moreover, some artificial intelligence system or expert system is mentioned and it leads to the invention of the new concept of M2F algorithm. The new co-ordinate detection techniques using image processing techniques in MATLAB are revised for the implementation in the design.

2. Proposed Methodology

The method following to convert the concept into a working mechanism is described below. To clarify, the concept is turned to be an algorithm and then it becomes a program after that implementing it into a fabricated model is mentioned here. The stages are notated as a flow chart shown in Fig.2.

After the literature survey an overall idea of the new concept of mobile modular fixture is obtained. The concept is derived from the automation of mechanisms and application of robotics in mechanical field. Implementing an artificial intelligence system into a modular fixture with a new fixture design is the overall view of this work. From the beginning stage more concentration is the CAD modeling of the proposed design using design software.

Next step followed is the invention of a new algorithm called M2F algorithm for the development of a program to automate the system smoothly. In accordance with that some pseudo codes are developed. To implement all these things one real time model is needed for that considering the manufacturing aspects and developing the mechanism. The electronics and communication architecture is the main step for the automation of the mechanism. Last not the least step is the image processing and interfacing the microcontroller with mat lab. After all these steps the system works with image as input and producing electrical signals as output to the motor.

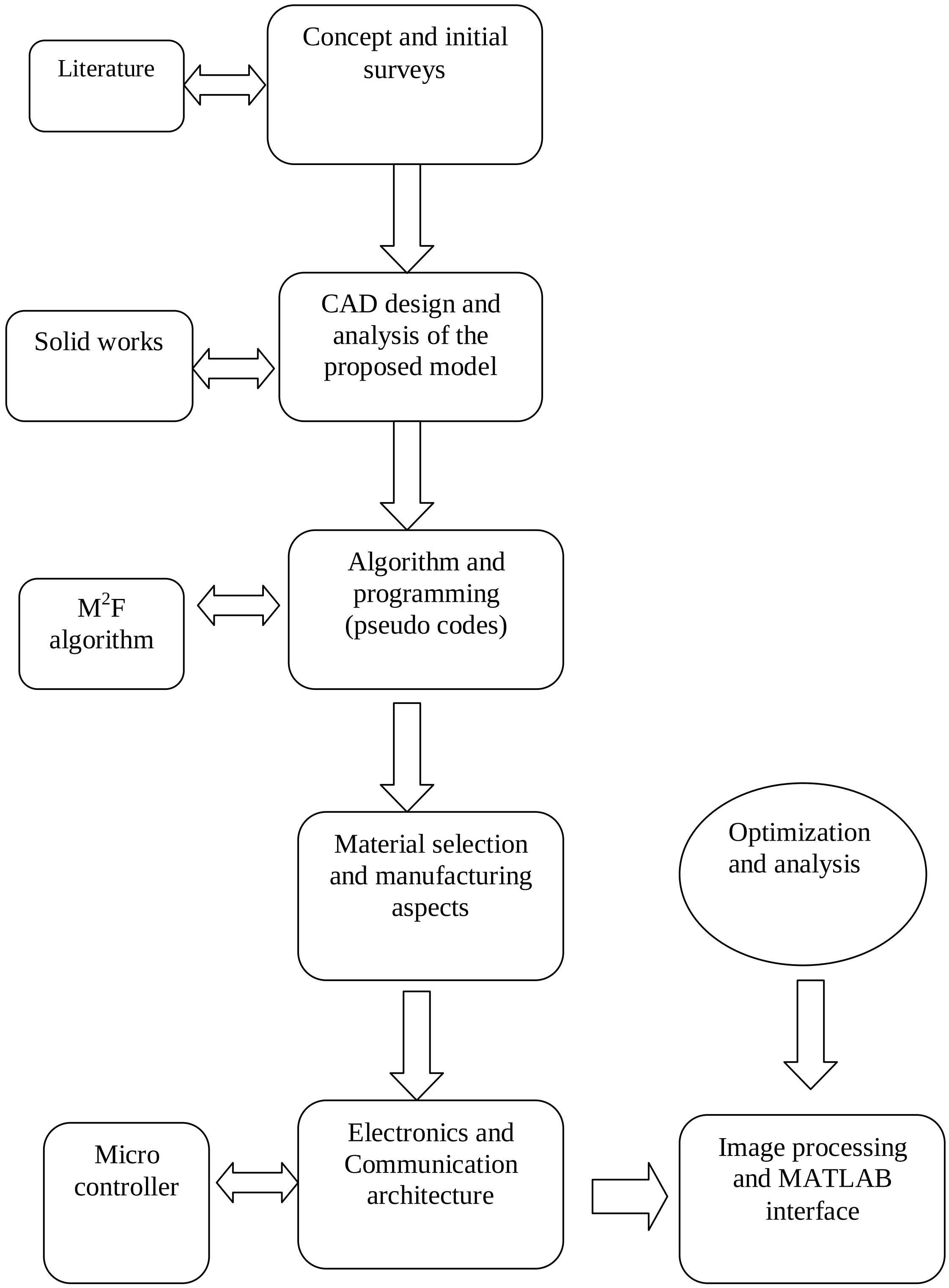

Fig.2. Flow chart for working principle of modular fixture

2.1. Modeling of Modular Fixture
The computer aided modeling is done for modeled the modular fixture in the latest version of the solid works software (SOLIDWORKS 2013).

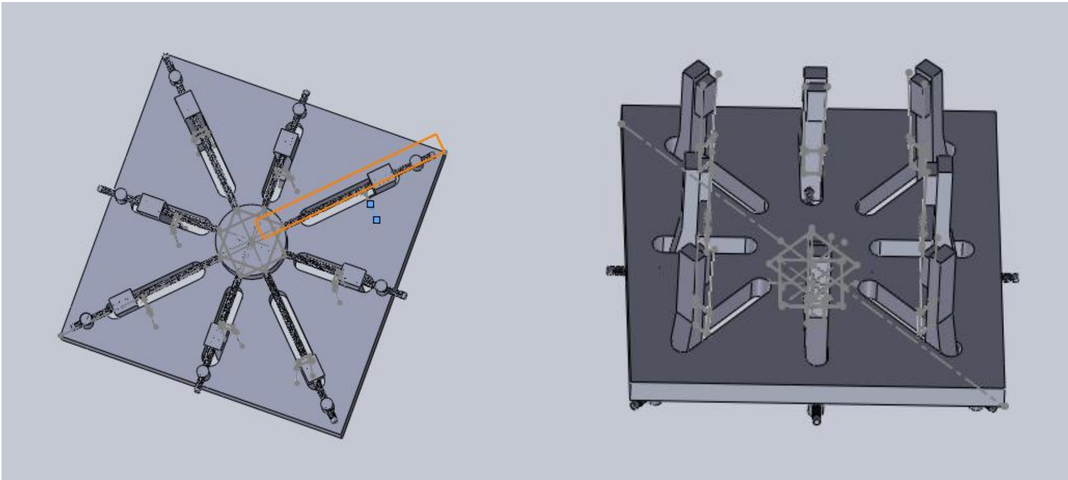

Fig 3. Plan view (left) and assembled view of Modular Fixture (Right)

2.2 M^{2}F Algorithm
It is a new developed algorithm for the conversion of image into corresponding electrical pulses according to the object boundary co-ordinates to grasp it. In the modular fixture base one coordinate system is followed in the work volume, so any object placed in the center of the work volume will have a boundary co-ordinate value .After that the following steps are followed to grasp the object.

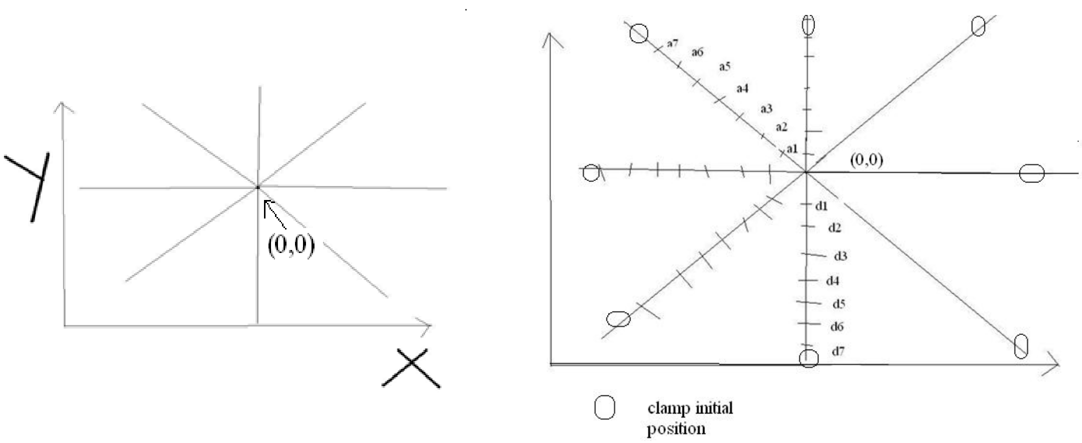

Fig.4 work space and Coordinates of Fixture

Step 1: From the Fig.4, center point of the work space coordinate is marked as (0, 0) and the whole work space is divided into eight equal parts .The lines showing around the center is the center line of each clamps, where the co-ordinates are marking for different linear position of the clamp. So each and every position, one address or one co-ordinate value should be there for each clamp.

Step 2:

Clamp 1; a1, a2, a3, a4, a5, a6, a7

Clamp 2; b1, b2, b3, b4, b5, b6, b7

………………………………………..

Clamp 8; h1, h2, h3, h4, h5, h6, h7

Center axis of clamp is divided in 7 equal parts with equal spacing. For one clamp, seven possible positions are there, are equally distributed. For example for clamp 1: a1 to a7, so the system knows how much movement needed to reach each addresses in the clamp. Similarly, 56 addresses taught to the system, 7 for each clamp. These all are there in the work space.

Step 3:

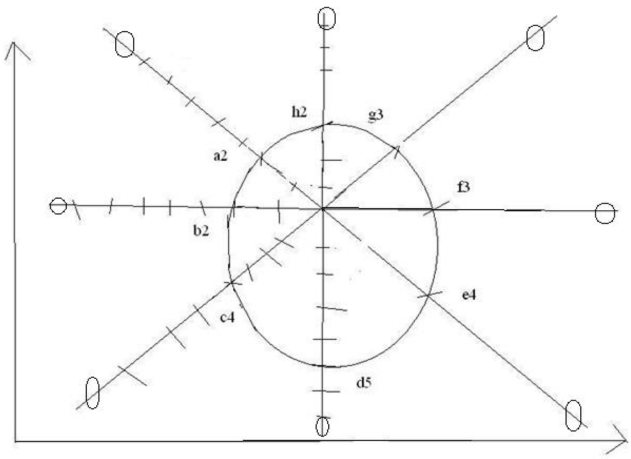

Fig.5 An object was placed in fixture.

Address of this object is: a2-b2-c4- d5-e4-f3-g3-h2

Consider the object with address a2-b2-c4- d5-e4-f3-g3-h2. After getting this address by image processing (edge co-ordinates), the signal will received by the motors to reach particular address to each and every clamp. (Ex; a2 to clamp1, b2 to clamp 2etc.).So the system forms the shape of the object to hold it. Similarly each and every object placed in the work volume has an address. These addresses are the input signal to the motor and works according to it. So any irregular shape with a defined size can be hold using this algorithm.

Step 4:

The software is defined like,

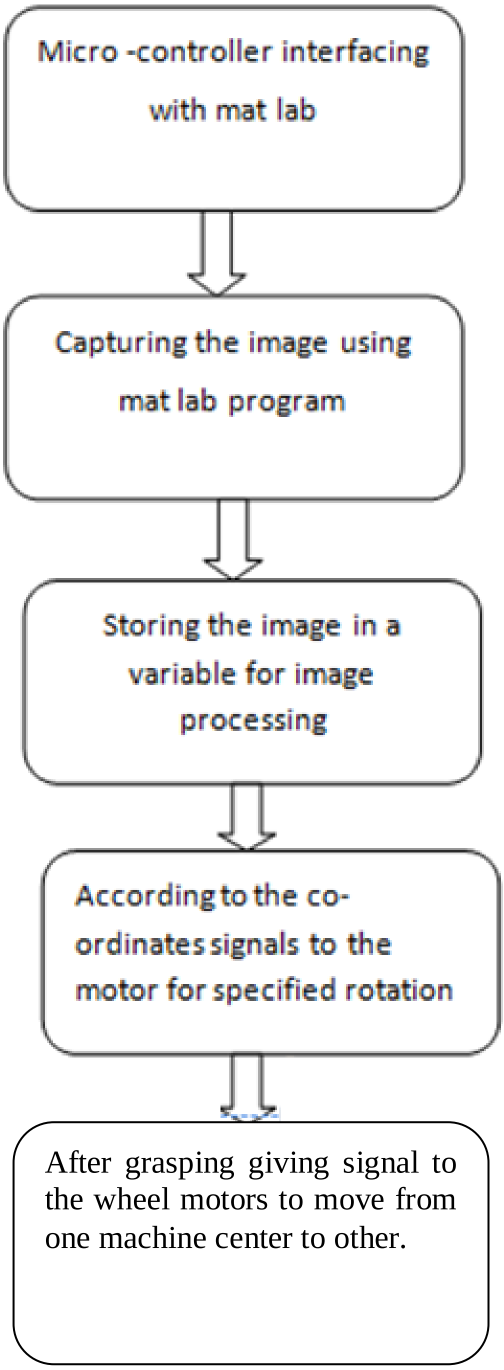

Fig.6 Programming steps of Image processing

Step 5:

After the program execution the clamps reaches the particular coordinate position without giving much effort to the work piece and is formed the shape of the particular object to grasp it.

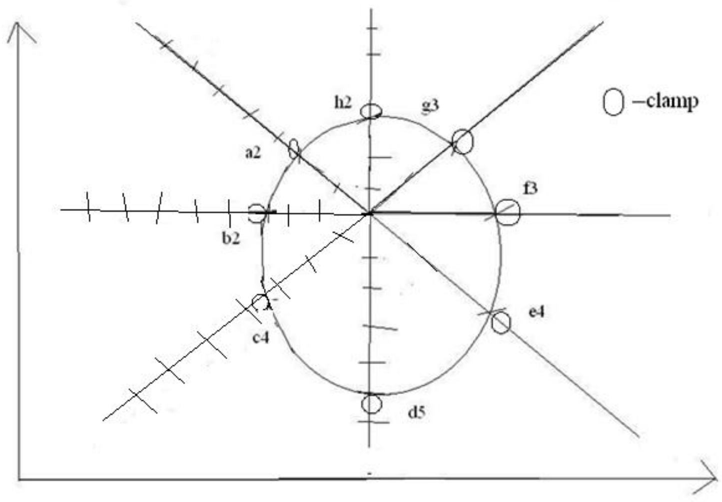

Fig.7 Grasping the object

Step6:

After the machining process, the whole system is move from present machining center to the next machining center for the next process. For example, first drilling the work piece then boring it .the process is continued till all the machining operations will be done. After all machining the clamps loosen and reach to the initial position and the process will start from the beginning. The locomotion is achieved by actuating the wheels by the motors

3. Result and Discussions

The main force acting member in mobile modular fixture is the clamp when it moves and supports the work piece some force will be exerted. Here taking the gripping force is from calculation and the force exerted in due to the lead screw movement as 2N based on the assumption analysis and simulation is done in CAD software. Based on machinability data handbook the total clamping force is 350N. In this design eight clamps are used so the clamping force for one clamp is 43.75N.The factor of safety is taken as one. Gripping force is taken as minimum of 30 and maximum as 100 N. Force produced due to the lead screw movement is assumed as 2N.Material selected is aluminium1060 alloy.

3.1 Modeling of clamp fixture

The clamp was modeled using solid works software. As a part of analyzing the clamp arrest the degrees of freedom, here the bottom portion of the clamp is fixed. The force is applied along the gripping position and lead screw attaching position .for better results different magnitudes of forces were applied.

Fig.8 Modeling and meshing of Clamp

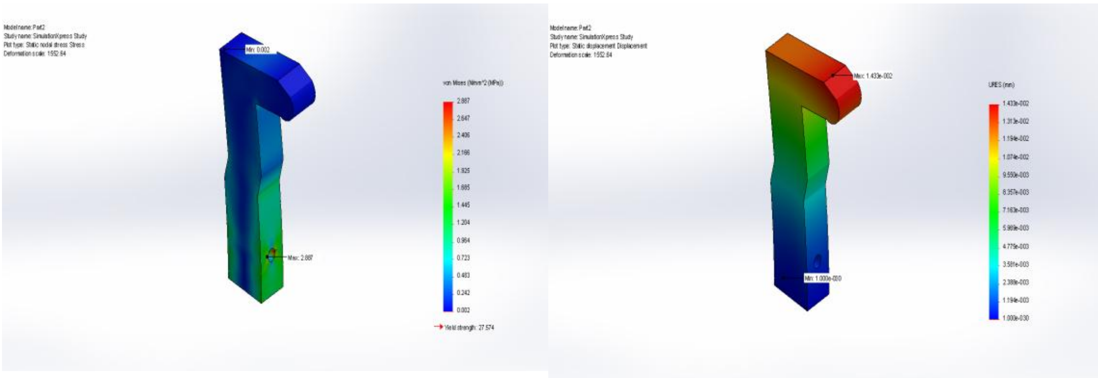

Fig.9 Stress and Displacement analysis of Clamp

From the analysis 5N force has applied then the minimum von Mises Stress acted at the node 9632 with 0.001694 N/mm^2 and maximum in the node 9632 with magnitude of 2.88732N/mm^2. The minimum displacement occurred at the node 108 and maximum displacement occurred at a magnitude of 0.0143256 mm in node 380.

3.2 Deformation analysis of clamp

The analysis is done from 30N to 100 N with 10N intervals and the clamp bottom is fixed. The results were tabulated in Table.1.

Table.1 displacement obtained for different forces

Sl.No.	Force(N)	Displacement(mm)
1	30	0.0107442
2	40	0.0143256
3	50	0.0179069
4	60	0.0214883
5	70	0.0250697
6	80	0.0286511
7	90	0.0322324
8	100	0.0358138

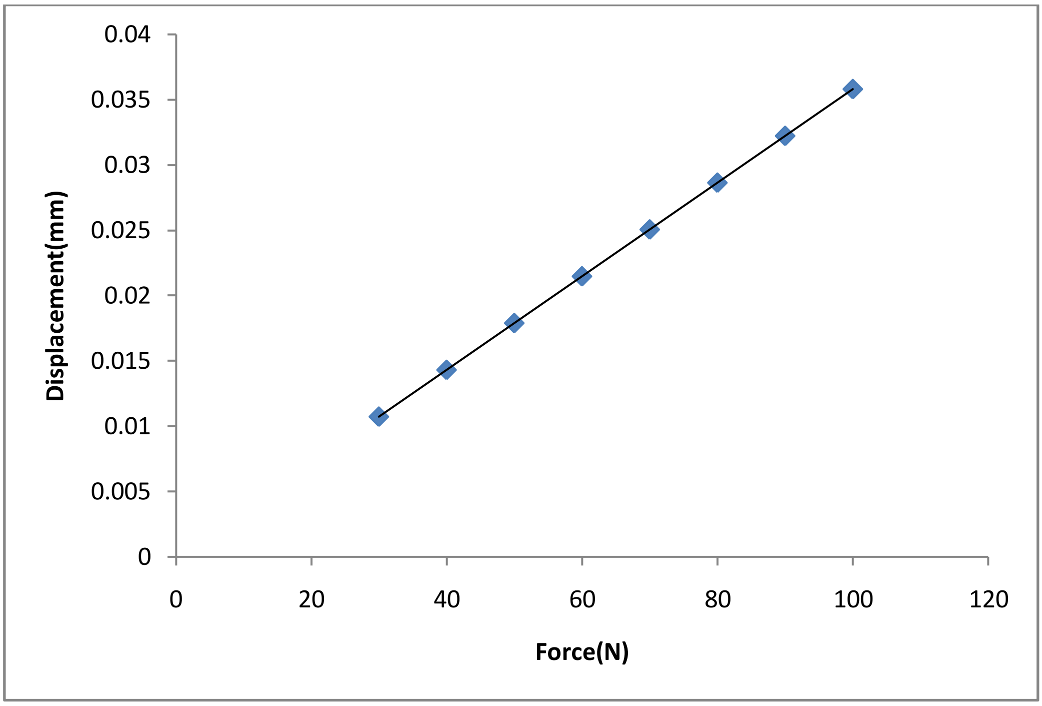

Fig.10 Force Vs displacement of clamp

The clamp is studied, analyzed and stimulated using CAD software. Due to the application of the forces some deformation is occurred. More stress is acting along the lead screw position of the clamp. Mesh analysis gives the accurate results. Manual calculation the obtained gripping force for the particular operation is 43.75N. The minimum deformation occurred at 30N and the maximum deformation occurred at 100N. The least von mises stress acting to the clamp is 0.0016941 N/mm^2 (MPa) and the maximum at the lead screw position with a magnitude of 2.88732 N/mm^2(MPa). Factor of safety is the main consideration of a design; here it is taken as one. The obtained graph is a straight line.

First task in image processing is the edge detection of the work piece so one image is analyzed with a program to find out circular objects and coordinate of the objects is mentioned in Fig 11,after getting the co-ordinate values, it is possible to convert into corresponding addresses. The input image containing different objects and the program is run for finding the circular objects in this image. In the output image the circularity is identified in each object. Similarly program can develop to find the boundary of the object in fixture and easily find out the coordinate of the object. Then the corresponding signal also can give to the motor, ie, the address of the work space is already taught to the system so that system can form the shape based on the image. The image mentioned here only for a reference purpose, the programming is in the developing stage.

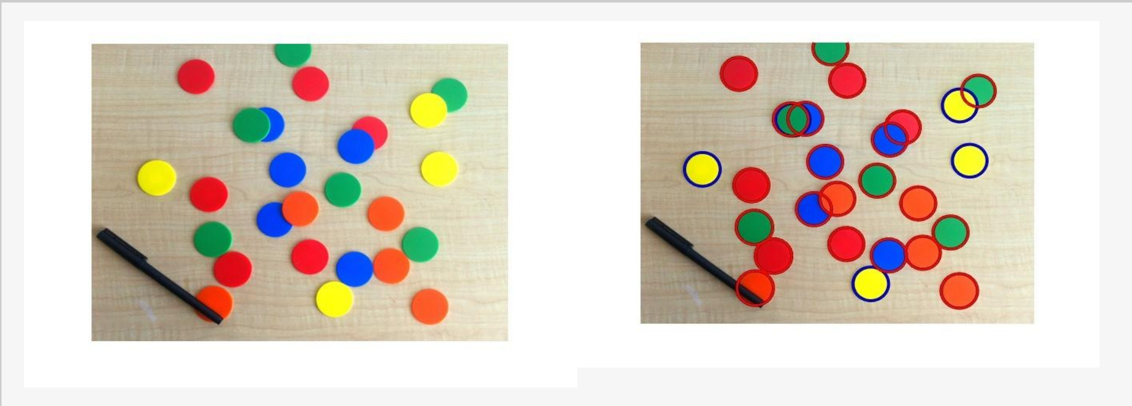

Fig. 11 Input images and output image.

4. Conclusions

The M2F (Mobile Modular Fixture) algorithm has been developed for the automation of the fixture with the help of image processing technique using MATLAB platform.

1. The final fixtured simulation is graphically represented as solid models on the screen of a Computer-Aided Design (CAD) system. The clamp is analyzed and simulated in CAD software which visualized the results due to the application of forces.
2. In manual calculation the obtained gripping force for the particular operation is 43.75N.The minimum deformation occurred at 30N and the maximum deformation occurred at 100N.The least von mises stress acting to the bottom of the clamp, which is 0.0016941 N/mm2(MPa) and the maximum at the top position with a magnitude of 2.88732 N/mm2(MPa).
3. The final result obtained from the analysis is, deformation is proportional to force, the graph obtained as a straight line. Locomotion capability reduces the cycle time and increase the machining capability. User friendly and smooth operation leads the system to a good multi tasking expert system.

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