A Thesis report on

AN APPROACH FOR WEB-ENABLED CLIENT BASED MACROS FOR 3-DIMENSONAL DESIGNING AND TOOLPATH GENERATION FOR ARTISTIC FEATURES

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "**AN APPROACH FOR WEB-ENABLED CLIENT BASED MACROS FOR 3-DIMENSONAL DESIGNING AND TOOLPATH GENERATION FOR ARTISTIC FEATURES**", in partial fulfilment of the requirements for the award of degree of **MASTER OF ENGINEERING** in **CAD/CAM & ROBOTICS** submitted in **Mechanical Engineering Department**, Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **R. K. Duvedi** and **Ravinder Kumar** refers other researcher's work which are duly listed in the reference section.

The matter presented in this dissertation has not been submitted for award of any other degree of this or any other University.

(Aniket Bangotra)

This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

In the present work an attempt has been made for web based automation of 3-Dimensional design features using SolidWorks^{TM} application programming interface (API) environment. A web based environment has been developed for providing interactive access to automatic API macros. In the present work, the domain of 3D design features is restricted to artistic feature designing. The concept demonstrated in the present dissertation work can be extended for web-based automation of all types of 3D solid/surface modelling which is permitted inside any commercial CAD package supporting API based macro development. The web-based interactive API macros will help the client to chose various parameters required for 3D design creation and help them incorporate their creativity to create the design they like. The design model is made available on the webpage so that the user can get a feel of what is being designed by him. When the design get finalised, the CAD model is saved in the required format at the server end. In the present work, the CAD model is saved in STL format which can be further used as an input for downstream applications like rapid prototyping, NC toolpath generation or automatic assembly operations etc. The STL is then further used for the generation of toolpath by using two methods Raster toolpath and Contour Toolpath. This toolpath file can be used with any customized machine available with customer to manufacture the feature.

The overall design strategies for creating some 3D design within some pre-defined families can be made more productive, cost effective and remotely excessive. A lot of research has been going in the field of 3D design automation and modelling which also uses Web Based application for real time data exchange and approvals. Under the present work, an initiative has been taken for development of web-enabled client based designing and toolpath generation for Artistic features with the help of pre-defined MACRO developed in SolidworksÊ .

This is the ultimate aim of the present work is to develop an integrated design and manufacturing environment which can be used by anyone even a engineering background or a non-engineering background person or a hobbyist.

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CHAPTER 1
INTRODUCTION

Throughout history and around the world, humans have been used various artistic feature to embellish their buildings, their tools, their belongings and themselves. These artistic features gives the world perspective and personality at human scale. All these opportunities for decoration still exist and are joined by a new class of artifacts, which exist only as information [1]. The manufacturing of these artistic features are very time consuming, unrepeatable and not accurate using conventional methods. Due to the increase in globalization of the economy and international competition, it is also required to reduce the cost of the designing and manufacturing. Globalization had also added further challenges for the artisans and craftsman across the world as they are now being forced to produce the better quality product in shorter duration and sell at marginal profits.

Computer Aided Designing (CAD) plays an important role to reduce the cost of the design and manufacturing. CAD system coupled with Computer Numeric Controlled (CNC) system or computer aided manufacturing (CAM) systems enhance the potential of profitability for customized products. The integrated or combined CAD and CAM systems also serves as a great tool for the artisans and craftsman to produce identical designer product with more accuracy, quality and repeatability at shorter times.

The product life cycle starts with the need of the customer followed by concept of the product till the manufacturing and production of the product. Similarly, for a product in a manufacturing company, the cost of the CAD/CAM system (fixed cost) gets distributed over a large number of product. However, for a small scale production or for customized production system, the cost is too high for designing and manufacturing owing to high fixed and running cost of automation system like CAD and CAM systems. Thus, it is not economical to buy a CAD/CAM system package for small scale production of customized product and this is also less popular in industries or else the customer should be ready to pay higher prise for his customised product. Furthermore, the benefits of CAD/CAM systems can be exploited by experts having proper knowledge about their usage for designing and manufacturing.

In the present work, an attempt has been made to explore the possibility of integrating the automation of design and toolpath generation for realizing an artistic designs using web based application. This web based paradigm will help the customers to create customised artistic

features within the scope of designs provided, and will help them overcome the burden of higher cost of CAD/CAM system by making this software generalized over the web [22]. The customised designs created by the customer over the web can be used with in the same web application for creation of NC toolpath data [1], [23], [25], which can be further used with any three-axis vertical milling machine to create/realize the final product.

This server based web based application can be easily accessed by anyone sitting around the world. This technology is a user friendly in the sense that anyone can use it even if he/she is an expert or a laymen in the field of CAD and CAM. The client or customer can create these artistic features using guided steps over a web page with an ease and without spending more time on a CAD/CAM system to produce a customized design and corresponding NC toolpath. This technology will give the costumer freedom to use this CAD/CAM system without paying a single penny except only paying for the internet fee and nominal charges for accessing the designed web application.

1.1 COMPUTER AIDED DESIGN (CAD)

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis or optimization of a design. CAD software has been used extensively around the worlds to increase the productivity of the designer, improve the quality of design, improve communications through documentation and to create a design and manufacturing database for future reference. CAD output is often in the form of electronic files for print, machining or other manufacturing operations [8]. This also involves for the creation of computer models as defined by the geometrical parameters [1], [26]. CAD systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real-world conditions.

CAD is an important tool which is extensively used in many applications including automotive, ship building, aerospace industries, industrial and architectural design, prosthetics and many more. CAD is mainly used for detailed engineering of 3D models or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components.

Thus in todayôs scenario, CAD technology has become an important part of the product design process, and it offers benefits like lower product cost, reduce the design cycle time and unbeatable design accuracy as compared with the handmade artistic design by artesian.

1.1.1 Limitations of CAD and CAM systems for design and manufacturing of artistic features

In spite of being the backbone of modern automated industries the CAD and CAM systems do have some disadvantages for customised artistic product design and manufacturing. Some important disadvantages are as listed below:

1. CAD systems have no means of comprehending real-world concepts, such as the nature of the object being designed or the function that object will serve. CAD systems function by their capacity to codify geometrical concepts. Thus, the design process using CAD involves transferring a designer's idea into a formal geometrical model, with no guarantee for the design to be manufacturable or not.
2. CAD and CAM system required special skills and training for their appropriate use.
3. Owning the CAD and CAM packages/technology is an expensive affair, and cost of these applications is justified for larger batch or mass production system only.

1.2 MACRO BASED PARAMETRIC MODELLING AND NC TOOLPATH GENERATION

A macro (merge and correlated recorded output) in computer science is a rule or pattern that specifies how a certain input sequence should be mapped to a replacement input sequence according to a defined procedure to generate a particular output. The macro-parametric approach is another kind of history-based parametric method [2]. This methodology is used to transfer parametric information including design history and standard commands. A macro file that records the modelling command sequence or userôs modelling history is recorded and communicated in a neutral format to the software that will run the macro to generate the output data. The history of user commands which define a high-level dynamic interface is recorded in a macro file and the macro file is used for the static model exchange [3] and [4]. Macros are used to make a sequence of computing instructions available to the programmer as a single program statement that makes the programming task less tedious and less erroneous.

There are two approaches used for the exchange of design intents using macro, such as parameters, features and constraints, as detailed below:

- An explicit model approach based on constraints between predefined parameters and features. There is a relation between the parameters and constrains for a geometrical model.

- A procedural approach or History based model approach based on the sequence of operations issued to construct the models. This includes the construction of the model through a set of entities for representing a CGS model as defined in STEP part [3].

Most of the commercial CAD packages provide an interface via Application Programming Interface (API), which enables the user to interact with the model environment and its mathematical representation with the help of macro. API also offers designers and manufacturers to algorithmize the commonly required steps to create a design model using a CAD system. Using these algorithms, the set of required steps can be repeated automatically and unattended [21] to create the same model repeatedly or to create a new design with minor modifications in the existing design model.

The 3-dimensional CAD models of the part can be saved into a number of data formats that can be then translated into customized or commercial CAM packages to generate the NC toolpath data. This NC toolpath data is used for machining of part out of raw stock using a CNC machine tool. Additionally, a number of input parameters like machine type, tool type, direction of machining, feed rate, speed of cut, required surface finish, distance between machining passes, direction of axis, and operation dependent data (like threading, surface machining, or contoured machining) are required to be specified by the CNC machinist or CAM engineer in a CAM package to get the correct NC toolpath data. Thus translation of the CAD model to CAM package, and then entering the desired machining information needs an expert and takes a lot of time till the NC toolpath data is generated for customised 3-axis vertical milling machine [24].

Using properly designed web based macro the procedure of NC toolpath generation can also be automated and a lot of non-productive time can be saved. Thus the web based integrated approach for NC toolpath generation is going to be a very user friendly approach, as the service providers at the host server end will manage the various aspects like purchase, maintenance and up-gradation of integrated CAD and CAM package, while the customer/client will pay a nominal fee per access through the designated web-page.

1.3 WEB BASED APPLICATION

Today the world is globally connected over internet. With the help of internet the world has became too small that information can be exchanged, processed or accessed between any number of terminals between remote locations. There has been enormous success and development of the ñ*World Wide Web*ò (www). Today many applications are developed by

using the web-based technology in different areas such as banking, e-commerce, education, government and entertainment. The information and database systems are being migrated to web environments in order to deploy their functionality over the web. Modern web-based application development has enabled us with the opportunity to save time, money and the way the companies/ service providers interact with their clients. The two main component of web based applications used for its proper functioning are:

- The unique features of the web.
- The operational environment of web applications.

The goals of the ñwwwò project was to establish a shared information space through which the client or customer can access the information from anywhere around the world. Using above advantages of web based applications, an attempt has been made for designing a web based approach for exchange of data for integrated interactive 3D part modelling and NC tool path generation.

1.3.1 Physical representation of a web application

The physical view of a typical web application represented in figure 1.1 given below, shows the mapping of the components used in the development environment [9].

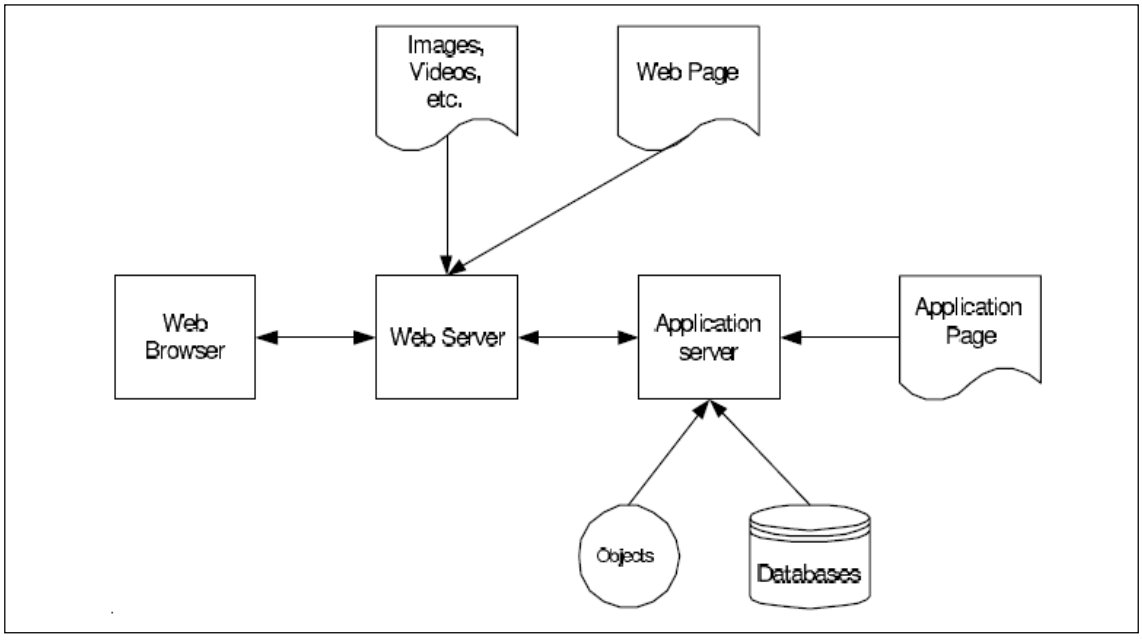


Figure 1.1 : Physical view of a web application

1.3.2 Various tools used for development of web based applications

Different tools are being used for creation of web application, a few of them are listed below:

- NetBeans.
- Microsoft Visual Studio 2010.
- Firebug.
- Photoshop.
- Dreamweaver.
- Fireworks.

Web-based application can be developed by using any of the above listed software tools. Out of the mentioned software tools, NetBeans is an integrated development environment (IDE) from Oracle Corporation which works on Java based platform and is available as an open source. Thus anyone can download and use NetBeans application for free. Moreover Java is compatible with all the cross platforms system. Thus in the present work NetBeans had been used as a working environment for development of web based application.

1.3.3 Web page design

Web design encompasses many different skills and disciplines in the production and maintenance of website. The different areas of web design include web graphic design, interface design, authoring, including standardised code and proprietary software. A web designer should have working knowledge of using a variety of languages such as:

- ASP.NET
- HTML
- XML
- CSS
- JavaScript
- PHP
- Flash

Although the extent of the knowledge required will differ from one web application design to other based on their complexity. Thus any of the above languages can be used to develop a web design. In the present work JavaScript, JSP and HTML had been used for designing of web graphic design because it is the simplest and easiest of all other languages.

1.3.4 Web server/service

A web service is a method of communication between two electronic devices over the world wide web. A web service is a software function provided at a network address over the web or the cloud, it is a service that is ñalways onò as in the concept of utility computing. The world wide web consortium (W3C) defines a web service as ña software system designed for interoperable machine-to-machine interaction over a networkò [28]. There are a number of web services which are as listed below:

- Web Services Description Language (WSDL) from the W3C.
- Apache Tomcat
- GlassFish

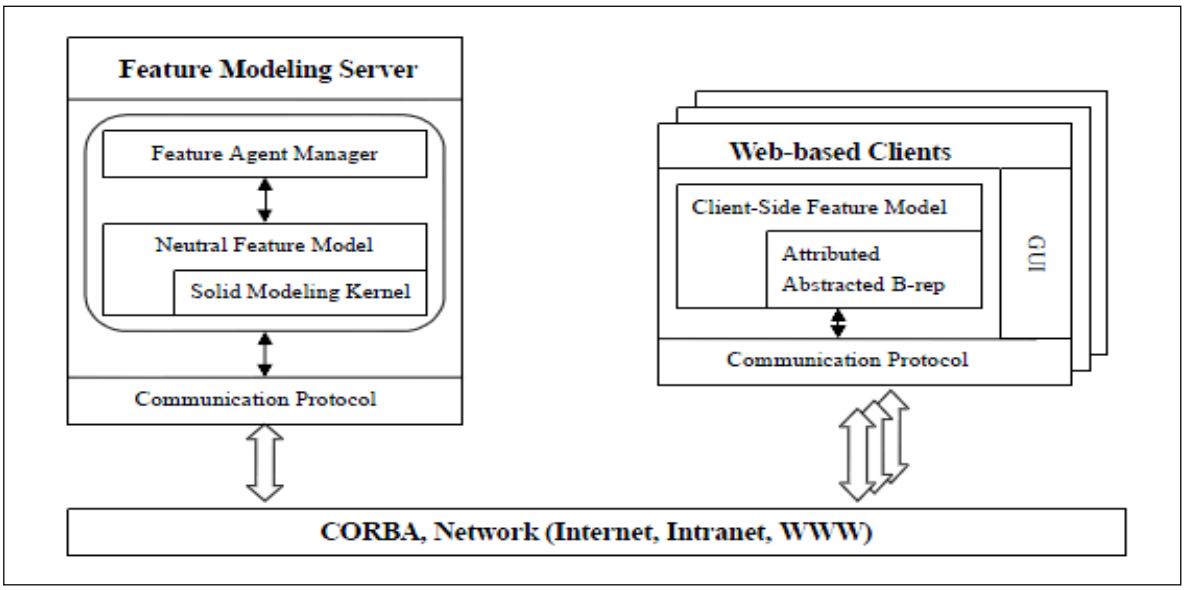


Figure 1.2 : System architecture for web enabled feature based modeling [10].

1.4 WEB-BASED MODELLING APPROACH

Advancement in the computer network has rapidly changed the way engineering is being performed for making the CAD packages as the front door to a web of interconnected software and data exchange environment. Networking and Internet technology opened up a domain for building future CAD/CAM environments [10]. Its environment has provided with a global platform for the product designers to effectively communicate with the global designers and exchange the wide range of product designs during product development.

Feature-based modelling had been considered a new paradigm for integrated design and engineering activities. It enriches product data representation with semantic information that

allows more efficient and direct communication between engineering processes. Thus, the concept of this features has been used in a wide range of applications such as part and assembly design, design for manufacturing, process planning and many other applications. Further, these applications are moving to distributed heterogeneous computing environments to support design and manufacturing processes that are temporally and spatially distributed [14], [15]. In the present work, an attempt has been made to developed a web-based application by using the concept of web-enabled feature based modelling approach for designing and manufacturing of customized 3D models.

1.5 COMPUTER AIDED NC TOOLPATH PLANNING

The computer aided NC toolpath planning is the key technology for todayôs manufacturing industries. The NC toolpath data for CNC machining of complicated parts like forming dies used for sheet metal, cannot be created manually. Thus for all complicated shapes to be machined in CNC machining centres, the reliable CAM packages has to be used, which means CAM package should be able to generate interference-free toolpath data. The toolpath consist of a series of gouge-free cutter location (CL) data. The CL data is then used in CAM post processor for creation of machine specific NC part program. Using web based applications, a new paradigm can be thought of where automated part modelling can be integrated with automated NC part program generation. Thus the total integrated CAD-CAM environment will save a lot of time as well as total cost to be incurred by the user.

1.6 PRESENT WORK

The scope of this dissertation work is to create an interactive online macro enabled automated CAD designing system which allows the user to interactively create predefined model with user-defined parameters. This system can be integrated with the automatic toolpath generation system for developing a fully web-based automated CAD-CAM system. The online system should be able to allow users to create customized parametric features that will not only be used to designing of artistic 3D models but also allow the model to be shared with other users using the system. User-defined parametric features offer a new and innovative way for non-CAD designers to create actual 3D models over the internet without prior training. This web-based application needs to be managed using a client script and the backend server modelling using predefined parametric macros in SolidWorks^{TM} . Thus this approach can be thought as a step forward for web enabled integrated CAD-CAM environment.

CHAPTER 2
LITERATURE REVIEW

In this chapter, a literature relevant to the concept of automation of CAD systems, web based technologies used for design automation, NC toolpath generation and various aspects those related to formulation of a web-based environment to create a parametric models, have been reviewed. The study of literature reviewed for present work has been divided in four main parts as given below.

1. Parametric feature based solid modelling.
2. Automation of CAD based design procedure.
3. Web-based modelling techniques.
4. Web-based NC toolpath generation methods.

2.1 PARAMETRIC FEATURE BASED SOLID MODELLING

All the CAD software or packages works on the concept of parametric design to create any kind of 3D or 2D model. With the help of parametric based designing technique, one can create geometric models based upon parameters. The papers discussed below give the brief detail about the parametric feature based solid modelling techniques.

Choi et al [2]: purposed a macro parametric approach that is intended to provide capabilities to transfer parametric information including design intents. To transfer parametric information including design history, a set of standard commands is defined and used as a neutral format. Mapping relations was also defined between the standard modeling commands and the native modelling commands of commercial CAD systems. In this approach modelling commands in a CAD system are categorized into sketch, solid, surface and constraints.

Mun et. al. [3]: studied a set of modeling commands required by the macro-parametric approach. There are two approaches for the exchange of design intents such as parameters, features, and constraints. An explicit approach based on constraints between predefined parameters and features. A procedural approach based on the sequence of operations issued to construct the models. This macro-parameter approach helps the user to interact with different

system by using a standard set of modelling commands for the history-based or implicit parametric approach.

Kripac [4]: purposed a feature-based parametric modelling systems usually define models by a sequential history of modelling steps. The modelling steps contains an operation and its defining parameters. This method helps in finding the solution in areas such as edge and vertex intersections of curved surfaces (using the Edge-IntersCode and VertexIntersCode), split faces and merged faces (using the FaceZdGraph), distinguish between the individual faces resulting from splitting another face (using the FaceIdLoop) and Object-oriented software architecture with a narrow application interface

Li And Han [5]: gave an approach concerned about the representation of shape but, totally ignored its structural description. Also, described a theory which is totally depended upon the logical representation of geometric objects. Studded about the different methods which are used for the generation of a parametric model such as parametric and feature based modelling, constructive solid geometry and boundary representation . On the generative geometry on bases of theoretic grounds, presented an integrate explanation about the evolution of a geometric shape.

Hoffmann and Arinyo [6]: described some basic mechanisms for realizing UDFs that permit compounding shapes, encapsulating attributes and parameters, and associating topological validity rules. The author derived that the compound mechanisms are expressed using a generative paradigm using Erap technique. The basic unit for these paradigm are feature and parts construction by a sequence of feature operations. The usefulness of the mechanism relies on functional capabilities which is given by the end-user such as shape and size of the user-defined features according to parameter values, positions and orientations of the feature in the part being designed by means of geometric gestures on geometric references.

Kim and Han [7]: implemented a shared integrated platform, TransCAD system, which separates translators from a neutral file. The translators for a commercial CAD system only communicate with TransCAD system. Using automation APIôs, the functions of TransCAD can be able to communicate with CAD system. These automation APIôs in TransCAD either helps to translate a parametric CAD model from sending CAD system into XML format or to translate from XML format into the model of the receiving CAD system.

2.2 AUTOMATION OF CAD BASED DESIGN PROCEDURE

From the above discussion, the CAD packages have a lot of capability that allows designers and engineers to create 3D models of various kinds. But CAD modeling itself is a professional job and requires both knowledge and experience to create well constrained geometry when designing complex models. Modeling gets complex when parts need to be edited many a times during the engineering design process [21]. Moreover the design industries typically specialize in making one or more products of the same type and they all require standardized methods of modeling. These standardized methods helps in evaluation of the design as well as the procedure followed for creation of design model. By automating the commonly performed CAD operations, an industry can simplify and accelerate their design and modification process.

2.3 WEB-BASED MODELLING TECHNIQUES

As discussed above, CAD designs can be modelled with parametric feature based solid modelling and can also be automated if model or product is to be made by same technique. Automating CAD design give us an advantage to make an design using only few parameters and fixing all other geometry. With the help of this web based designing technique, these few parameters can be input to the CAD system by using web based techniques to make 2D or 3D models. The papers discuss below will give the brief detail about the web based feature based solid modelling techniques.

Chen et al [8]: presented a web services based platform for the exchange of procedural CAD models between heterogeneous CAD systems. A collaborative design environment was developed using a web service based platform for exchange of procedural GAD model between heterogeneous CAD systems. The exchange of procedural CAD models between heterogeneous CAD systems is achieved based on Neub-a1 Modelling Commands and the APIs of CAD systems. Furthermore, web services technology is adopted to encapsulate the procedural CAD model exchange functions, which are then released on the Internet as a standard interface and can be used by remote developers in their windows applications, web applications and so on.

Ziemer [9]: discussed about the development of the high quality web application user must take into account the feature and operational environment of the web application. Author

discussed about the various aspects for the high quality development of the web application such as architecture of web environment, software architecture and emerging field of web engineering

Lee et al [10]: purposed an approach that implemented on a client/server architecture in which web-enabled feature based modelling environment, neutral model server and other applications are communicated via standard communication protocol. This approach combines feature-based modelling technique with distributed computing and communication technology for supporting product modelling and collaborative design activities over the network. Neutral feature model server act as service provider, Attributed Abstracted B-rep (AAB) and B-rep used for processing and data model on client side and WEF client programming using Java for distributed application was developed.

Chen et al [11]: extend the synchronized collaborative design environment that is based in web services for the exchange of CAD models between heterogeneous CAD systems. In this approach, first a single real time operation is extended to exchange of complete procedure. Secondly, a web services is adopted to encapsulate the CAD model exchange functions to release on internet to be used by remote developer window. Finally, a web service for exchange of procedural CAD models between SolidWorks^{TM} and Autodesk Mechanical Desktop is realized.

Yang et al [12]: introduces a XML technology to represent the macro parametric exchange. Using XML to represent macro-parametric commands enables the management of a large amount of dynamic content, Web-enabled distributed applications, and the inherent characteristics of structure and validation. A standard macro file was developed that helps in transferring the designer intent such as parameters, features and constraints. It is suitable for network environment because standard macro commands are open and explicit and the data size is small. Using XML to represent macro-parametric commands enables the management of a large amount of dynamic content, Web-enabled distributed applications and the inherent characteristics of structure and validation.

Abrahamson et al [13]: described some of the technologies tends to have influence in network-enabled CAD. In this environment, expert participants and product development organizations are empowered to publish their geometric design, CAE, manufacturing or

marketing capabilities as live services that are operable over the Internet. These services are made available through a service marketplace. It will be possible to rapidly interchange equivalent design service providers so that the development of the product and the definition of the product development organization become part of the same process. Computer-aided design tools will evolve to facilitate the publishing of live design services.

Li et al [14]: an Internet-enabled system had been developed to support collaborative and concurrent engineering design by seamlessly integrating three functional modules i.e., co-design, Web-based visualisation and manufacturing analysis based on some state-of-the-art Java and Web technologies. The task which are performed using a collaborative environment are co-design, co-modelling and co-manufacturing. Services in the manufacturing analysis module can be invoked by users dynamically to evaluate and optimise the manufacturing costs and the manufacturability of a design part. An Internet-based system, which includes three modules for co-design, Web-based visualisation and manufacturing analysis, has been developed to support collaborative and CE design.

Ong et al [15]: developed a client/server framework to enable a dispersed team to accomplish a feature-based design task collaboratively. Based on feature-to-feature relationships, a distributed feature manipulation mechanism has been proposed to filter the varied information of a working part during a co-design activity to avoid unnecessary retransferring of the complete large-size CAD files each time when any interactive operation is imposed on the model by a client. A distributed environment based on the 3D feature-based modelling and Java client/server technologies has been discussed to support collaborative design.

Jiao and Helander [16]: developed a electronic configure-to-order platform to customized the product development over the internet. Configure-to-order platform provides a dynamic session to create and maintain the design using J2EE and VRML provides visual portal for customer to view, remark and evaluate a product design efficiently. A generic product family (GPF) master model is proposed to support product customization over the Internet while achieving a synergy of sales force automation, product design, manufacturing planning, and supply chain management within a coherent framework.

Li et al [17]: purposed a web-based parts library for Collaborative Design, Concurrent Engineering and Supply Chain Management System. Based on research of a web-based parts library system some key technologies are put forward which are a web-based part data description norm on data dictionary, a feature-based neutral representation of part geometric information and a hoops-based visualization method of part feature model. The technical foundation to propose the international standards with independent intellectual property right. Henceforth, the mechanisms of neutral expression and preview of parts feature model are studied further.

Cheng et al [19]: described an effort in applying web-enabled technologies using both software Autodesk Architectural Desktop (ADT) and Google Sketchup. The author implemented Sketckup plug-in that links to the integrated environment solution (IES) for the evaluation of design according to their analysis results. The CAD program and web browser are directly interacting using CAD software plug-in namely SpecifiCAD to perform configuration design.

2.4 WEB-BASED NC TOOLPATH GENERATION METHODS.

Ahn et al [20] : presented a macro machining service (MIMS) based on the world wide web technology. A three dimensional geometry generated from a commercial CAD system is uploaded as an STL (Stereo Lithography) file and the process parameters for three-axis CNC micro milling are to be elected via the user interface. Also, develop a web-based user interface which contains DFM paradigm and fully automated tool path generation that enables real time feedback. STL-based CAM module gives a strong stability and efficiency to the web-based integration was developed and its capability was verified by actual micro machining.

Adamczyk And Kociolek [18]: discussed about the Databases as interactive applications on the Web are a very up-to-date, promising and perspective solution. This technology is based on KSP-OSN/WIN distributed environment system which in turn introduce to KSP language statement formed automatically in the background. Solution of the Internet database for KSP-OSN/WIN system is particularly interesting for low cost CAM systems like KSP-OSN/WIN system, addressed to small and medium enterprises to improve their cooperation and decrease the cost of cooperation taking advantage of Internet/Intranet network.

2.5 CONCLUSION OF LITERATURE REVIEW

In the above literature, a brief discussing of papers has been studied with the aim that how customized solutions for web based are available over internet, which includes a mixed real time environment for collaborative product design and development has been discussed. A macro-parametric approach, which is a history-based method of parametric CAD model exchange also has been discussed which can be further used as to automate the CAD designs. So, a thought has been purposed to develop an environment that implement the strategies of the above discussion to develop a web-based application for creation of 3Dimensional model and NC toolpath generation.

CHAPTER 3

WEB BASED 3D PART DESIGN PARADIGM

3.1 PARAMETRIC CAD SOFTWARE

Most of the design industries use commercial CAD packages to assist in the creation, modification, analysis and optimization of a design. To perform these tasks different kinds of design software packages are available which depends upon the variety of product modeling method such as solid modeling, surface modeling, parametric modeling and knowledge based except system tools. Some of most commonly used commercial software packages used for the creation and modification of customized products available in market are as listed below.

1 AutoCAD.

2 Pro-E/ Creo.

3 Unigraphics.

4 Catia.

5 SolidWorks™.

Most of the commercial CAD packages have an integrated automated programmable interface (API) which help in customization and in extending the design and modeling of 3D models. Out of the listed CAD packages, SolidWorks™ API provides an easy access to the internal functions of the package which helps in the creation of the model. By using the API tool kit which works though Visual Basic for applications (VBA) editing environment, the internal functions of SolidWorks which creates the solid model and associated model data can be accessed. Further the user friendly environment of VBA inside the SolidWorks can be used for writing the customized macro for automating the 3D design procedure. Thus in the present work macro has been developed in the API environment using VBA editor for the customized 3D models.

3.2 MACRO IN SolidWorks™

The API uses application of Visual Basic for Applications (VBA) to develop procedural algorithm into SolidWorks™ modeller. This approach allows to use of the predefined native geometrical entities and operations together with an homemade computational algorithm. The three kinds of objects: those coming from SolidWorks™ (model native entities), those coming from math utility database (math entities) and user defined entities (Figure 3.1). The native geometrical objects concern the sketch entities (point, line, circle, spline etc.) and their

constraints, the features (extrusion, revolution, loft, etc.), the assembly management (mating, inserting, moving, etc.). The math native objects concern points, vectors and transformations for manipulate entities (projecting from model space to sketch space and vice versa, performing basic operation on vectors, etc.) as shown in Figure 3.1

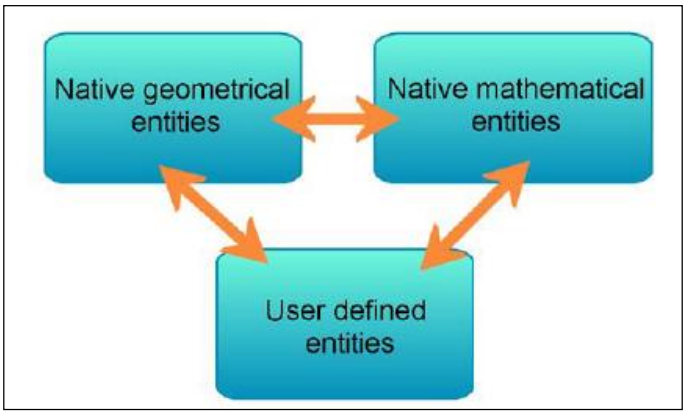


Figure 3.1 Solidworks™ API entity scheme

Using the software without API the user can only access to single model entity and the direct access to internal database is not permitted [30] Using API the database of entity can be directly accessed saving time to execute command and model entities can be interlaced with math and user defined ones.

3.2.1 GENERAL STEP FOR DEVELOPING MACROS IN SolidWorks™

The step require to record macros [29] is given below:

Operations performed is recorded with the SolidWorks™ user interface and replay them using SolidWorks™ macros. A macro contains calls to the Application Programming Interface (API) that are equivalent to operations performed in the user interface. A macro can record mouse clicks, menu choices and keystrokes The macro toolbar contains shortcuts to the macro recording commands. These commands can also be accessed from the tools, macro menu as shown in figure 3.2.

Figure 3.2: Macro toolbar.

1. Run  launches the run macro dialog box, where the user selects the macro to execute

2. Stop  launches the save as button macro dialog box where the user enters a valid name and extension for the macro. If the save is cancelled, a prompt appears that allows the user to continue or cancel the recording.
3. Record/pause  allows the user to begin or pause macro recording.
4. New  performs three steps, it launches the new macro dialog box where the user enters a valid name for the macro. Next the macro file is populated with standard lines of programming code to connect to SolidWorks™. Finally the VBA editor opens the macro file for the user to begin programming.
5. Edit  Launches the edit macro dialog box for selecting the macro to view or modify.
6. Custom  allows the user to customize a button on the Macro toolbar. An image is selected, a file path to a macro is set, and the custom button is dragged onto the Macro toolbar for use.

The macro is recorded by pressing the record button. The activity which is performed in the SolidWorks™ environment, almost all of them recorded successful. Now, by pressing the save as button that macro has been saved successfully. Now that recorded macro has been opened by pressing edit macro button. When that button has been pressed, browse the file saved earlier. The VBA editor open the coding of that macro. The above method can be illustrated with an example as written below.

Example:

The recorded sample code for the generation of cube of Length, width and height 40 mm respectively using MACROS in VB editor is shown below.

```
Dim swApp As Object
Dim Part As Object
Dim boolstatus As Boolean
Dim longstatus As Long, longwarnings As Long

Sub main()
Set swApp = Application.SldWorks
Set Part = swApp.ActiveDoc
```

```
boolstatus = Part.Extension.SelectByID2("Front Plane", "PLANE", 0, 0, 0, False, 0, Nothing, 0)
Part.SketchManager.InsertSketch True
Part.ClearSelection2 True
Dim vSkLines As Variant
vSkLines = Part.SketchManager.CreateCornerRectangle(0, 0, 0, 0.04, 0.04, 0)
Part.ClearSelection2 True
Part.SketchManager.InsertSketch True
Part.ShowNamedView2 "*Trimetric", 8
Part.ClearSelection2 True
boolstatus = Part.Extension.SelectByID2("Sketch1", "SKETCH", 0, 0, 0, False, 0, Nothing, 0)
Dim myFeature As Object
Set myFeature = Part.FeatureManager.FeatureExtrusion2(True, False, False, 0, 0, 0.04, 0.01, False, False, False, False, 0.01745329251994, 0.01745329251994, False, False, False, False, True, True, True, 0, 0, False)
Part.SelectionManager.EnableContourSelection = False
End Sub
```

3.2.2 SolidWorks™ API standalone and add-in applications

The programming languages used, that supports COM to create SolidWorks standalone API (.exe files) and add-in (.dll files) applications. The programming languages most commonly used are:

- Visual Basic .NET (VB.NET)
- Visual C++/CLI
- Visual C# .NET
- Visual C++ 6.0

Visual Basic .NET Standalone and Add-in Application:

Standalone Applications (.exe files)

Additionally, references to the SolidWorks type libraries must have added.

3.3 USE OF MICROSOFT EXCEL FOR SolidWorks™ API

Microsoft excel is a spreadsheet that provides simple to advance means to create and manage any type of data. Microsoft excel comes with a pre programmable language called microsoft visual basic for applications [29]. This environment automatically installed on the time when you installed microsoft excel. Itôs environment gives an application writing platform to write any type of code. It features also includes calculation, organizing data , manipulating data, arithmetic operations and a macro programming language. Visual basic for applications allows the user to provides a variety of numerical methods for solving equation and report the results back to spreadsheets. Microsoft excel can also be used as a database to store data from any external database or through a web . Microsoft excel used a proprietary binary file format called Excel Binary File Format (.XLS) as primary format.

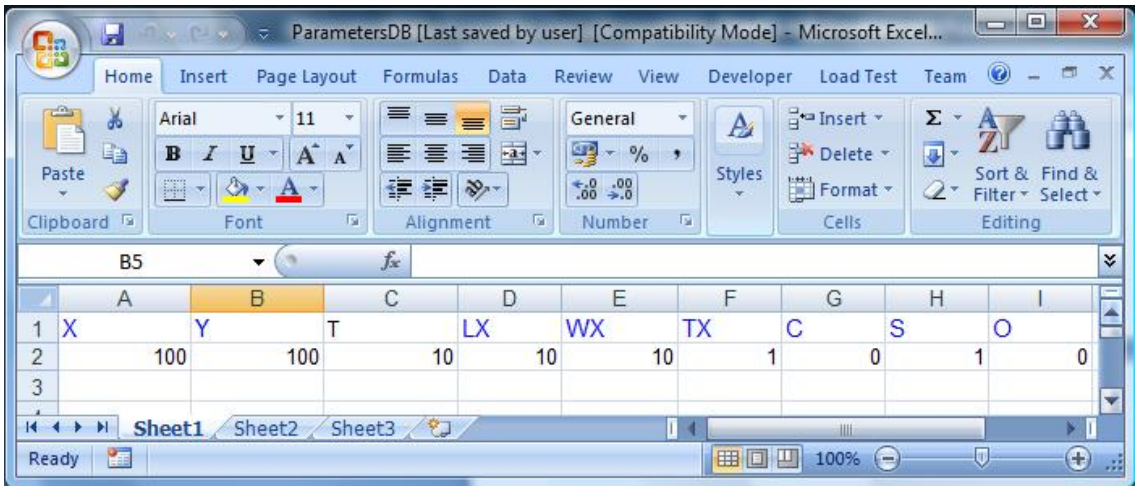


Figure 3.3: Parameters used in excel database.

The above figure 3.3 show the data which is stored from the website as per the user input. These are the various parameters which are then required to make an 3D solid model in SolidWorks™ by using macro programming.

Where,

X	=	Length of the Plank
Y	=	Width of the Plank
T	=	Thickness of the Plank
LX	=	Length of the Canvas
WX	=	Width of the Canvas

TX	=	Thickness of the Canvas
C	=	Shape of the Circle Wire
S	=	Shape of the Square Wire
C	=	Shape of the Octagonal Wire

Microsoft excel provides a platform to the user for programming which is called as Application Programming Interface (API). Programmer can write the code directly using the Visual Basic Editor (VBE), which includes a window for writing code, debugging and module organizing environment. User can also implement multi task and automatic task performing methods for desired output. The common way for generating a VBA code is by using a macro recorder. The macro recorder records all the actions which are performed by the user on the spreadsheet in a form of VBA code. These macro code can be used to perform repeated actions for a particular work.

The figure 3.4 given below show the VBA Project (ParametersDB.xls). In this VBA project, different module had been created which help in performing different function for the creation of the 3D solid model in SolidWorks™ by using the required input parameters which are given by the user through website page.

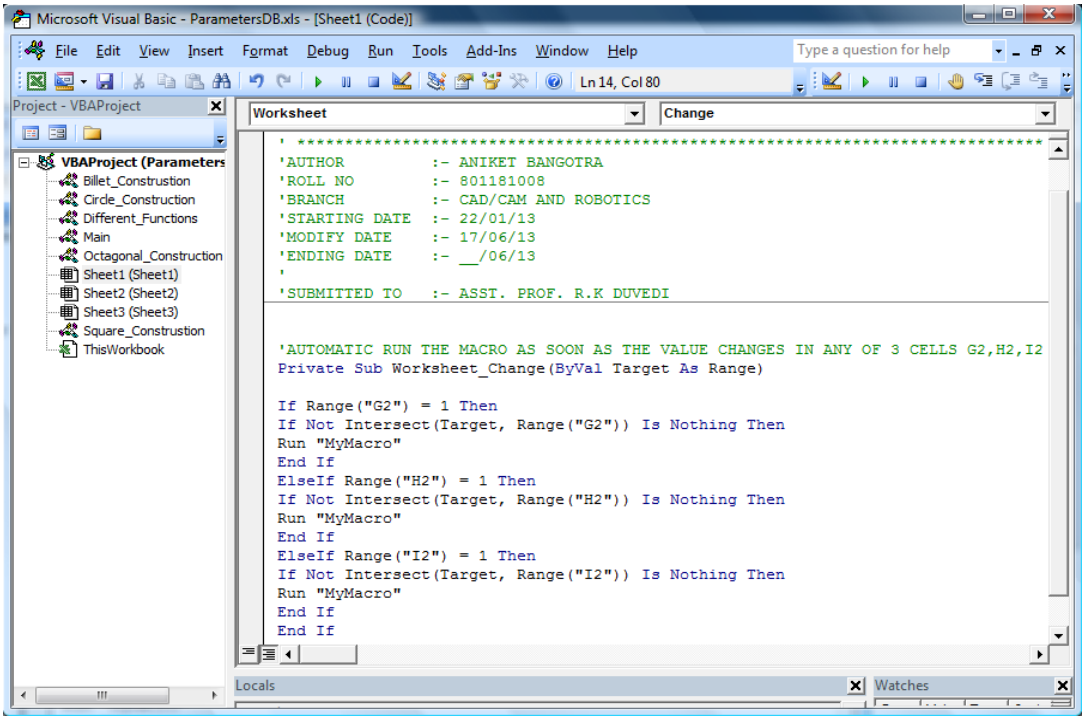


Figure 3.4: Code in VBA project.

The functions in the code given above in figure 3.3 is explained below.

Private Sub Worksheet_Change (ByVal Target As Range)
If Range (ñG2ò) = 1 Then
If Not Intersect (Target, Range (ñG2ò)) Is Nothing Then
Run ñMyMacroò
End If
Where,
Private Sub Worksheet_Change (ByVal Target As Range)
It is a Macro function that get invoke every time as soon as the value in any cell get changed.
If Not Intersect (Target, Range (ñG2ò)) Is Nothing Then
This function on look for the value change in a particular cell, like here its only looking for a value change in cell ñG2ò.

Run ñMyMacroò
Run command will run the ñMyMacroò, where all the code has been written, which is use for the creation of solid modelling.

3.3.1 Connectivity of excel with SolidWorks™

SolidWork™ give a great access and connectivity with microsoft excel by using an explicit method [29]. The most basic functions in SolidWork™ modelling are dimensions. Design tables are a great way to use microsoft excel spreadsheet functionality to drive these dimensions. These dimensional parameters can be controlled by using the methods of excel VBA and application programming interface. VBA in excel is based on older Visual Basic 6 language structure, it is similar to Visual Basic.NET but not the same. To make our code compatible with VBA in excel, the modification of code is done using older VBA style macro recording method in SolidWork™.

3.3.2 Procedure for using excel as database

JDBC (Java Database Connectivity), is a programming interface that is part of the Java programming language. It allows the client to access databases or database files such as spreadsheets to conduct data retrieval and storage in the database. The ability for JDBC to access formatted data such as spreadsheets comes from the ODBC (Open Database

Connectivity) bridge connection. By using the ODCB bridge, a programmer can access data stored in Microsoft Excel spreadsheets and conduct advanced manipulations of the data.

Basic Step for connect an excel spreadsheet with JDBC:ODBC in JAVA [31].

1. Navigate to your computers Control Panel and locate the Administrative Tools.
2. Once in the Administrative Tools section, locate Data Sources (ODBC).
3. The ODBC Data Source Administrator menu will open.
4. Select the User DSN tab and click Add as shown in the figure 3.5.

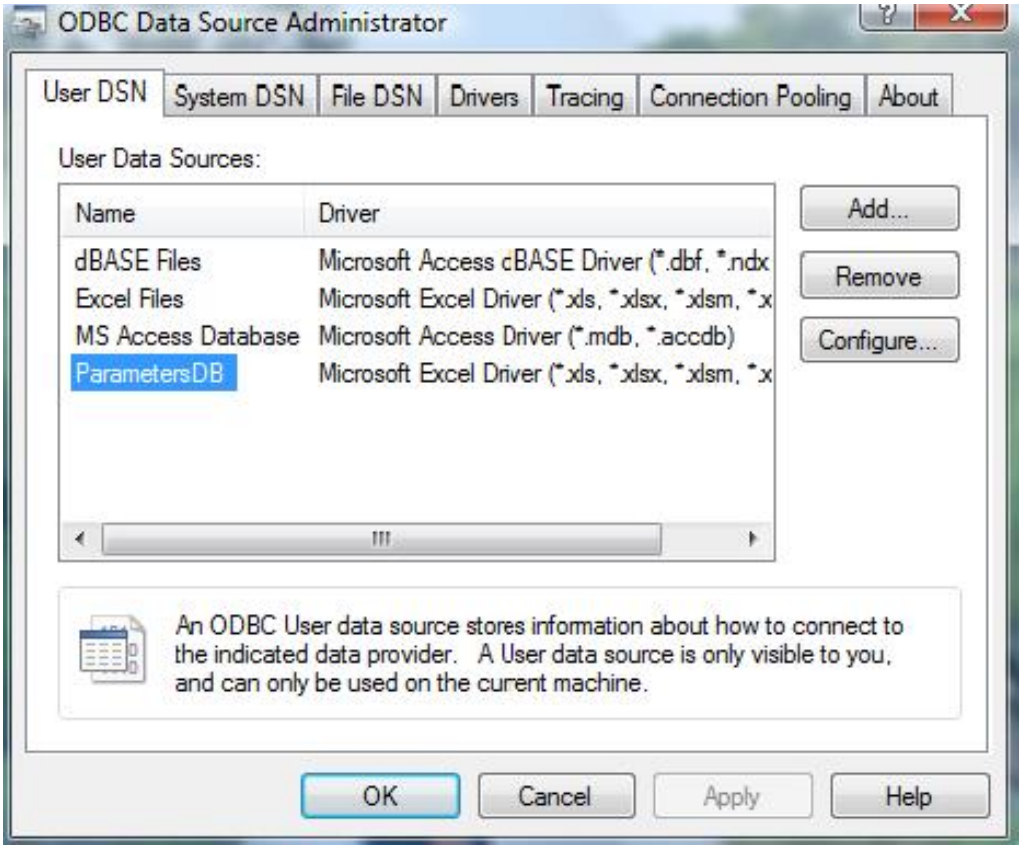


Figure 3.5: ODBC data source manager.

5. Find Microsoft Excel Driver (*.xls, *.xlsx, *.xlsm, *.xlsb) from the list and click Finish as shown in the figure 3.6 below.

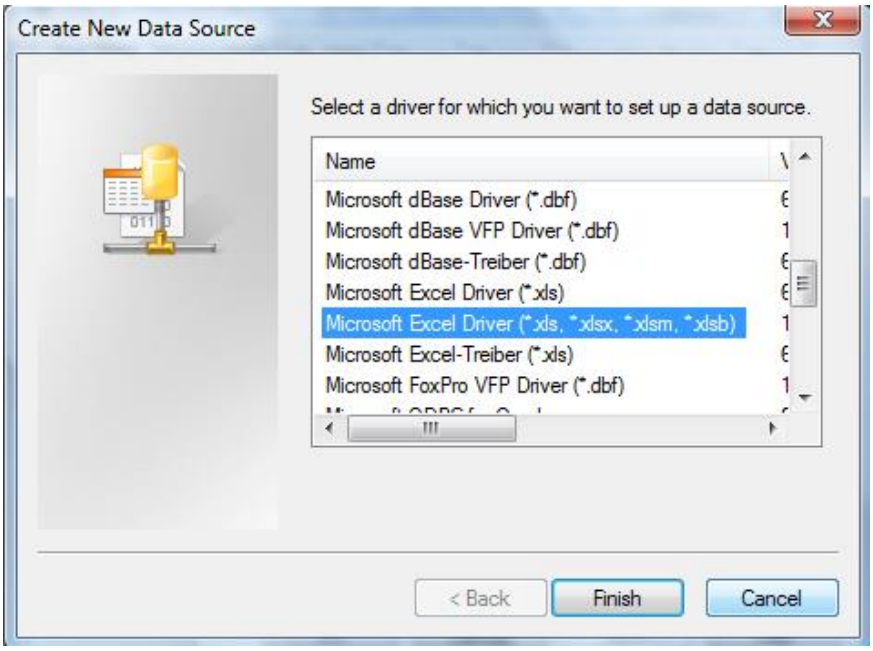


Figure 3.6: Create new data source drive

6. Give the Data Source Name & Description.
7. Next, click Select Workbook and locate the spreadsheet you wish to use as shown in the figure 3.7 below.

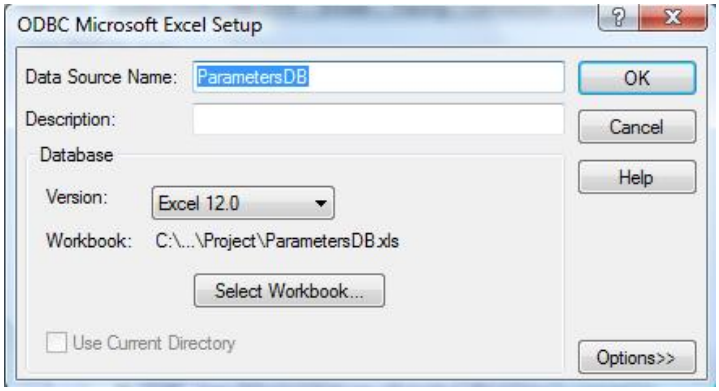


Figure 3.7: ODBC excel setup.

8. Click OK again to exit the setup. The ODBC connection is now complete.

3.4 NetBeans INTERGRATED DEVELOPMENT ENVIRONMENT (IDE)

NetBeans integrated development environment (IDE) is used for developing with Java languages but, this platform can also be used for other languages like PHP, C/C++, JavaScript, CSS and HTML. NetBeans IDE is based on Java that can be run on Windows,

MAC and Linux Solaris and other platforms supporting a compatible JVM [33]. It is a free and open source and has a large community of user and developers around the world. It is a free and open-source integrated development environment. NetBeans platform allows applications to be developed from a set of modular software components called modules.

3.4.1 Integrated modules

These are three types of integrated modules are part of the NetBeans IDE.

- NetBeans Profiler.
- GUI design Tool.
- NetBeans JavaScript Editor.

3.4.1.1 NetBeans profiler

The NetBeans Profiler is a tool for the monitoring of Java applications. It also help the developers to find memory leaks and optimize speed of the application. The profiler is based on a Sun Laboratories research project that was named JFluid [35]. This specific technique can be used to lower the overhead of profiling a Java application. Profiler also collects the information that is to large or complex for other profilers by using a technique called dynamic byte-code instrumentation and algorithm at the runtime. NetBeans also support profiling points that let you profile precise points of execution and measure execution time.

3.4.1.2 GUI design tool

The GUI (graphical user interface) design-tool enables developers to prototype and design Swing GUIs by dragging and positioning GUI components. In graphical user interface is a type of user interface that allows users to interact with electronic devices using images rather than text commands.

3.4.1.3 NetBeans JavaScript editor

The NetBeans JavaScript editor provides an extended support for JavaScript, Ajax, and CSS. JavaScript editor is a feature comprise syntax highlighting, refactoring, code completion for native objects and functions, generation of JavaScript class skeletons and automatic browser compatibility checks. It gives a easy and quick navigation to all the components through the navigation panel like, CSS features comprise code completion for styles names, displaying the CSS rule declaration in a List View and file structure in a Tree View, sorting the outline

view by name, type or declaration order (List & Tree), creating rule declarations (Tree only), refactoring a part of a rule name (Tree only).

3.4.2 Compatibility of NetBeans

The table given below gives the detail about the compatibility of the NetBeans with different platform.

Table 3.1: Compatibility table of NetBeans in different platforms.

IDE	License	Written in Java	Windows	Linux	Mac OS X	Other platforms	GUI builder
NetBeans	CDDL, GPL2	Yes	Yes	Yes	Yes	Solaris	Yes

3.4.3 Web Development

Web development is a broad term for the work involved in developing a website for the internet (World Wide Web) or a intranet (Private Network). Web developments can ranges from developing the website from simplest static page of plain text to complex web-based internet application and social network services. In a web development, the developer commonly refers to the following tasks more comprehensively includes web design, web contents, client liaison, client-side/server-side scripting, web server and network security configuration. The basic web development hierarchy can be split up into four main areas as shown in the figure 3.7.

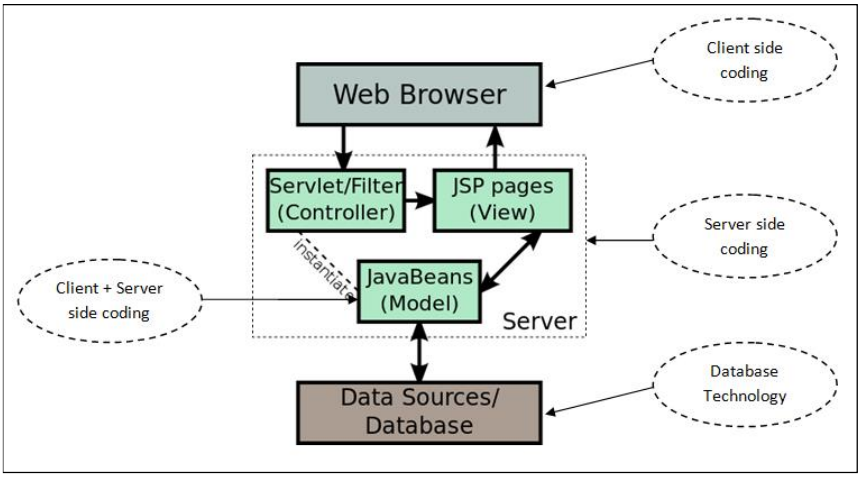


Figure 3.8: Basic web development hierarchy.

3.4.3.1 Programming language for web development

The programming language for web development are those languages which can be use to make an interface for developing a World Wide Web based applications. In todayôs world, there are many programming languages which are available to web developers for making a web design. The most popular programming language for web developments are Java/Servlet/JSP, HTML, PHP, C++ and ASP etc. There is no perfect programming language available for the web development.

Following are the some of the important aspects, which has been considered while selecting a programmable language for web development.

1 Server platform.

2 The server software running.

3 Budget.

4 Previous experience in programming.

5 The database to be chosen in the backend.

3.4.3.1.1 JavaScript

JavaScript (JS) is an interpreted computer programming language. It was originally implemented as part of web browsers so that client-side scripts could interact with the user, control the browser, communicate asynchronously, and alter the document content that was displayed. JavaScript is a prototype-based scripting language that has dynamic and first-class functions. Its syntax was influenced by the language C. JavaScript copies many names and naming conventions from Java, but the two languages are otherwise unrelated and have very different semantics. It is a multi-paradigm language, supporting object-oriented, imperative and functional Programming styles. The basic code of JavaScript is written below as shown in following example.

Example:

```
function upperCase()
{
var x=document.getElementById("name").value
document.getElementById("name").value=x.toUppercase
()}
```

3.4.3.1.2 Java/Servlet/JSP

Java is a powerful, open source, robust and secure web-based program that can run as standalone program or an applet embedded in a website. Servlets is used as a controller, JSP is used for viewing of web pages at client end and Java is to create a model architecture. Together, they creates a web-based applications by using MVC (Model View Controller). For creating robust secure web-application java has many frameworks like struts, spring and more in web application frameworks. The example shown below give us an information about how a JSP website pages are being created;

Example:

```
<html>
  <head>
    <title>A JSP Example</title>
  </head>
  <body>
    <% out.println("<p>Hello there!</p>"); %>
  </body>
 </html>
```

Architecturally, JSP may be viewed as a high-level abstraction of Java Servlets. JSPôs website pages are translated into servlets at runtime, each JSP's servlet is cached and re-used until the original JSP is modified.

3.4.3.1.3 HTML

HyperText Markup Language (HTML) is the commonly used markup language for creating website pages and other information that can be displayed in a web browser. HTML is written in the form of HTML elements consisting of tags enclosed in angle brackets (like <html>), within the web page content. HTML tags most commonly come in pairs like <h1> and </h1>, and although some tags known as empty elements are unpaired for example <img>. The first tag in a pair is the start tag, and the second tag is the end tag (they are also called opening tags and closing tags). In between these tags web designers can add text, tags, comments and other types of text-based content.

The web browser use the tags to interpret the content of the page and does not display the tags. HTML elements form the building blocks of all websites. It can embed scripts written in languages such as JavaScript which affect the behaviour of HTML web pages. Web browsers

can also refer to cascading style sheets (CSS) to define the appearance and layout of text and other material. The W3C, maintainer of both the HTML and the CSS standards, encourages the use of CSS over explicit presentational HTML markup. The basic representation of a HTML code is illustrated below with an example.

Example:

```
<!DOCTYPE html>
<html>
  <head>
    <title>This is a Title Page</title>
  </head>
  <body>
    <p> Hello World!</p>
  </body>
</html>
```

3.4.4 Web server

The term Web Server can be refer to hardware or the software that helps us to deliver web content that can be accessed by the client over internet. The primary function of the web server is to support web pages as per the request of the client using the Hypertext transfer protocol (HTTP).

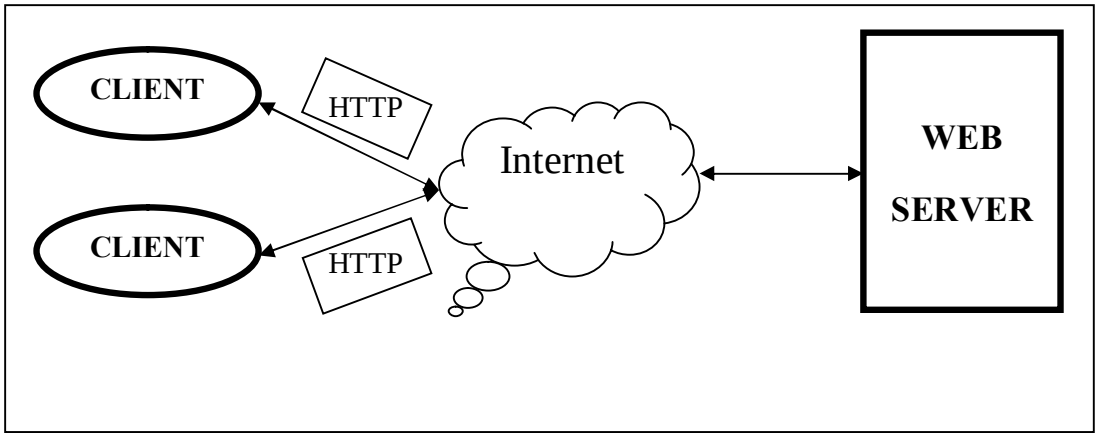


Figure 3.9: Basic web server hierarchy.

The full implementation of HTTP also includes receiving of contents from the client side like submitting of web form and uploading an image. Server can be run on any dedicated computer which act as a server but, many networks are capable of hosting server. The web

server also supports server-side scripting using active server pages (ASP), PHP and many other scripting languages. Web server is not only use for hosting a website over World Wide Web but , this can also be used for local networking.

3.4.5 Application server

An Application server is a software framework that provides a generalized approach for creating an application-server implementation. An application server acts as a set of components accessible for developer through an API defined by the platform itself. Application server components gives the same environment as that of its web server and its main job is to support the construction of dynamic pages. In Java application server, the server acts like a extended virtual machine for running application, database connectivity with web client on the other end.

Some of the Java Application Server are as given below:

- Glassfish
- Apache Tomcat
- Jetty
- Eclipse

3.4.5.1 Glassfish Application Server

GlassFish is an open-source application server started by Sun Microsystems for the Java EE platform. GlassFish is free software, dual-licensed under two free software licences: the common development and distribution license (CDDL) and the GNU general public license (GPL). GlassFish provides a pure Java HTTP web server environment for proper running of Java Servlet and JavaServer Pages (JSP). This allows the user to create an application which are portable, scalable and that integrated with inherit technologies. This application server is a cross-platform server that can run on any platform.

3.5 Topology of overall web-based application connectivity

As we discussed above in detail about the various aspects that assist us in making the web-based application. In the present thesis, all these aspects had been used for the connectivity of web-based application. The web-based application having one client end and another server end. The client side having web pages and GUI which are used for viewing of web-based application and to the server side JSP, HTML, JavaScript, JDBC:ODBC and database with

macro enabled which invoke SolidWorks™ to create model. The figure 3.9 given below gives an overview illustration about the concept.

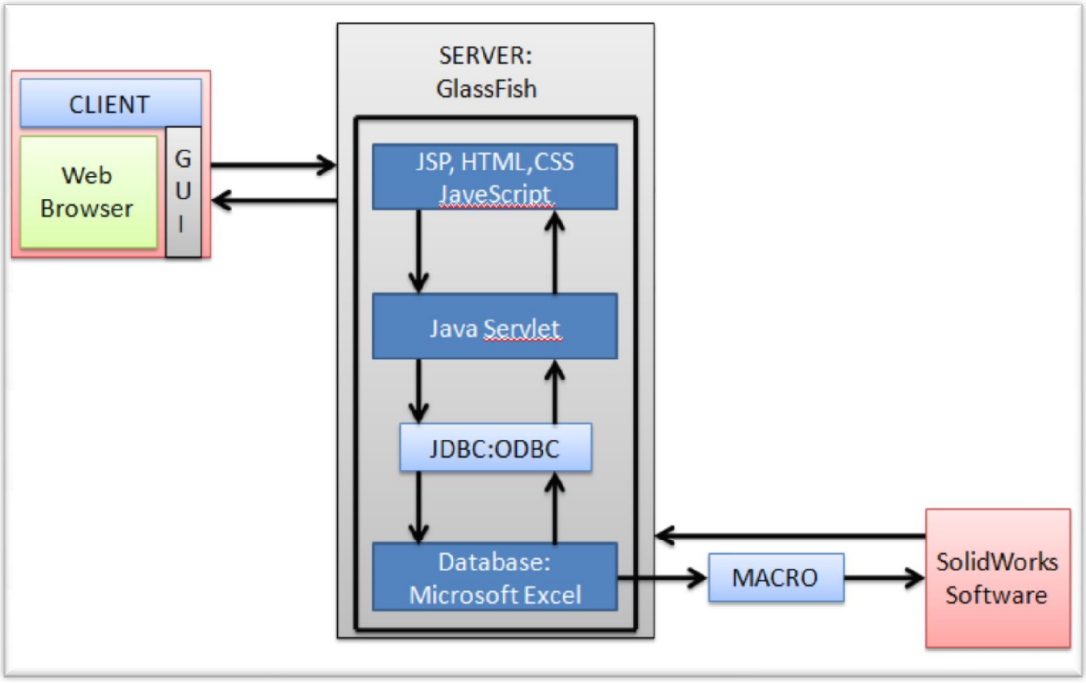


Figure 3.10: Topology of Application Connectivity.

CHAPTER 4

LOGIC AND MATHAMATICAL MODELLING

A computer program in visual basic for application has been created in API of SolidWork™ can be used for the generation for parametric and non parametric design elements for creating 3D design. The following section describe the details of the mathematical modeling used and user interface forms those appear in the SolidWork™ environment when the macro are invoke to create pre-designed 3D patterns. In the present work, mathematical macro for parametric design elements has been developed for the creation of customized 3D model using web-based application. The strategies for the developed presented work include the following different components which has been discussed as given below.

1. Design automation of the parametric model using macro.
2. Integration of raster and contoured NC toolpath algorithm with design automation Macro
3. Web based implementation of integrated design and NC toolpath algorithms.

4.1 DESIGN AUTOMATION OF THE PARAMETRIC MODEL USING MACRO

The literature has been purposed in chapter 2 that discussed about the design automation for parametric modelling using macro. By implementing the concept of automation in design creation few model which has been created using macro would be discussed in this chapter. The model which has been created in the present work are created using parametric design elements and the mathematical modeling for parametric design elements, for which the macro are created in SolidWorks™ environment has been discussed below.

4.1.1 Parametric design elements

The mathematical modeling for parametric design elements for which the macro has been created in SolidWork™ environment are discussed below. The basic three types of parametric design has been developed in this presented work are as followed:

1. Circular arc pattern.
2. Linear square pattern.
3. Polygon pattern.

The canvas used for these pattern was a fixed 2D sketch. These 2D sketched patterns can be scaled or de-scaled as per the parameters entered by user.

4.1.2 Circular arc pattern

The initial 2D sketch of the circle can be created in two ways in SolidWorks™.

1 Specifying centre and radius of circle.

2 Specifying three points on the perimeter of the circle.

Here in the present work, the circle has been made by specifying three point on the perimeter of the circle on the canvas. The shape of the initial 2D canvas remained fixed as a square and size depends on the length L_x and width W_x i.e.

$$L_x = W_x$$

Depending upon the length and width of the square canvas, the size of the circle can also be varied as per the parameters entered by the user through web-based application. The various entities used for the construction of the 2D circular pattern are shown in the figure 4.1 as given below.

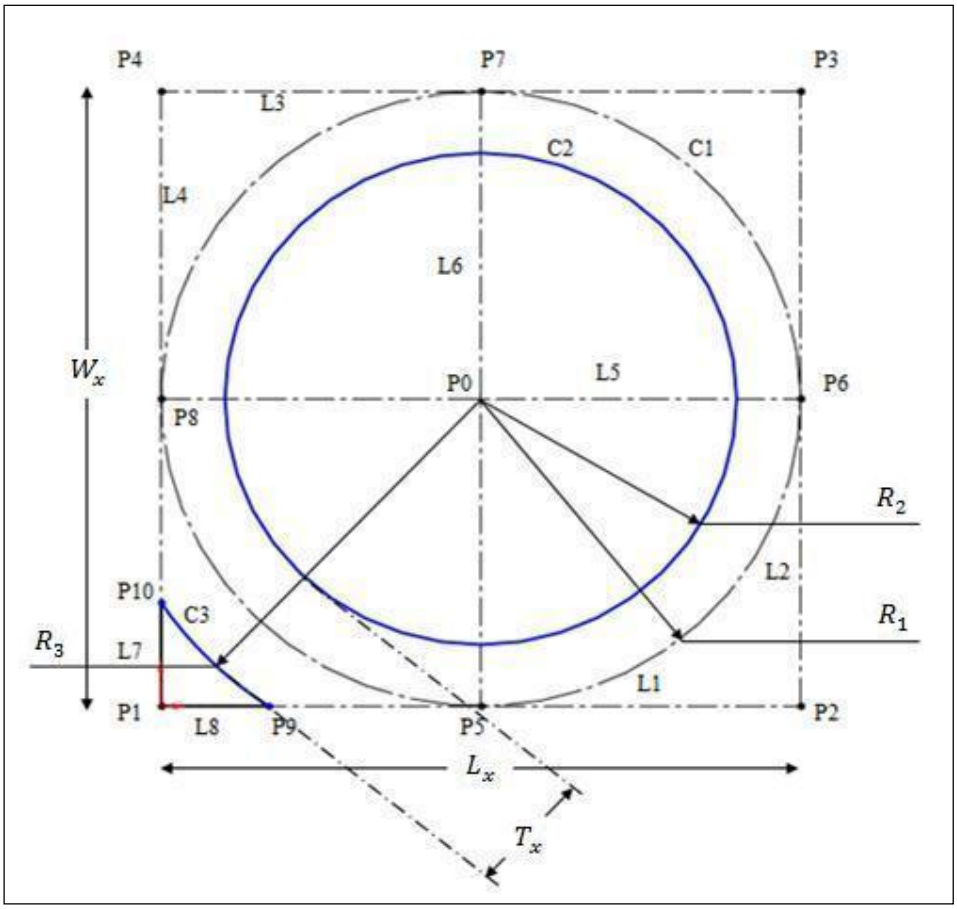


Figure 4.1 Canvas for 2D circular arc pattern.

Mathematically, the radius R_2 of the construction circle C1 depends on the half of the length of the canvas given by:

$r_2 = r_2/2$

Further, radius r_2 of the main circle C2 has been calculated as given below:

$$r_2 = r_2 - \frac{t_2}{2}$$

Where, t_2 is the thickness.

Similarly, radius r_2 of the arc C3 can also be calculated as given below:

$$r_2 = r_2 - \frac{t_2}{2}$$

So, the radius r_2 and r_2 of respective circle C1 and C2 can be changed by varying the value of t_2. The value of thickness has been entered by the user through web based application and the minimum value give for the thickness t_2 should be 1 and maximum can be anything as per the user entered parameters. Further, the intersection of arc C1 with lines L1 and L4 has been calculated which gives the coordinated point P9 and P10. Thus, the calculated points are then used for the construction of line L7 and L8, which give an arc pattern as shown in the figure 4.1. After the construction of an arc pattern, further the line L7, L8 and arc C3 has been mirrored about line L5 and then further line L7, L8, L9, L19, arc C3 and C4 has been mirrored about line L6 using SolidWorks™ (Part.SketchMirror) as shown in the figure 4.2 below.

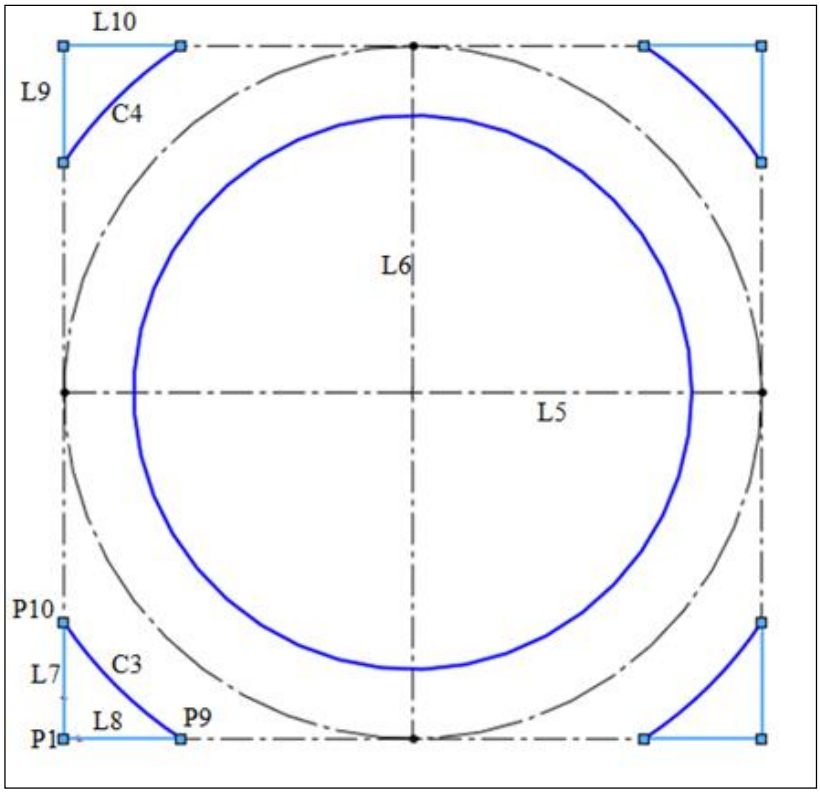


Figure 4.2 Mirroring of 2D arc pattern about centre axis L5 & L6

The table 4.1 below describe the various points and connecting lines, circle and arc used in circular arc pattern.

Table 4.1 description of canvas for circular arc pattern

Name of entity	Point generating entity
Line L1	P1, P2
Line L2	P2, P3
Line L3	P3, P4
Line L4	P4, P1
Line L5	P6, P8
Line L6	P5, P7
Circle C1	R1 and Centre Point P0
Circle C2	R2 and Centre Point P0
Arc C3	R3 and Centre Point P0
Length □□	P1, P2
Width □□	P1, P4
Thickness □□	Distance between Circle C2 and Arc C3

4.1.3 Linear square pattern

The linear line patterns are the extension of the rectangular pattern with all the side are equal. There are various type of method to generate rectangle in 2D sketch are given below.

1. Corner rectangle by specifying left lower and upper right corner.
2. Centre and upper right corner.
3. Three point corner rectangle.

The linear pattern has been made by specifying three point corner rectangle on the canvas. The shape of the initial 2D canvas remained fixed as a square and size depends on the length □□ and width □ □. The various entities used for the construction of the 2D square pattern are shown in the figure 4.3 as given below.

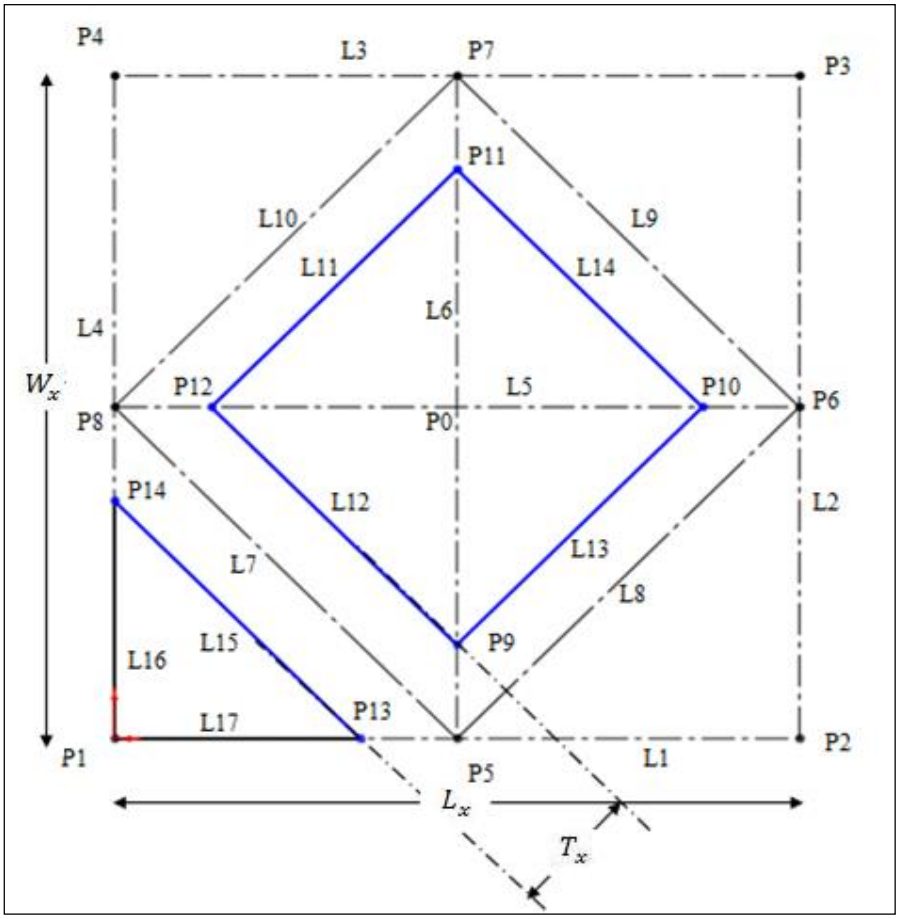


Figure 4.3 Canvas for 2D linear line pattern.

Depending upon the length and width of the square canvas, the size of the construction square can also be varied as per the parameters entered by the user through web-based application The table 4.2 below describe the various points and connecting lines used in square pattern.

Table 4.2 description of canvas for Linear square pattern

Name of entity	Point generating entity
Line L11	P11, P12
Line L12	P12, P9
Line L13	P9, P10
Line L14	P10, P11
Line L15	P13, P14
Line L16	P14, P1
Line L17	P1, P13
Length □□	P1, P2

Width w_1	P1, P4
Thickness t_1	Distance between line L7 and L12

The equation governing line L12 having parameter t_1 is given by,

$x_1 = x_9 + t_1(x_{12} - x_9)$

Where, x_9 and x_{12} are the *x* coordinated of point P9 and P12 respectively. The point x_1 varies with parameter t_1.

Similarly, for line L1

$x_2 = x_2 + t_2(x_2 - x_2)$

and L4

$x_3 = x_3 + t_3(x_3 - x_3)$

Where, x_2 and t_3 varies as per the values entered by the user.

The equation governing line L15 having parameter t_2 is given by,

$x_2 = x_{13} + t_2(x_{13} - x_{13})$

Where, x_{13} and x_{13} are the *x* coordinated of point P13 and P14 respectively. The point *xk* varies with parameter t_2.

The value of thickness has been entered by the user through web based application and the minimum value give for the thickness t_1 should be 1 and maximum can be anything as per the user entered parameters.

As the t_2 and t_3 parameter vary the equation of line L15 and L4 also varies. There would be a certain value of t_2 corresponding to t_3 where these both line intersect each other at a particular point. The intersection point for the line L15 and L4 has been calculated to get the required points P13 and P14 as shown in figure 4.3 above. Let (x_2, x_2) be the intersection point of line L13 with L1.

The slope of the line L13 has been with line L1 calculated,

$m_3 = (x_{13} - x_{13})/(x_{13} - x_{13})$

$x_2 = m_3 \times x_2 + (x_{13} - m_3 \times x_{13})$

$x_{13} = (x_{13} - m_3 \times x_{13})$

$x_2 = m_3 \times x_2 + x_{13}$

So, $x_2 = (x_{13} - x_{13})/m_3$

The intersection point has been given by (x_2, x_2).

Similarly, the point (x_2, x_2) has been calculated for line L13 with L4.

After, calculating the points P13 and P14, two line has been made line L16 and L17. Thus creating a triangular patch in the corner as show in figure 4.3. Further, this triangular patch L15, L16 and L17 has been mirrored about line L5 and then further line L15, L16, L17, L18 L19 and L20 has been mirrored about line L6 using SolidWorks™ (Part.SketchMirror) as shown in the figure 4.4 below.

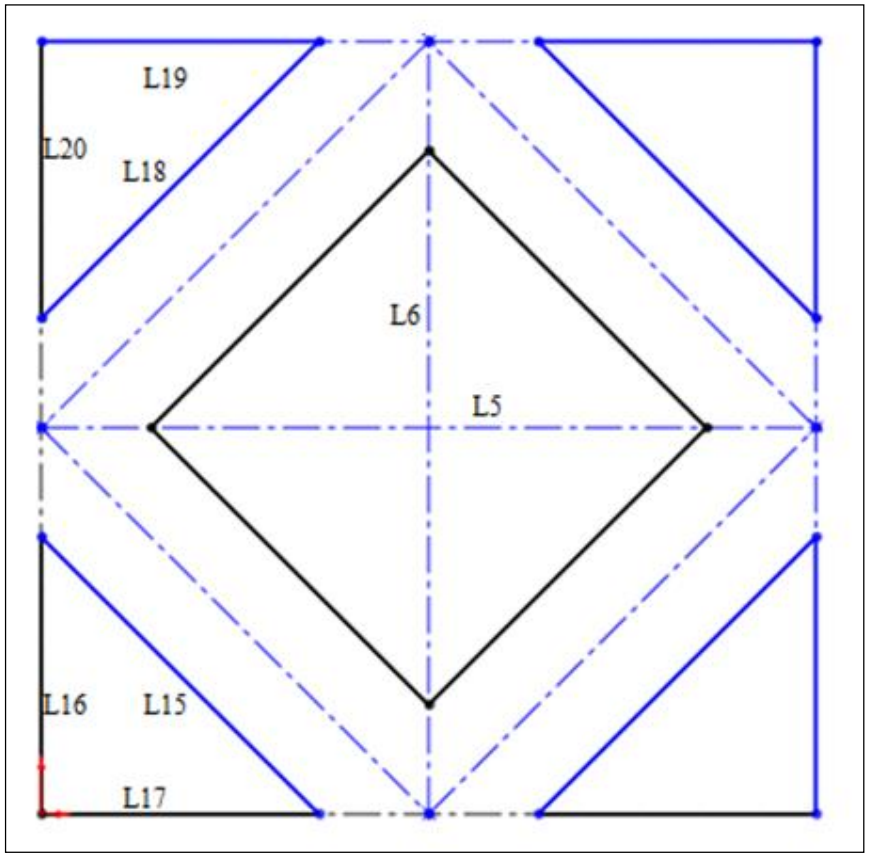


Figure 4.4 Mirroring of 2D triangular patch about centre axis L5 & L6

4.1.4 Polygon Pattern

Another, liner line patterns has been developed which is the extension of the polygon pattern. There are various type of method to generate polygon in 2D sketch are given below.

1. Inscribed circle with centre points and radius that defines the circle and number of sides
2. Circumscribed circle with centre points and radius that defines the circle and number of sides.
3. Specifying the eight line interconnection.

The polygon has been made by specifying the eight line interconnection on the canvas. The shape of the initial 2D canvas remained fixed as a square and size depends on the length Lx

and width Wx. The various entities used for the construction of the 2D polygon pattern are shown in the figure 4.5 as given below.

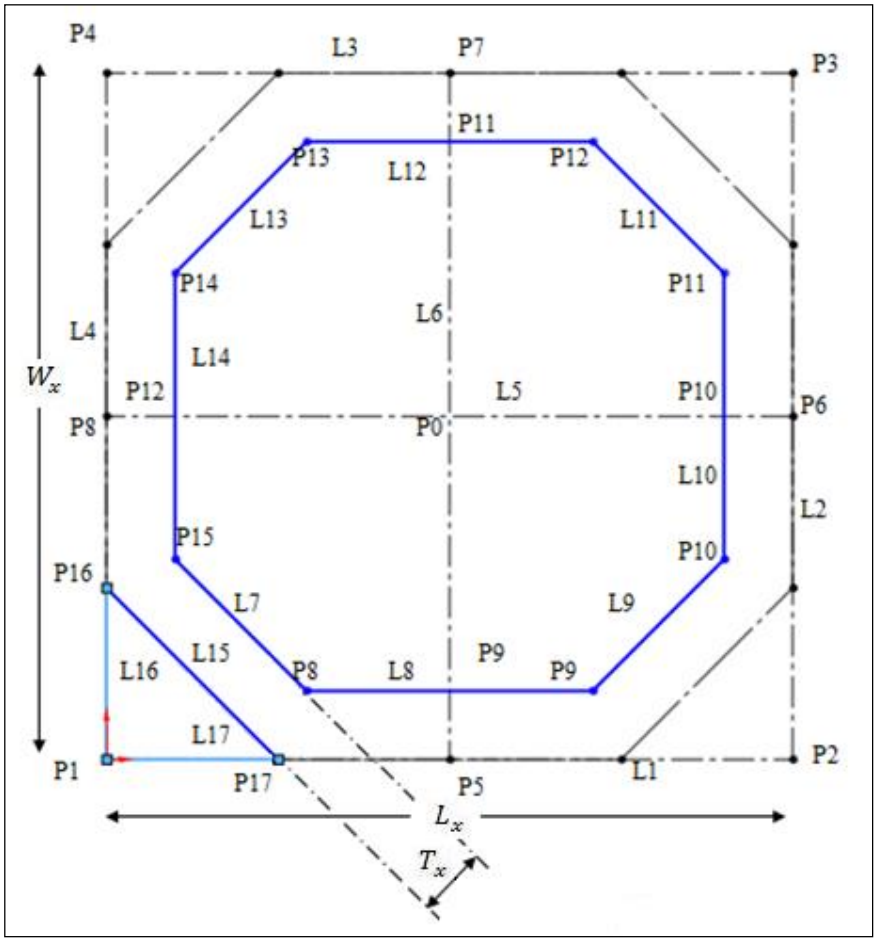


Figure 4.5 Canvas for 2D polygon pattern.

Depending upon the length and width of the square canvas, the size of the construction polygon can also be varied as per the parameters entered by the user through web-based application. The value of thickness has been entered by the user through web based application and the minimum value give for the thickness Tx should be 1 and maximum can be anything as per the user entered parameters.

The table 4.3 below describe the various points and connecting lines used in Octagonal pattern.

Table 4.3 description of canvas for polygon pattern

Name of entity	Point generating entity
Line L7	P15, P8

Line L8	P8, P9
Line L9	P9, P10
Line L10	P10, P11
Line L11	P11, P12
Line L12	P12, P13
Line L13	P13, P14
Line L14	P14, P15
Line L15	P16, P17
Line L16	P16, P1
Line L17	P1, P17
Length	P1, P2
Width	P1, P4
Thickness	Distance between line L7 and L15

As the , and parameter vary the equation of line L15, L1 and L4 also varies. There would be a certain value of corresponding to , where these both line intersect each other at a particular point and similarly for respectively. The intersection point for the line L15 and L4 has been calculated as shown above to get the required points P16 and P17 as shown in figure 4.5 above.

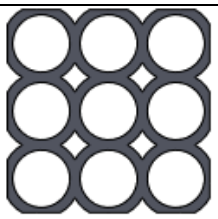
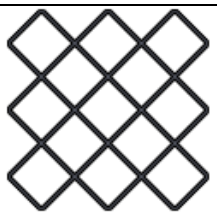
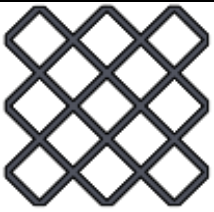
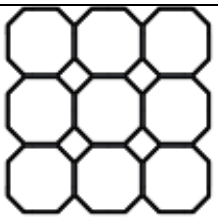
4.1.5 Three dimensional model generation from 2D patterns

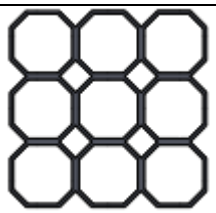
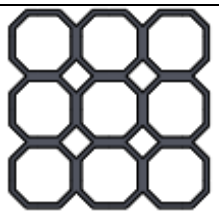
The various parametric patterns discussed in previous sections can help in generating three types of 3-Dimensional patterns on a rectangular part. The software package SolidWorks™ is used to developed these 3D patterns on the rectangular part. These three types of 3-Dimensional patterns are as given below.

1. Circular pattern.
2. Square pattern.
3. Octagonal pattern.

The different type of circular, square and octagonal pattern for circular arc and linear line for different value of Tx has been shown in table 4.4 below.

Table 4.4 Types of different parametric design varying the value of ⍰.

Types of parametric design	Circular arc pattern	Circular pattern	Value of ⍰. = 1	
			Value of ⍰. = 2	
			Value of ⍰. = 3	
	Linear Line pattern	Square pattern	Value of ⍰. = 1	
			Value of ⍰. = 2	
			Value of ⍰. = 3	
	Polygon Pattern	Octagonal pattern	Value of ⍰. = 1	

			Value of □□. = 2	
			Value of □□. = 3	

4.1.6 Macro development in SolidWorks™

The development of macro in SolidWork™ basically based upon the VBA codes, which includes a set of sequence information required for a meaningful output in the modelling environment. Macro development has been used to increase the efficiency, performance and the effectiveness of the user or engineer. The VBA codes can be modified as per the requirement of the engineer in the user form, so as to develop a convenient, friendly and interactive environment for correctively generation of the geometrical model.

The stepwise implementation of SolidWorks macro algorithm is discussed below:

STEP 1: Click Play button to start the a macro.

A VBA form has been popped up on the screen, which enable the user to perform various actions. The developed user-form which has been created as shown in the figure 4.6 below. This User-Form has the options of controlling the parameters which are required for the successfully creation of the required model like here we are making wire patterns.

This user-form which has been created having very interactive and user friendly environment, anyone can use this interactive form by following the procedure stepwise. The user-form contains three parametric models of wires patterns and different shapes of canvas are Circle, Square and Octagonal. So, let us started with this interactive User-Form and discuss about the various steps that helps to create the parametric model. The user has been asked to enter the following parameters such as length, width and thickness of the plank then selecting the shape of the wire from various option such as circle, square and octagonal followed by entering the parameters of the wire canvas respectively.

STEP 2: Pressing the START Button.

When the start button has been pressed which invokes the first frame of the user-form i.e. PLANK SIZE. The form will ask to enter the parameters such as length, width and thickness

of plank size as shown in the figure 4.6 below. This will create a geometrical model of the desired parametric as per the values entered by the user.

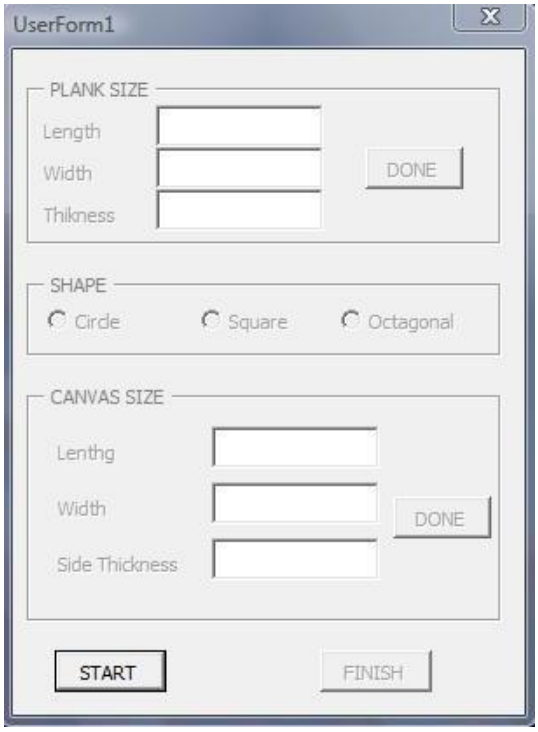


Figure 4.6 : User form for input data.

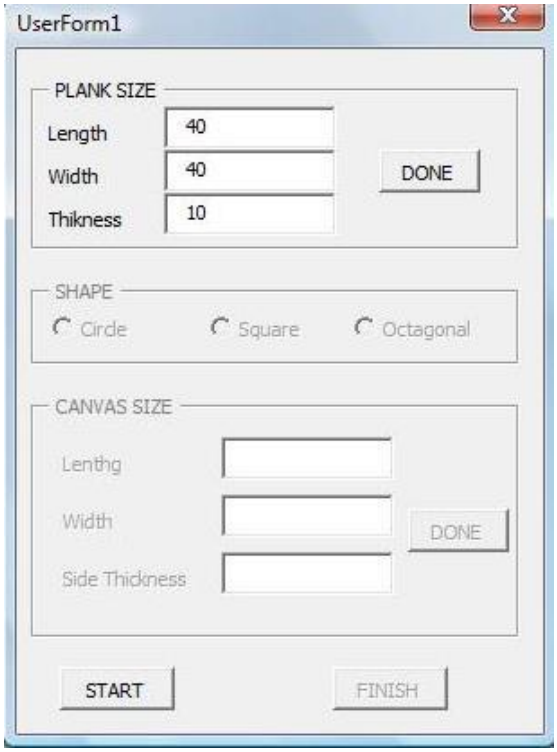


Figure 4.7 : Input data for PLANK SIZE.

STEP 3: Press DONE button for the for creation of PLANK

After entering the value length, width and thickness in their respective textbox, the user then press the done button to submit these value to the VBA code. The code will run as soon as the user click on the done button, this created a plank of given parameters. By pressing the done button next frame i.e. SHAPE also get invoked as shown in figure 4.7 below and previous frame get hide, so that model doesnôt encounter any modelling problem.

STEP 4: Selecting the radio SHAPE button.

After done with the creation of the plank of required size. Further, the next step is to select the shape of the wire canvas that have to be made on the created plank is then selected. The user-form has three radio button from which only one button can be selected as shown in figure 4.8 and figures 4.9 shows the different shapes.

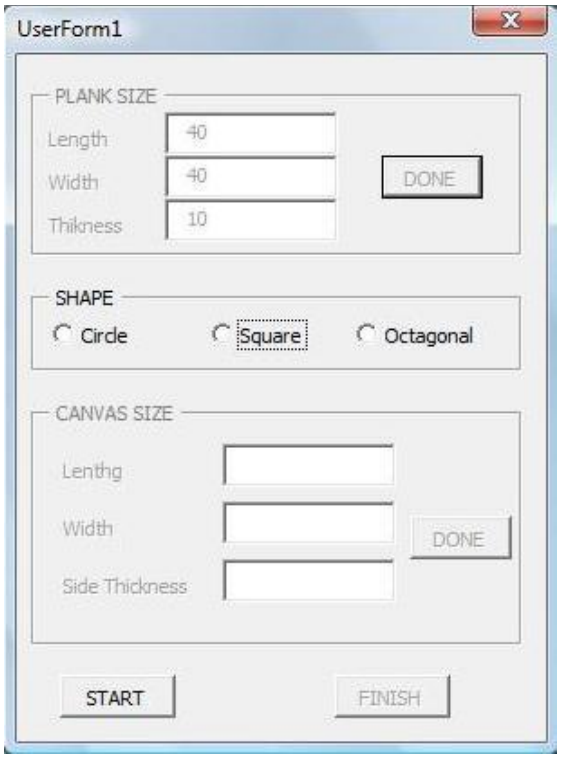


Figure 4.8 : Selecting the wire canvas SHAPE.

Figure 4.9 : Different shapes of the wire pattern.

STEP 4: Input for the wire CANVAS SIZE.

As the user select a radio button, it get hide for further selection and next step get invoked i.e. CANVAS SIZE. Here, the user has entered the desired length, width and side thickness of the canvas as shown in figure 4.10 below.

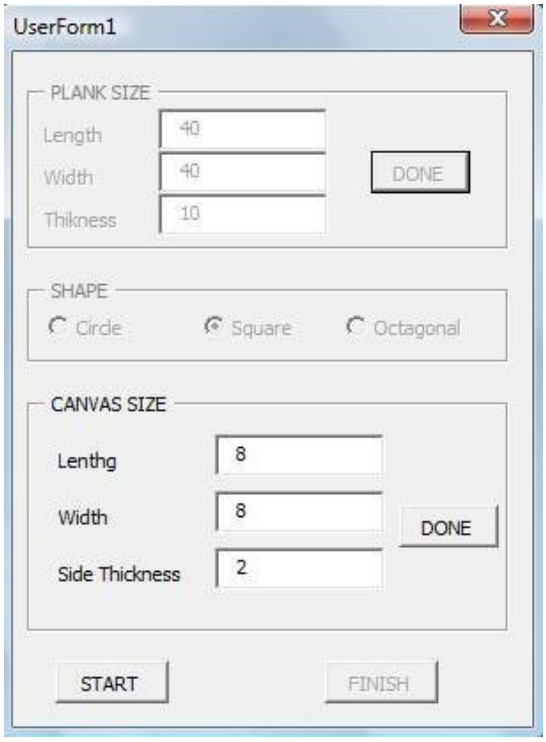


Figure 4.10 : Parameter input for required wire canvas size.

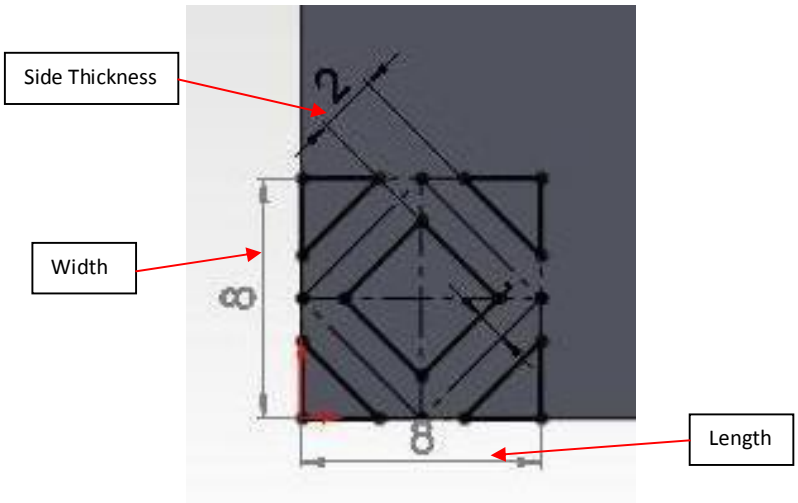


Figure 4.11 : Parametric design of the wire canvas.

The figure 4.11 above show the different parameters which are used as variables so that we can change the size of the canvas depending upon the parameters defined by the user/client.

STEP 5: Click on the DONE button in canvas size.

As the desired parameters are entered in their respective textbox. The user finally click the done button in CANVAS SIZE frame that also invoke the VBA code. The code run in background and take the parameters such as length, width and side thickness of the wire canvas from their respective textboxes from user-form. The code will perform different set of steps as defined by the user in the form of information or code and give an output as shown in the figure 4.12 below in SolidWorks™.

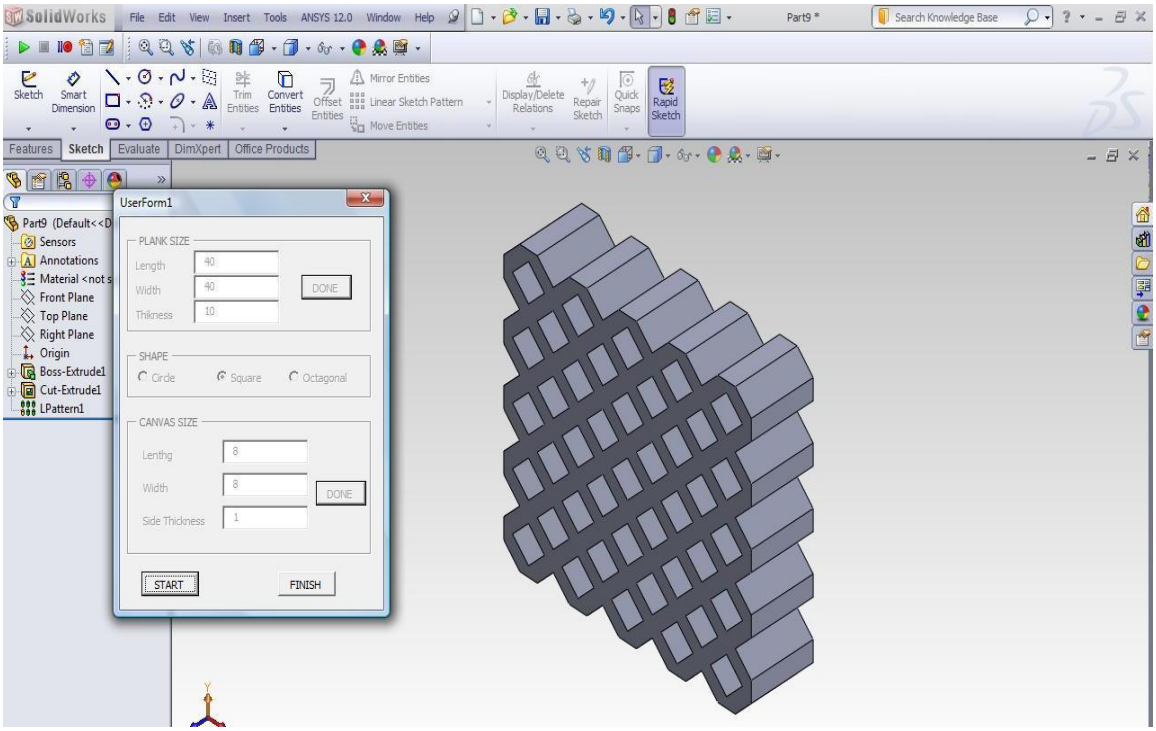


Figure 4.12 : Final geometrical model.

The final outcome of the different steps has created a geometrical model as shown in the figure 4.12 above. After the final outcome of the geometric model, the part model has been saved in the .SLDPRT format and to create a toolpath the geometric model has also been saved in the Stereo Lithography file (.stl) format. The CAD modeller provides the information about the part geometry has been taken as STL file, which can be further used as a input for the toolpath generating algorithms. After pressing DONE button FINISH button get invoke, clicking finish will stop the macro.

4.1.7 Flow chart showing the overall organisation of Design Macros

The procedure discussed above for creating a model can also be shown as in the form of a flow chart that can help to better understand the working and control of the design automation macro as given in figure 4.13 below.

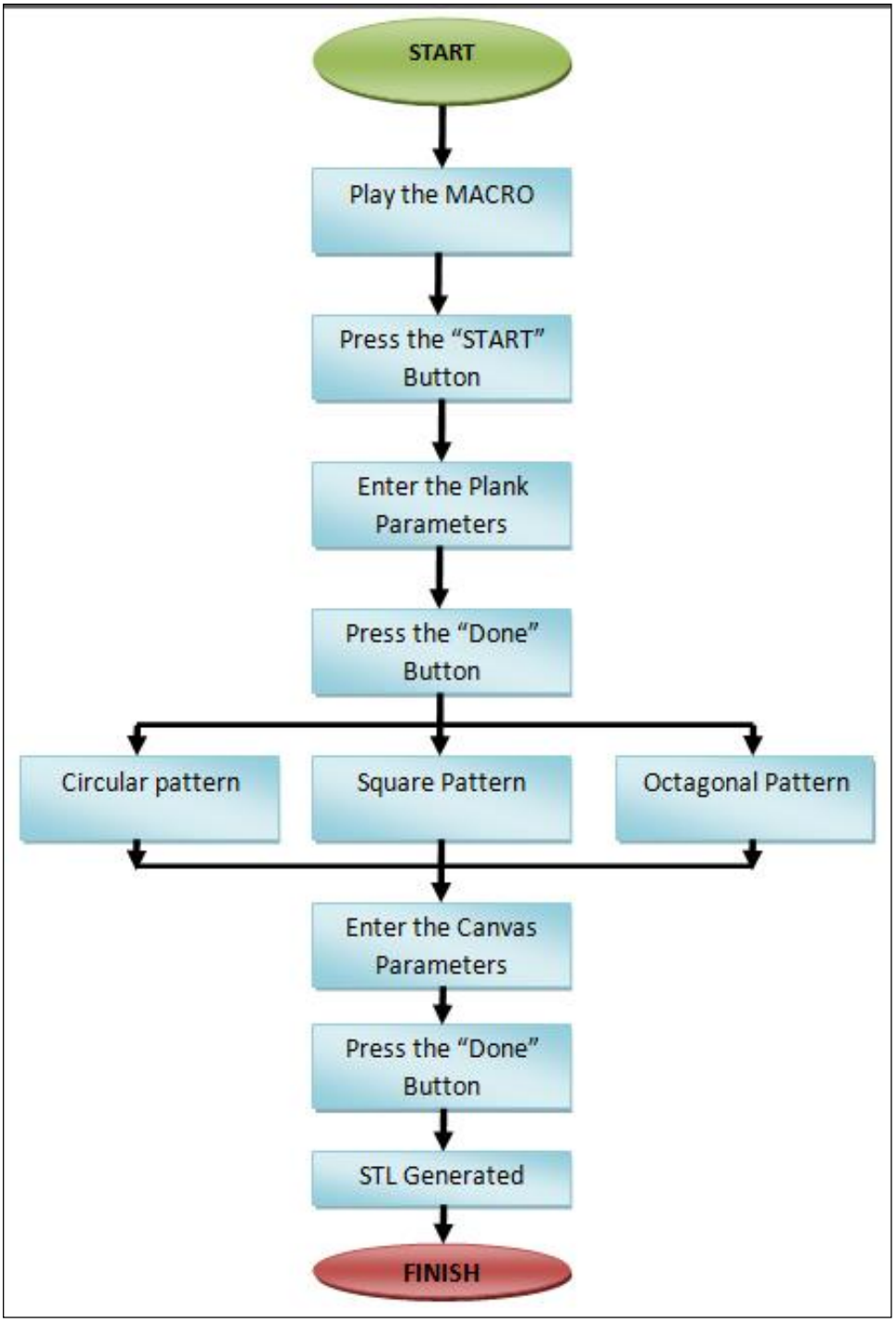


Figure 4.13: Flowchart explaining the flow of control of macro.

4.2 ALGORITHM FOR NC TOOLPATH

An algorithms has been used for the calculation and computation of the toolpath from STL file which has been saved in particular format as discussed above. These algorithms convert the CAD modeller information as STL file into machine understandable format which toolpath file in text format. These algorithm are already been developed previously in C++ and Java platform. So, in the present work an implemented of these algorithms has been embedded within the developed web-based application environment [25] [27]. The following are the two algorithms which are used as given below.

1. Raster toolpath algorithm.
2. Contour toolpath algorithm.

4.2.1 Raster toolpath algorithm

The raster based toolpath generation algorithm from STL models is a unique and faster development, which is useful in the rapid prototyping and computer-aided machining [25] and figure 4.14 show the raster toolpath.

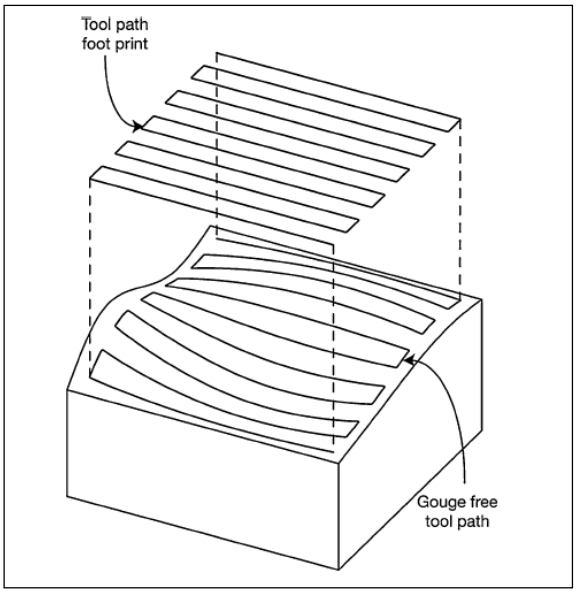


Figure 4.14 Raster NC toolpath [26]

4.2.2 Contour toolpath algorithm

This pencil or contour cut toolpath generated for tools will move only along the contour boundaries rather than cutting through the whole of the work piece, which will save a lot of machining time [27] and figure 4.15 show the contour toolpath.

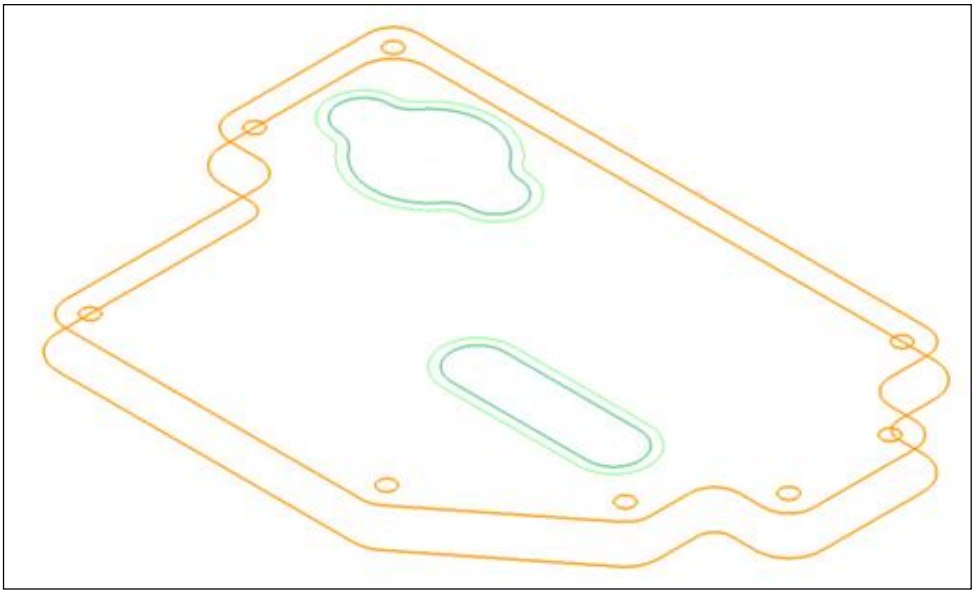


Figure 4.15 Contour NC toolpath

4.3 WEB BASED IMPLEMENTATION OF INTEGRATED DESIGN AND NC TOOLPATH ALGORITHMS

A web-based application has been developed with an interactive environment to create 3D parametric model and required NC toolpath as discussed in the above section 4. Both of these strategies/algorithms have been further enhanced through implementation using a web-based application for demonstrating the concept of online integrated CAD and CAM environment. The details of development phase of web application for this system has been discussed in chapter 5.

CHAPTER 5
IMPLEMENTATION: WEB TECHNOLOGY DEVELOPMENT

5.1 WEB BASED APPLICATION DEVELOPMENT IN JavaBeans

The development of web based application in NetBeans is totally a Java based programming, which further uses some programming languages such as JavaScript, HTML and JSP for the completion of the fully operated web based application. This web based application can be easily accessed by any remotely located client who belongs to anywhere in this world. As we already discussed how SolidWorks VBA programmable environment can be used to generate MACRO for parametric modelling. In this thesis report, we have created an web based application which can access these set of information or MACRO in SolidWorks remotely. This is an Explicit method to invoke the MACRO within SoildWorks by using an web based application through a website, which works on the client and server technology. Client can access this web based application over the internet or intranet through website.

5.2 ARCHITECTURE OF AUTO MODPart

The architecture of the web application is totally based on the server and client collaborative environment. It is a runtime user interactive environment that the client to interact with the server. The Figure 5.1 shows the interactive environment for the application.

The Figure 5.1 gives a platform for the interactive environment to the web based modelling environment. The application developed in web environment was programmed to connect to the server algorithms that ran the SolidWorks software in the background to model the parametric model and provided an output to the client to the web browser.

At client side the interface working is totally based on JavaScript and JSP (Java Servlet Pages) at the run time and further, is connected with the server side by using Java Servlet as shown in the figure 5.2 above. At server side, the interface had a totally collaborative environment that works simultaneously both with SolidWorks^{TM} by using MACRO and database by using data connector ODBC:JDBC.

At the runtime, the client interface act as a modeling design form for features where user can defined the model parameters. As soon as the client submit the filled design form, the user defined parameters passed on to the SolidWorks software for the designing purpose through ODBC:JDBC database connectivity as defined in previous chapter 3.

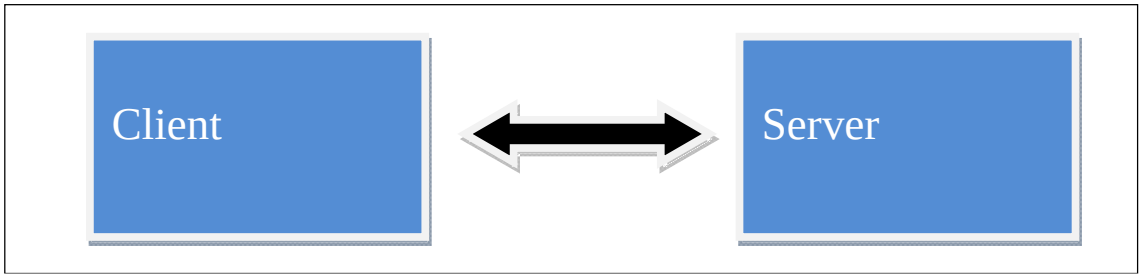


Figure 5.1: Interactive environment.

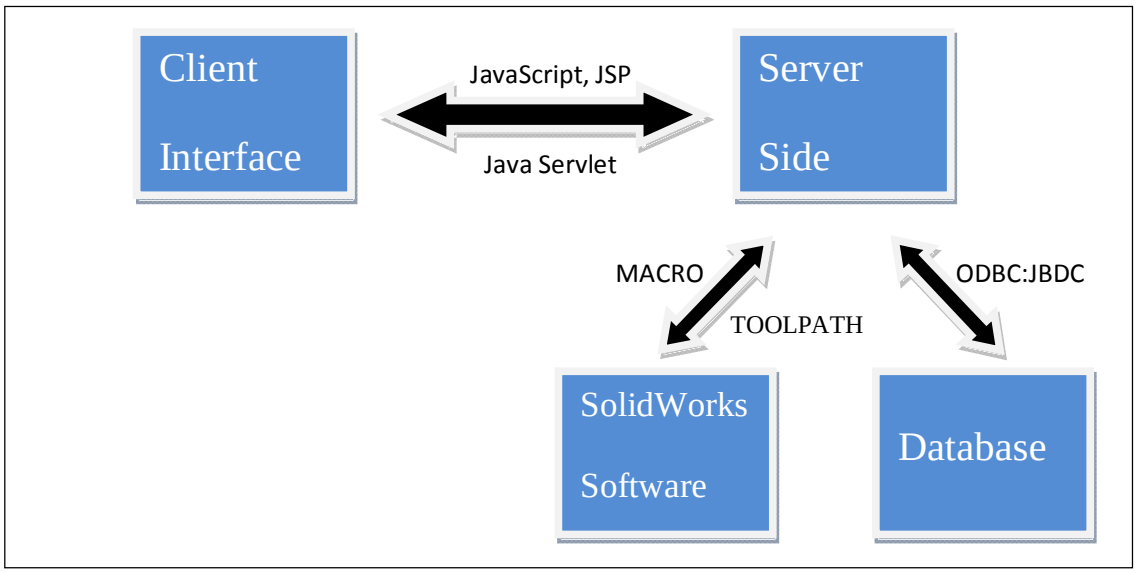


Figure 5.2: Architecture of Auto MODPart Application.

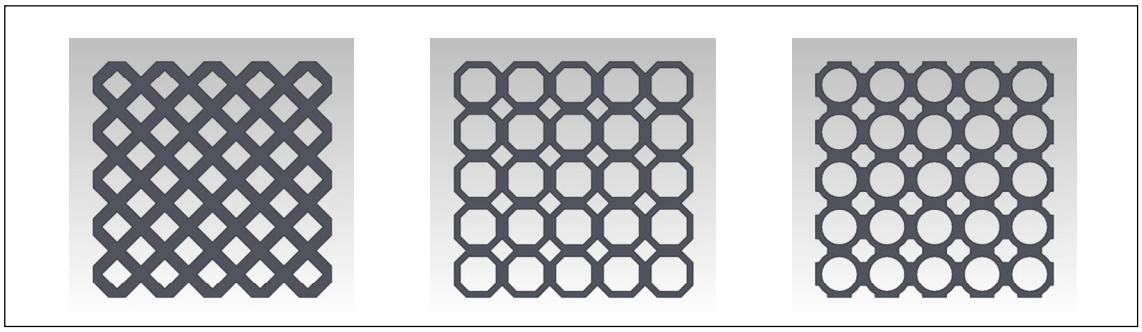


Figure 5.3: Designes based on diffrent shapes and size

5.3 Development of Web Based Design

The aim of the developed system has to allow the design of customised feature using and interactive web based interface. Customized features are of different shapes, size and can be of different patterns based on their canvas shape. Some of the illustration in this domain are shown below in figure 5.3.

5.4 COMPONENTS OF AUTO MODPart

The development of the AUTO MODPart web based application is based on different modules. The main modules is the design creation and display of the created design in the web browser using data transfer between client and server, server macro and generation of 3D solid modeller.

5.4.1 Creation and display of parametric design

As discussed in previous chapter 4, the parametric designs are created using SolidWorks software. The web based application provides the user a detail definition about design parameters, which are to be defined by the user itself.

In the chapter 2, discussion has been performed to find out the best suited method for implementing the web based technology. It has been concluded that Java platform [26] would be the top choice. Java has a simple programming structures and is an open source language making it an ideal option for building the web-interface. For creating a web based application Java Servlet pages with JavaScript as the scripting language was chosen to be used. For displaying the output or result of 3D object HTML with Jquery as the scripting language was chosen to be used. The reasons for this choice are discussed below.

- **Java Servlet Pages –** JSP is used for viewing of web pages at client end and JSPôs website pages are translated into servlets at runtime. Highly compatible with all the platform .
- **JavaScript –** JavaScript, which is required for dynamic modification of elements, a basic and important requirement for the application
- **Jquery –** It is used to simplify the client side scripting and their syntax are designed to make it easier to navigate, animate, event handling and Ajax control.

5.5 ALGORITHM FOR MODELLING OF WIRE PATTERNS BY USING WEB

The functioning of web based application is discussed in the algorithm below:

Step 1: Open the web browser and type http://localhost:8080/nextgenproject/index.jsp.

This link open up the website AUTO MODPart in web browser. Here, localhost can be replaced by the IP address of the running server where the web application is uploaded.

The figure 5.1 shown above is the front end for the client, which provide the access to the client for using the web based application.

The website also provides basic access to client such as feedback, contact us and also tells the client about how does this technology works.

Step 2: Click on the Create Design Link on the website.

When the link create design has been clicked the website goes to the web user form, where the client or customer can enter the desired parameters. Here, the following parameters has been asked to the client to create design, such as

- Select the shape of the wire canvas,
- Length, width and thickness of the plank,
- Enter the size of the canvas.

Step 3: Click on the Submit button after defining the parameters.

As soon as, the user or client defined the parameters in their respective textbox. The next step as shown in the figure 5.3 below is to click on the submit button to pass the defined value to the database. From the database, the excel macro get invoked and run the SolidWorks macro file to create the desired shape and size of the canvas.

Step 4: Click on the show pictures

After the completion of the previous step the model has been created in the background modelling software i.e. SolidWorks™. As soon as, the model has been created at the server end a notification is displayed on the client end informing that the ñModel is ready, now you can Click on the Show Pictureò link which is given on the bottom right side as shown in the figure 5.4 below.

Step 5: New window to see pictures and link to download picture, part and STL.

As soon as the client/user click on the show picture link, then the client is directed to another webpage where he/she can see the pictures of the created parametric model in different orientations. Also, the client is given with a download link from where he/she can download the pictures, part modelled and STL file of the model as shown in the figure 5.5 below.

Step 6: Next step to create toolpath for the final geometric model.

In this step, the user can further create toolpath for the final geometric model which has been created by using web page through based application. As per the convenience, the user can generate raster toolpath and contour toolpath by clicking the button on the web page as shown in the figure 5.6 given below.

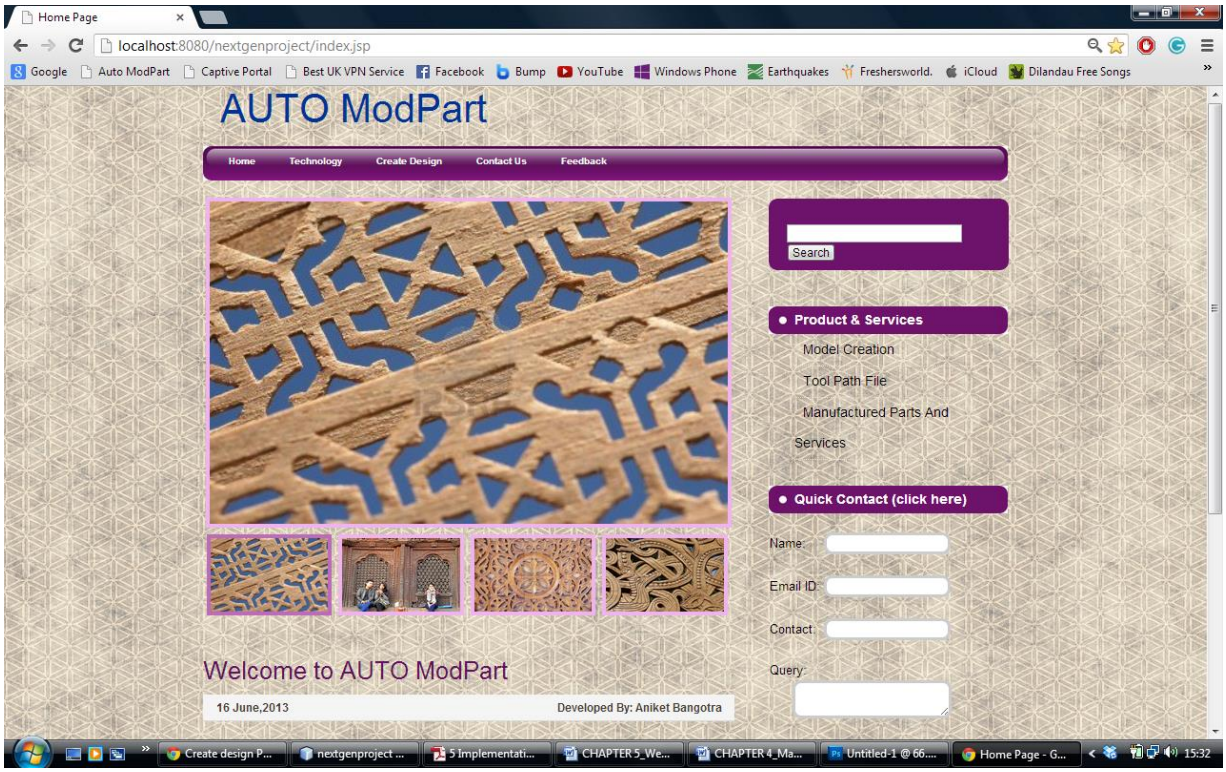


Figure 5.4: AUTO MODPart home page.

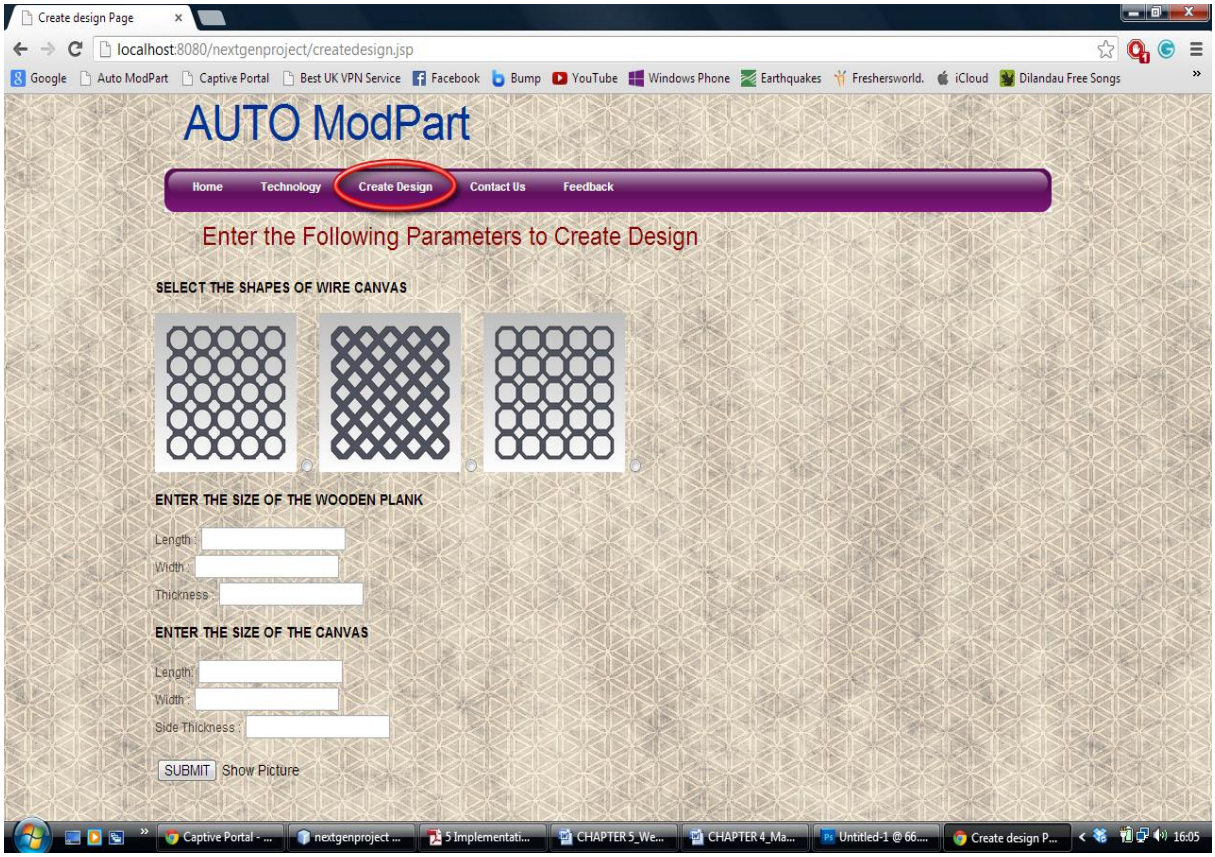


Figure 5.5: Web form to create parametric design

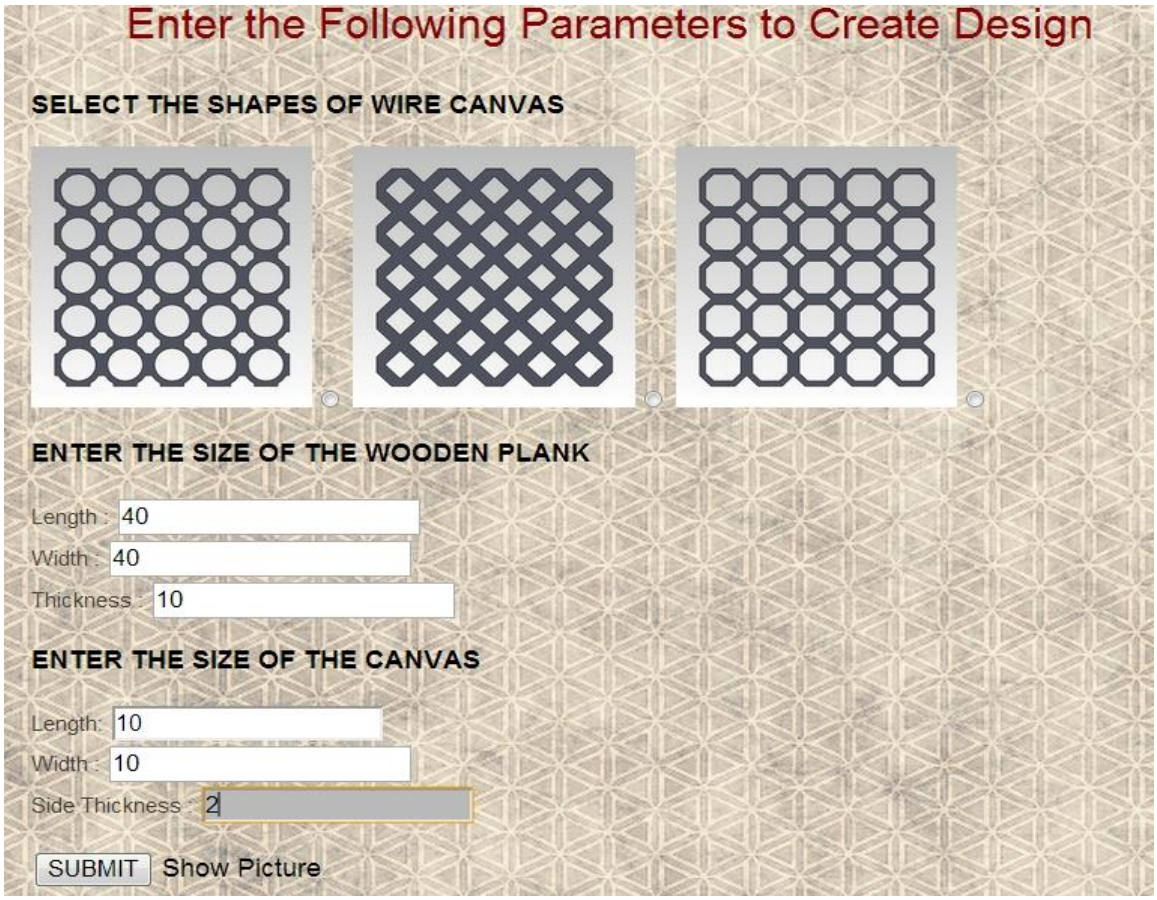


Figure 5.6: Parameters to create design.

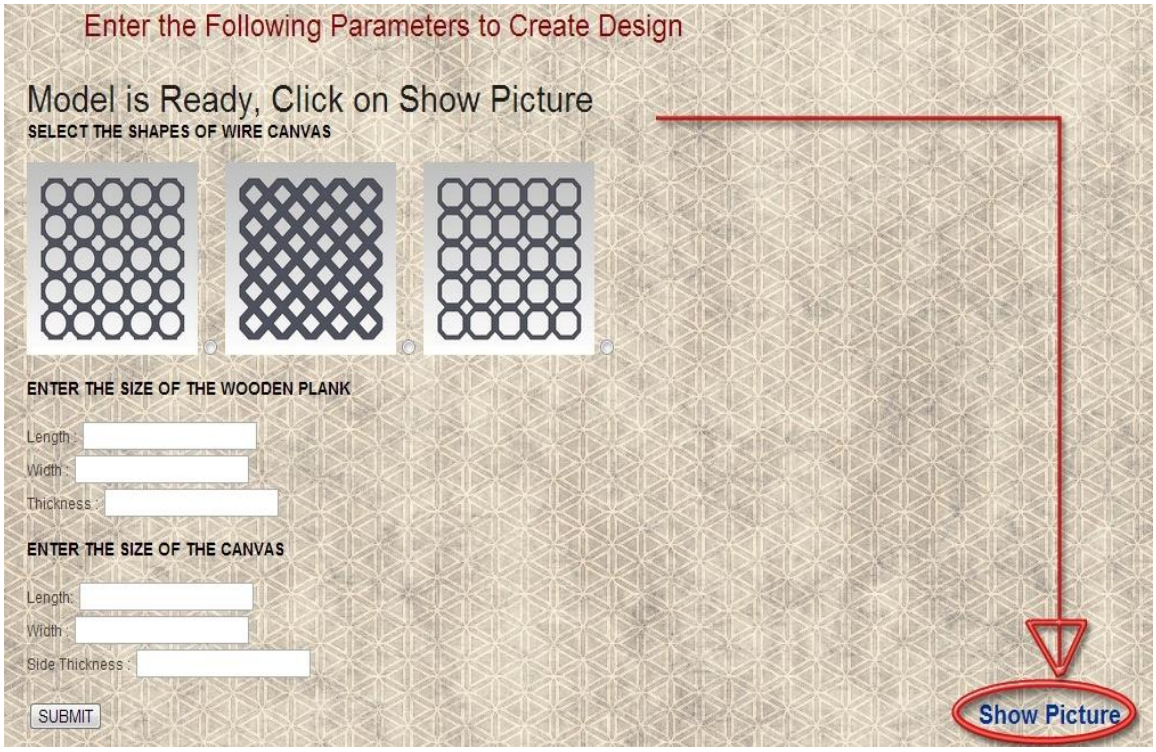


Figure 5.7: Notification and show picture link .

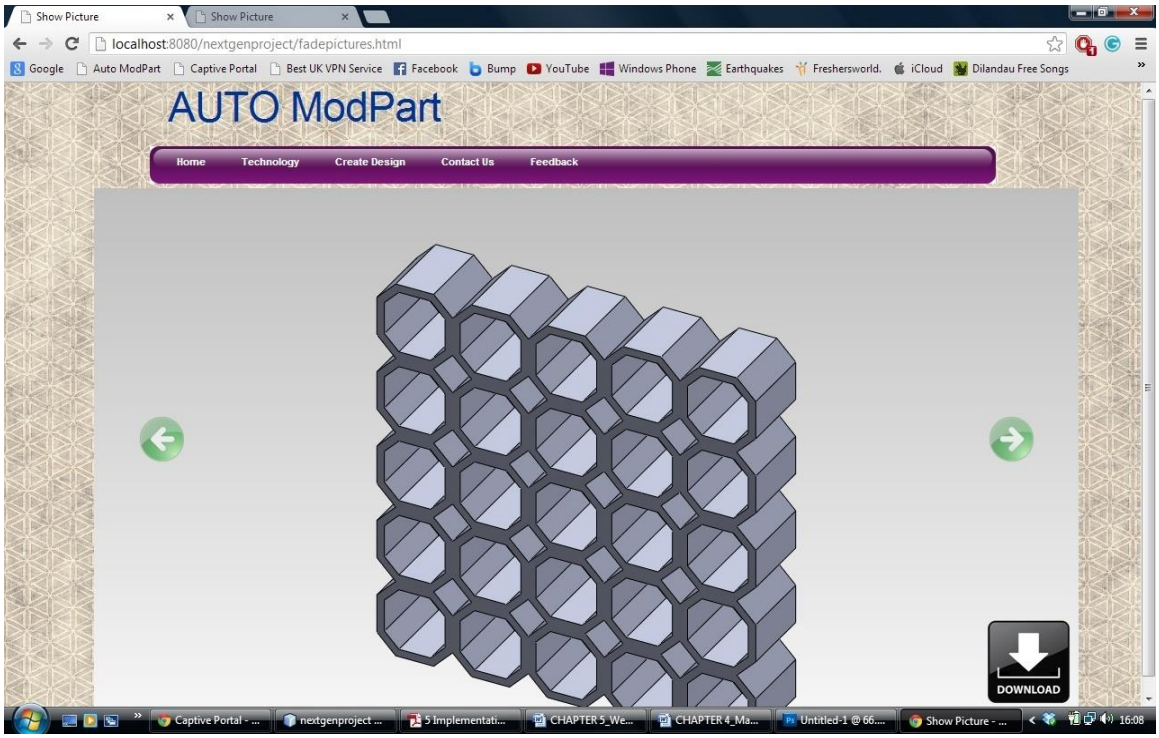


Figure 5.8: Different orientation viewing of the created model.

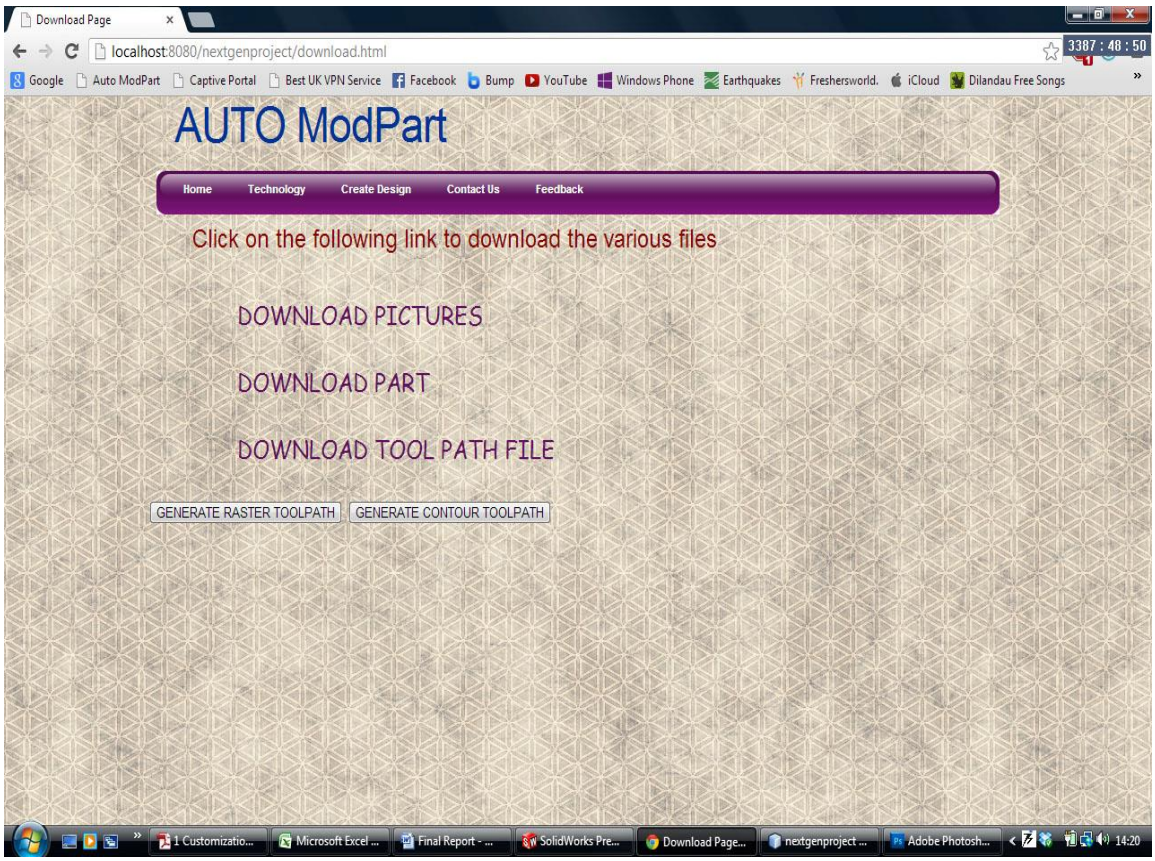


Figure 5.9: Download link and button for toolpath generation.

5.6 FLOW CHART FOR WEB BASED APPLICATION AND TOOLPATH

The procedure discussed above for creating a web-based 3D part model and NC toolpath data can be shown in the form of a flow chart as given in figure 5.10, and 5.11. In the figure 5.10 the working procedure of web implementation has been detailed, while figure 5.11 shows the detail working and controlling of the web-based raster or contour NC toolpath generation.

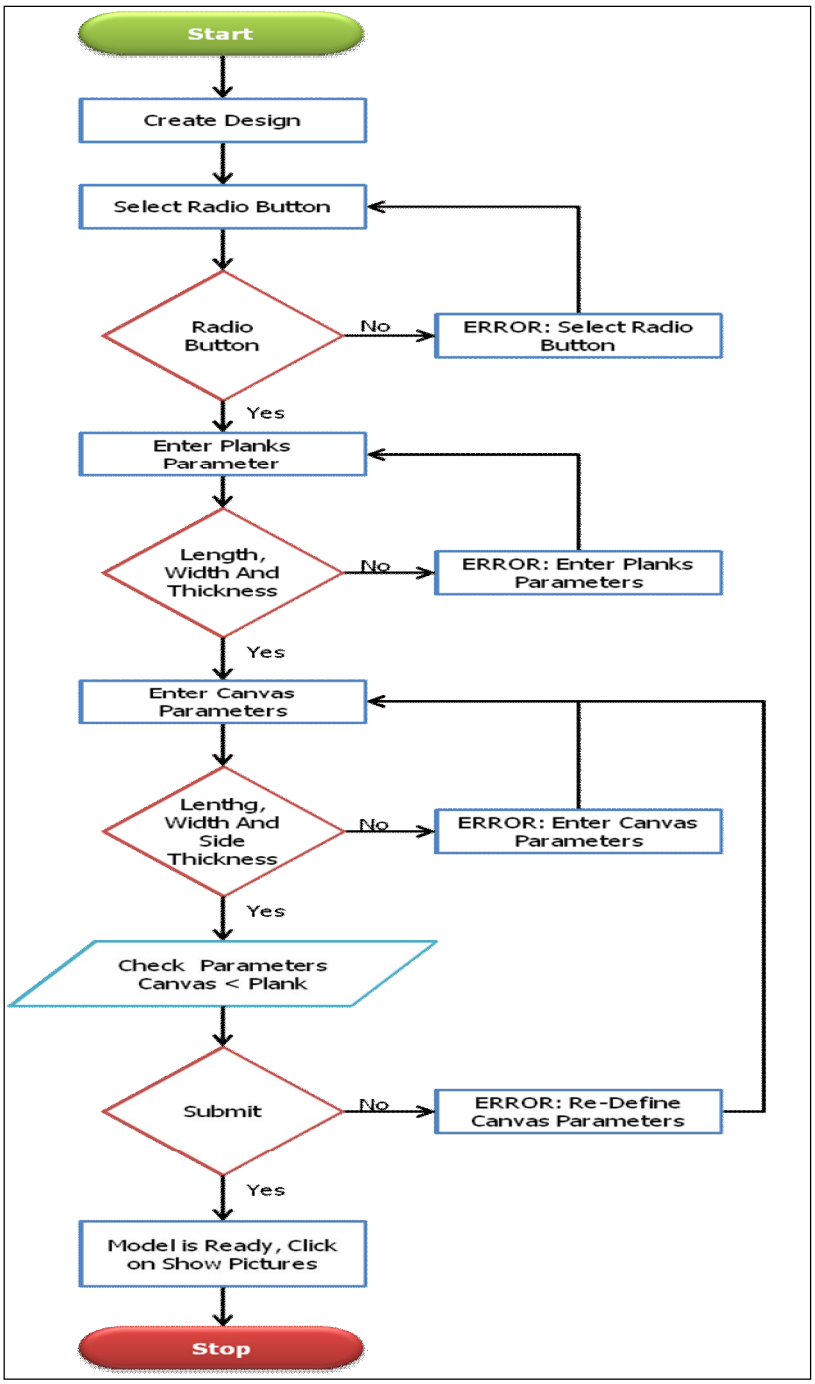


Figure 5.10: Flow chart shows the implementation of web based application.

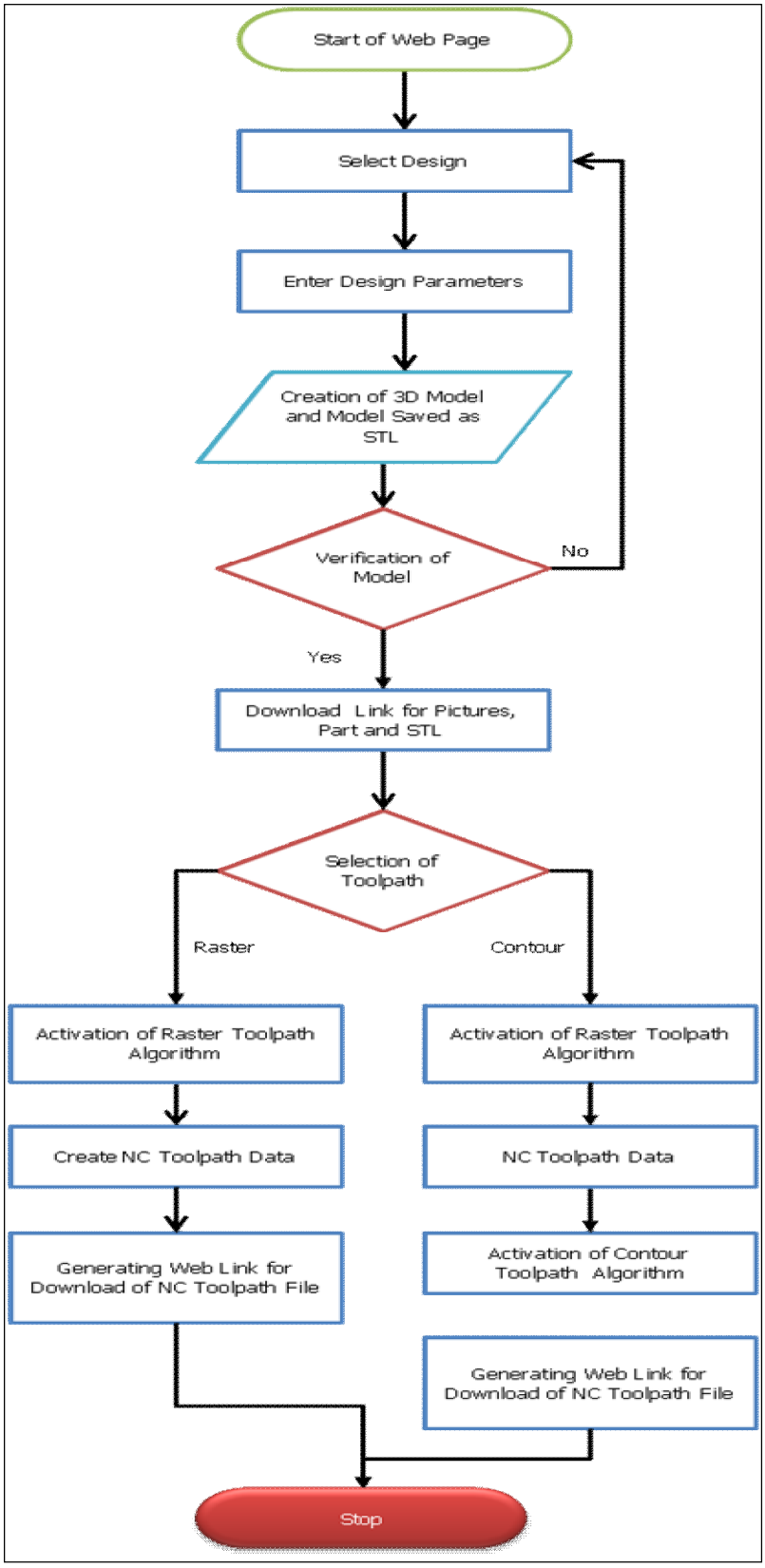


Figure 5.11: Flow chart for NC toolpath generation in web-based environment.

CHAPTER 6

RESULTS AND DISCUSSION

6.1 RESULTS AND DISCUSSION OF THE WEB ENABLED MACRO

The result and validation of the work shown in this chapter is the actual working of the web based application with the help of screen shots. In web based application, the user defined parameters are entered by the user at the run time, which are stored in the background database i.e. Microsoft Excel. As soon as, the parameters are updated in the excel spreadsheet by using user on the website. The excel macro automatically activate the SolidWorks macro and use the stored parameters which are defined by the user at the run time. These parameters are passed into functions of the VBA code to perform the specific action for which the code is meant. In this chapter, the working of the whole web based application is presented with the help of following three various illustration as discussed below.

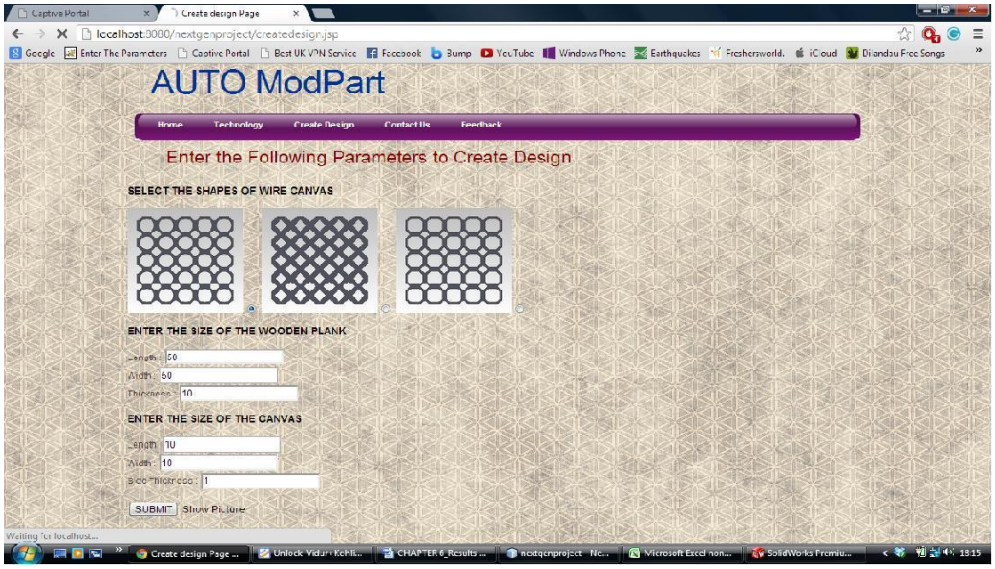


Figure 6.1 : Web page for user defined input parameters to create design.

The figure 6.1 represents the web based form, which act as a input form for the SolidWorks to create an parametric model or feature. Here, by using a single web based form user can create three various models depending upon the shape of its own choice and followed by the user defined input parameters.

The illustration discussed below will give the required results as we defined the input parameters in the web-based modelling form.

Illustration 1:

Shows the Validate Output of the following input parameters enter by the user in run time.

Length of the Plank	= 50 mm
Width of the Plank	= 50 mm
Thickness of the Plank	= 10 mm
Shape of the Canvas	= Circle
Length of the Canvas	= 10 mm
Width of the Canvas	= 10 mm
Side Thickness of the Canvas	= 1 mm

Illustration 2:

Shows the Validate Output of the following input parameters enter by the user in run time.

Length of the Plank	= 50 mm
Width of the Plank	= 50 mm
Thickness of the Plank	= 10 mm
Shape of the Canvas	= Square
Length of the Canvas	= 10 mm
Width of the Canvas	= 10 mm
Side Thickness of the Canvas	= 1 mm

Illustration 3:

Shows the Validate Output of the following input parameters enter by the user in run time.

Length of the Plank	= 50 mm
Width of the Plank	= 50 mm
Thickness of the Plank	= 10 mm
Shape of the Canvas	= Octagonal
Length of the Canvas	= 10 mm
Width of the Canvas	= 10 mm
Side Thickness of the Canvas	= 1 mm

The above illustrations proves that it is possible to model the parametric features in SolidWorks by using a web based technology. This concept will open the doors for low cost tend for parametric 3D modelling, manufacturing, easy and 24 hours accessibility for everyone, and user. Thus, this technology is a tool for the future web based modelling.

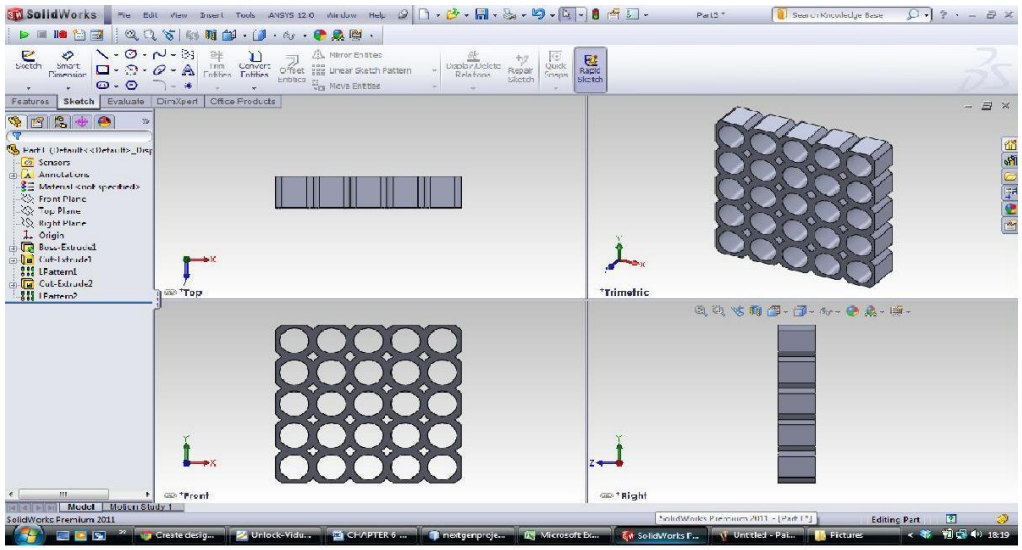


Figure 6.2 : Output for the Circular parametric model.

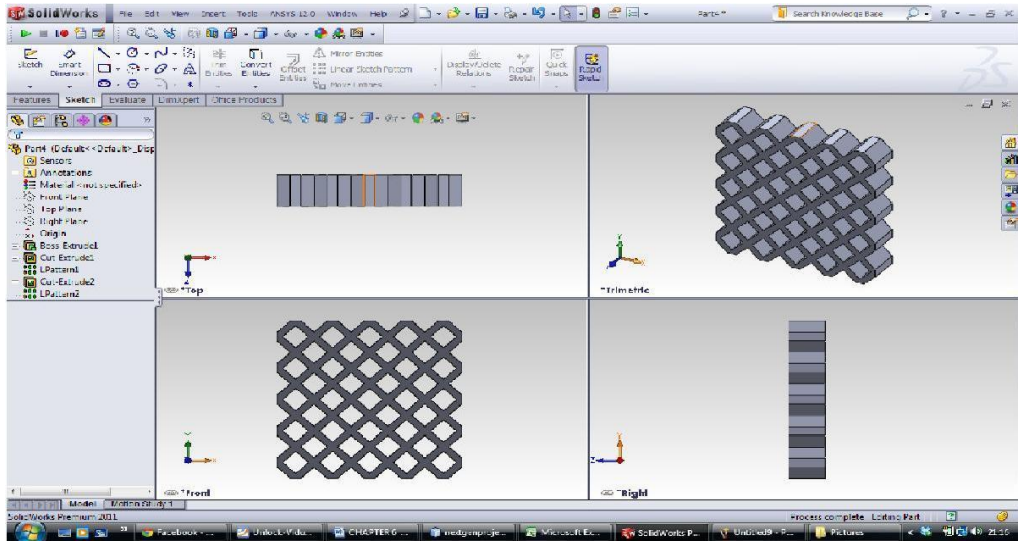


Figure 6.3 : Output for the Square parametric model.

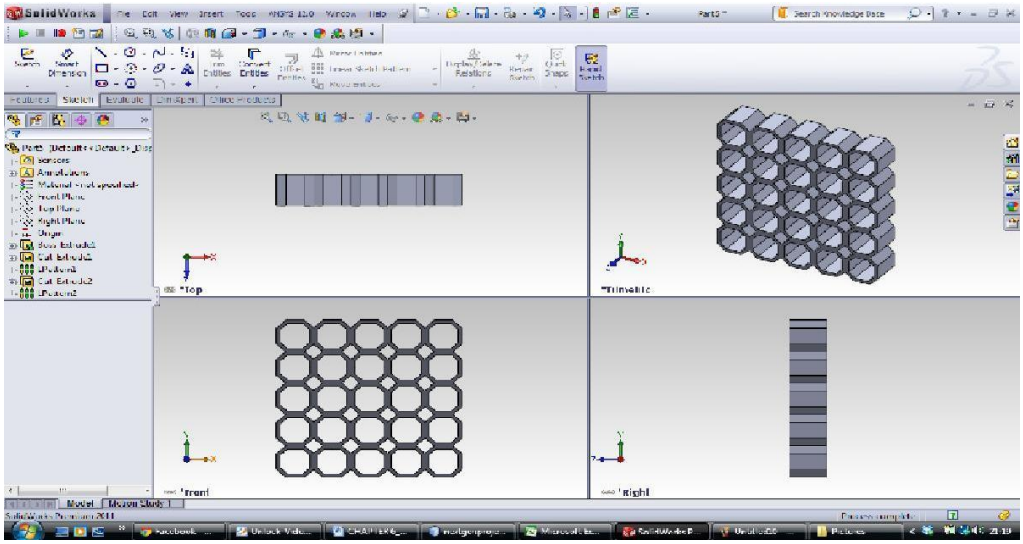


Figure 6.4 : Output for the Octagonal parametric model.

6.2 VALIDATION AND RESULTS OF NC TOOLPATH

The validation of the raster and contour toolpath has been validate by using Toolsim software in State Initiated Design Centre (SIDC) for Wood Working Lab in Thapar University, Patiala as illustrated for circle, square and octagonal in figure 6.6 (a)(b), 6.7(a)(b) & 6.8 (a) (b).

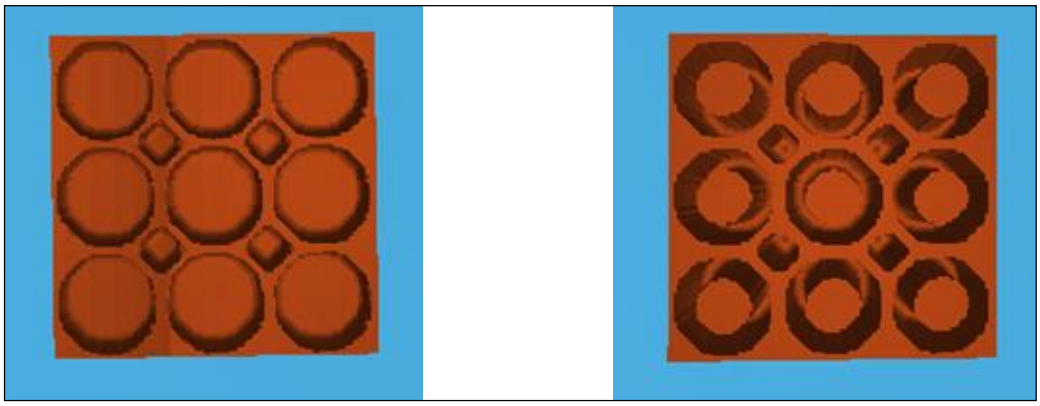


Figure 6.5: Simulation results for circle pattern (a) raster NC toolpath, and (b) Contour toolpath.

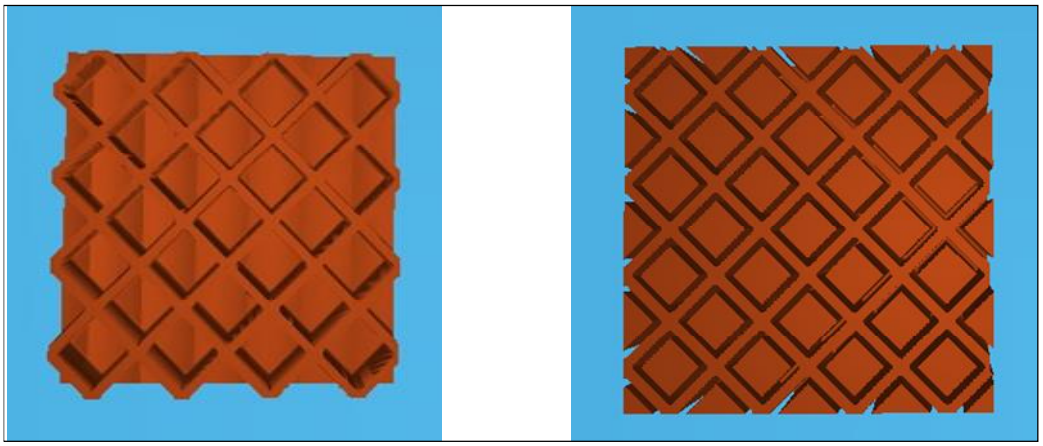


Figure 6.6: Simulation results for square pattern (a) raster NC toolpath, and (b) Contour toolpath.

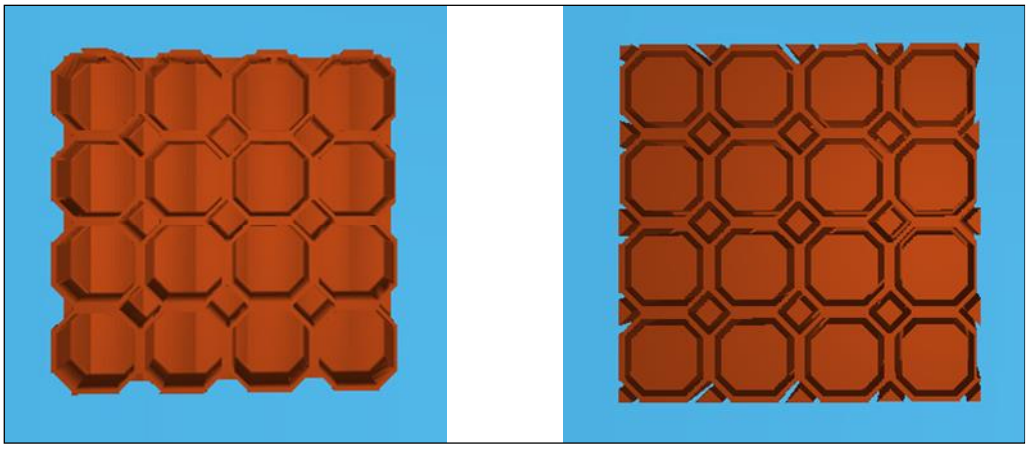


Figure 6.7: Simulation results for octagonal pattern (a) raster NC toolpath, and (b) Contour toolpath.

As apparent from figure 6.5(b), 6.6(b) and 6.7(b), the X-Y projection of pencil cut tool path shows the confirmation with the part contours as shown in figure 6.8, 6.9 and 6.10 below.

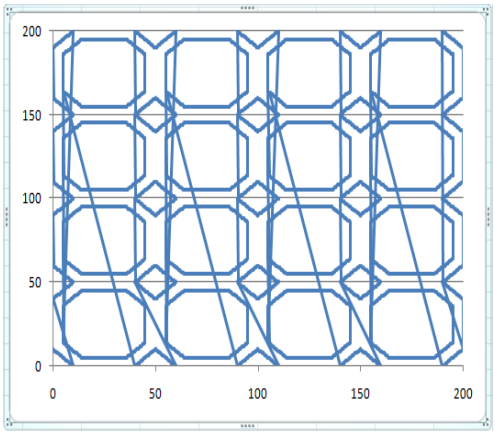


Figure 6.8: Contour toolpath representation for octagonal model.

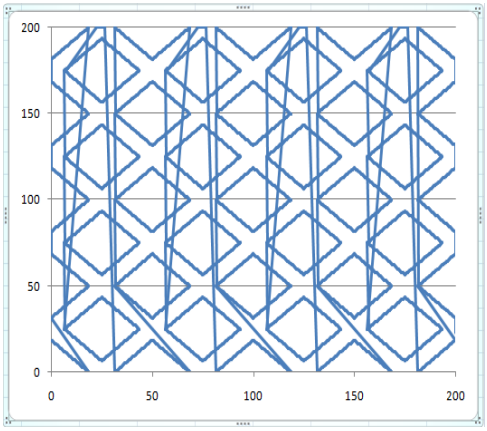


Figure 6.9: Contour toolpath representation for square model.

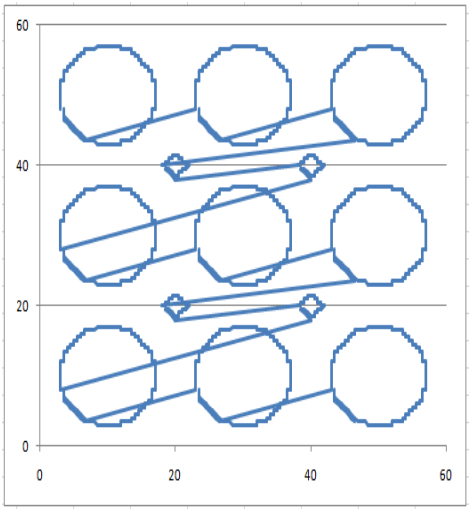


Figure 6.10: Contour toolpath representation for Circle model.

6.3 CONCLUSION

In the present work the details about various procedure for construction of automatic macro with the help of SolidWorksTM API(Application Programming Interface) has been discussed.

1. SolidWork^{TM} has been integrated with web based application to create predefined artistic features.
2. The automatic macro can be effectively used through web-based modelling environment for designing of CAD models.
3. Raster and Contour Toolpath has been generated for complicated artistic features.
4. No avoidable imperfections has been left on a piece of work and the quality of artistic features has been improved.

6.4 SCOPE FOR FUTURE WORK

The following activities can be undertaken for extending the work presented in this thesis work.

1. The different patterns can be included in the web based environment. So that customer have choice of his/her interest.
2. Optimization can be done to make the generation of the NC toolpath faster which decrease the waiting time and make the system more effective.
3. The web based application can be further improved that helps in the multiple accessing of application by the user at the same time to creation model and generation of NC toolpath for a particular product.
4. The different types of tool shapes like flat, conical and bull-nosed end mills can be considered within web based application for NC toolpath generation.

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