Re-Design of Drivers' Car Seat Using Three Dimensional Reverse Engineering

Thesis submitted in partial fulfillment of the requirements for the Degree of

Bachelor of Technology (B. Tech.)

In

Industrial Design

By

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<u>Declaration</u>

We hereby declare that this thesis is our own work and effort. Throughout this documentation wherever contributions of others are involved, every endeavour was made to acknowledge this clearly with due reference to literature. This work is being submitted for meeting the partial fulfilment for the degree of Bachelor of Technology in Industrial Design at **National Institute of Technology, Rourkela** for the academic session **2010 – 2014.**

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Certificate of Approval

This is to certify that the thesis entitled RE-DESIGN OF DRIVERS' CAR SEAT USING THREE DIMENSIONAL REVERSE ENGINEERING submitted by Ms. Lipsa Mishra and Ms. Harshika Singh has been carried out under my supervision in partial fulfillment of the requirements for the Degree of Bachelor of Technology in Industrial Design at National Institute of Technology, Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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Harshika Singh

Abstract

Automobile seat design in current practice requires satisfying the ergonomics guidelines as well as considers the comfort expectation of the population. The main aim is to re-examine the existing car seat designs and to propose a novel seat design for better comfort. The number of cars reviewed for drivers' seat features and user comfort are based on the analysis using a statistical tool. The statistical tool analysis is defined using data from the survey conducted. The proposed design is obtained using the 3-D Reverse Engineering procedure on the selected car seat models. The result is assessed to show that the modified car seat design is superior in terms of form, shape, seat features, usability and comfort. Through this work, the basic seat needs while driving, for example pain preclusion aspects and comfort weightage are defined. The survey done can expunge the expenditure for test experimentations in the future and the proposed methodology can be useful in establishing new design standards for the seat.

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CHAPTER 1

Introduction

Today’s globalized market competitions among the various automobile industries drives the automotive creators to design their commodities specific to consumers’ choices and satisfaction. The interior environment of a car is categorized as a confined workstation in which the drivers are required to adapt and perform the driving tasks. During the design and development of car seat, posture of drivers is the most important factor to be considered among others the user comfort has to be maximized. The human perception of short and long-term comfort is vastly dependent on the seat design along with the placement of controls in the car. The nature of vibration endured by the drivers and existence of poor workstation configuration also results in poor posture while driving that lead to physiological symptoms of discomfort and pain. With growth in technology the needs and expectations of the users increases in respect of gaining a more comfortable and aesthetically pleasing product.

The comfort ability and safety of a seat is very vital to a car's design and fabrication. Drivers’ comfort is equally important as the functional and aesthetic aspects of automobiles since it is given more preference by the customers for a comfortable drive [3]. As the seated posture of a human being exposes him to a variety of musculoskeletal complications, sitting comfort is of top priority that requires ergonomic interventions in the early designing stages.

In this chapter the need to take up this work along with background is discussed. It also presents a review of available relevant literature. Objectives of the present work along with methodology adopted to accomplish the goals have been discussed here.

1.1 Problem Definition

This work makes an attempt to develop a novel car seat design that is obtained mainly from the feedback and suggestions of the users. The novel car seat design is obtained by combining the features and attributes crucial to the comfort of the users as responded by them. The comfort of a car seat is related to many of the design factors like adjustability, weight distribution, seat geometry, seat cushion properties, vibration isolation and aesthetic appeal [5]. Ergonomics principles underline the relationship between behaviour of the human body and the above factors. Hence they are to be given a must consideration while the designing of a car seat. The main reason for this work can be stated as the significance of comfort for the driver of a car seat. The comfort of a driver influences his performance and concentration on the task which is return prevents unfortunate accidents from occurring. The objectives of this task can be determined as follows:

- To conduct a survey among the users of various popular car models based on comfort features and attributes responsible for the pain perception among drivers.
- To perform analysis on the data collected and obtain car seat models having the best features and least pain experience while driving for the users.
- To achieve a three-dimensional point cloud data through scanning using CMM measuring devices of the selected car seat models.
- To collaborate the best features of the selected models and recreate a car seat design taking into account the feedback and modifications suggested by the user.

1.2 Human Factor Consideration in Car Seat Design

During the seated posture, in the human anatomy the buttocks, thighs, lower legs and knees act as mechanical levers that provide stability to the body. According to research, prolonged exposure to an inadequately supported posture results in excessive static loads on the above mentioned body parts culminating in a sensation of discomfort [2]. Experiencing localized high pressure at the human-seat interference causes soft tissue deformation that result in restricted blood and nutrient flow to the lower extremities leading to human discomfort [1]. Additionally, prolonged exposure to vibrations caused while driving over irregular surfaces and due to automotive components is known to cause chronic health problems including: low back pain, spinal disorders and abdominal pain and vision disorders in 0.5-80 Hz frequency range [4]. The combination of prolonged sitting and the physiological effects of enduring vibrations create an uncomfortable environment that may lead to a decrease in the level of performance resulting in unsafe driving [5].

Ergonomics is the applied discipline of science connecting human life to its well being during handling of consumer products. The car seat being situated in a restricted workbench experiences dynamic forces like centrifugal forces during motion, hence causing discomfort for the driver [6]. This has led to the designing of seats using the basic ergonomic principles. The most significant role that ergonomics plays in the automobile design process is providing data on the physical attributes of driver and his/her favoured postures while driving [7]. The most important region that requires support in a human body is the backbone. The backbone has three curvatures (Figure 1) and supports the head, arms and is also put through thorax-abdominal visceral draw.

Figure 1Side view of the Backbone in its natural shape [7]

Hence it is necessary to provide the seat equipped along with a properly shaped and inclined low back support (l-b-S), positioned vertically so as to reduce the work of the trunk musculature. The backrest's l-b-S should touch the back, when sitting in orthostatic position; hence contrary to our usual belief, the backrest has to be put up in forward position so as to appear, in estimation, as being inside the seat (Figure 2).

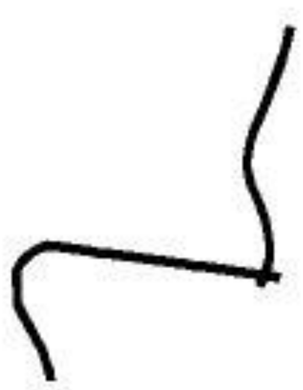

Figure 2 Backrest correct position and shape [6]

1.3 Review of Literature

Considerable efforts have been made in the past by researchers to provide the designers of car seats with effective guidelines towards providing the automobile industry with more comfortable seats. The capability to understand the comfort level provided by the automotive seat requires an in depth understanding of biomechanics of seated posture, seat geometry effect on humans, seat properties and the vehicle environment on perceived comfort.

Seat comfort is a complex phenomenon (Looze et al, 2003) [26]. Many researchers have studied factors that influence subjective comfort or the perception of comfort in humans. Looze et al. (2003) [26] made an analysis of the scientific literature concerning the relationship between sitting comfort and discomfort and objective measures. He found pressure distribution was the objective measure that provided absolute transparency in its association with the subjective ratings. Looze et al (2003) [26] focused on comfort effects and Nordin (2004) [21] on the effects of sitting and back complaints. Lueder (2004) [25] uses the literature to show the importance of movement while seated and Zenk (2008) [24] made a literary review of comfort and sitting while driving. Factors influencing the subjective ratings also include skin perception, muscular activity, posture, joint angle interface, pressure, stiffness and suspension of the seat cushion and backrest. Posture variation and frequencies of posture changes are also measured. Mergl (2006) [23] states that the seat should reduce postural stress and optimize muscular tension. Porter et al. (2003) [22] explained the importance of pressure distribution to avoid high pressure areas. For instance, the tissues around the ischial tuberosities are subjected to extremely high pressure while sitting that can result in reduction of blood circulation through the capillaries. In such cases it is necessary to realign body position, else then the symptoms of aches, pain, discomfort and numbness start surfacing up. Nordin (2004) [21] also showed that sitting in restricted postures as well as sitting in combination with vibration is a risk factor. This means that for car seats the risk is there. Ariens (2001) [19] showed that unsupported static postures also increase the chance of neck pain.

Kolich. M, (2002) [20] published a paper refuting the claim that ergonomics criteria related to anthropometry satisfied the consumer comfort. In this he discovered the discrepancies between the survey conducted for 12 subjects in five compact car seats and the contour characterstics scanned for those seat environments. This led to the conclusion that ergonomic criteria could not be blindly applied for ensuring comfortable automobile seats. In 2008, Kolich [16] published a work concerning the automobile seat comfort development process presently in work and the restrictions associated with it in detail. Through this he initiated a regulated framework intended to lead the investigative process related to seat comfort research. The framework aimed at producing theories and methods that could provide guidelines and further validate the discipline of automobile seat comfort.

Chateauroux and Wang (2010) [18] analysed the egress motion of younger and older citizen with th objetive of using the data to simulate a digitized human model. The Motions were reconstructed using RPx Software and the RAMSIS model. This also explained the constrainsts that play up for people while getting into car. Fazlollahtabar H (2010) [17] proposed a framework of subjective nature for the seat comfort based on the heuristic multi criteria decision making technique and human anthropometry. This satisfied the essentiality for a theoretical and methodological automobile seat comfort criteria by providing a numeric value to the consumers' preferences. The applicability and effectiveness of the proposed approach was validated using a case study. Bower-Carnahan et al. [13] conducted survey on preference of heavy truck drivers regarding seat design. The overall ratings for driver comfort and adjustable suspension damping featured them as the most important features. The importance of adjustable lumbar, kidney and thigh support was also highlighted, obtaining scores of 4.56, 4.5 and 4.12, respectively. This study also specified the regions of physical discomfort through a discomfort point plot. The five areas in particular that were highly related to seating discomfort:

- Discomfort in upper neck and back; caused mainly due to strain of driving all day and due to the requirement of maintain the head in proper position for extended durations.
- Discomfort in shoulders; originating mainly due to improper positioning of seat with respect to steering wheel and steering wheel angle.
- Discomfort in lower back due to insufficient and improper lumbar support.
- Discomfort in buttocks attributed to the uneven pressure applied at the human-seat contact region.
- Discomfort in back region of thighs just above the knee region caused due to improper pressure distribution.

Even though the workstation and geometry of truck and automobile are different, the concerns pertaining to the seat comfort and sense of discomfort can be generally addressed. Adequate adjustable lumbar support, sufficient cushion contouring with appropriate padding to reduce magnitudes of peak pressure and evenly redistribute interface pressure are the essential features that can help eliminate discomfort among drivers.

The review of literature for evaluation of seat comfort by using subjective assessment methods has shown that this method is an essential tool in distinguishing the seat features that provide comfort or discomfort.

Siefert et al. (2008) [14] published a work on the optimisation of the car passenger seat in a virtual environment. He used an adequate human model for the virtual experimentation of the static and dynamic effects caused during seating comfort. This method when applied at an early stage of the procedure enabled the user to optimise a car passenger seat structure accordingly to both types of comforts. The construction of vehicle seats after considering the boundary conditions as higher load amplitudes and accelerations can be done putting the advantages of virtual development into use. Yang et al. (2007) [15] presented a new digitized human model for performing assessments of the vehicle interior design. A digital human helps in reducing the procedure followed during design cycle along with time and money. This method differs from the traditional digital human environment in the aspect that this method is optimization-based. Gragg et al. (2012) [13] projected a method for the accommodation of drivers in car seat putting in use an optimization-based digital human model. The proposed hybrid method combined three dissimilar approaches: a boundary manikin approach, a population sampling approach, and a special population approach. Using this method is beneficial as the human aspect of design could be included early in the design process, thereby reducing or eliminating prototypes and hence reducing cost of manufacturing.

1.4 Flow of Work

The approach adopted to accomplish the present work is described as below:

- Critically reviewing and classifying the parameters or features responsible for the comfort perception on the consumers.
- Identifying and selecting the group of personnel for surveying process. The identification is based on the frequency of the use of car seat by the personnel.
- Interviewing of the consumer participants and obtaining ratings for the various features and attributes accountable for the comfort or discomfort of the participants over the long hours of driving.

- Data is collected and collaborated with each other using a statistical workbench. This provides the car seat model or models with the best features of each of them and attributes in each model that cause the least pain concentration.
- Scanning of the best car seat models is done utilising the coordinate measuring machine available to obtain three-dimensional digitized data for modeling process.
- Contour extraction from the digitized data is done to obtain profiles of the best car seat models in the three orthographic planes.
- Novel design is created taking into account the various best features and attributes that are obtained as a consequence of the statistical analysis. In addition to this modifications based on feedback and suggestions of consumers are also incorporated into the design

CHAPTER 2

Subjective Analysis

2.1 Introduction

Subjective analysis method is the act of an individual describing their own experiences following introspection on physical or psychological effects under consideration. The method of subjective analysis also encompasses obtaining information from a subject's own recollection, such as verbal case histories, or experiences in the individual's daily routine. The concept of comfort is extremely subjective in nature as it varies according to subject’s perceptions about comfort and discomfort. Every individual has their own personal parameters to define their endurance for pain and comfort zone while driving. Subjective analysis is based on these personal opinions, interpretations, personalized point-of-view, emotions and judgment influenced by individual’s experiences. The comfort sensation for a driver can be defined in many ways depending on various studies conducted in relation to seating dynamics. Some of them are as follows:

- A feeling of relief or controlled well-being [8];

- Affording or enjoying physical comfort [8];
- Some state of well-being or being at ease [9];
- A state of conscious well-being [10];
- Occupant's empirical perception of being at ease [11];
- Absence of discomfort [12];

The subjective analysis helps by providing a basic assessment of the consumers' need and requirements. This is helpful as the designers are provided with constraints that they have to adhere early in the designing process. This is beneficial as it improves the credibility of the product in the market. Giving consideration to the consumer suggestion and feedback improves the product's demand and also comfort level.

The subjective assessment method is carried out in various ways. The analysis techniques may vary from open-ended interviews to formal questionnaires consisting of specific, response-constrained questions, the latter being used in quantitative and qualitative analyses. It also includes evidential, controlled methods of experimentation which yield objective information on processes that are objectively observed by the experimenter. The data obtained is then subjected to analysis including the subject's own opinion on a particular task and allows study of effects outside of the scope of controlled clinical analysis.

The major disadvantage of applying this assessment method is the time factor and the large inter-subject variability regarding comfort. Accurate results require a large population sample. In many of the studies, subjective measures are used along with objective measures so as to correlate the ratings along with measurable parameters. This enables the designer to set the design target values with which a known level of comfort has been associated.

2.2 Factors Considered in Subjective Analysis Method

The protocols in subjective analysis method mostly require highly well thought out questionnaires that guide occupants to assign values for discomfort at the specific regions of the seat. The seat should position the driver with unobstructed vision and within reach of all the features on dashboard, including distance from the steering and adjustment features (height, angle, forward-backward movement of seat). The seat should provide optimum back-support, headrest and thigh-support. Shape, size and cushion compressibility also enhances the comfort level of the driver. The factors that define the seat comfort development process can be defined in the following manner:

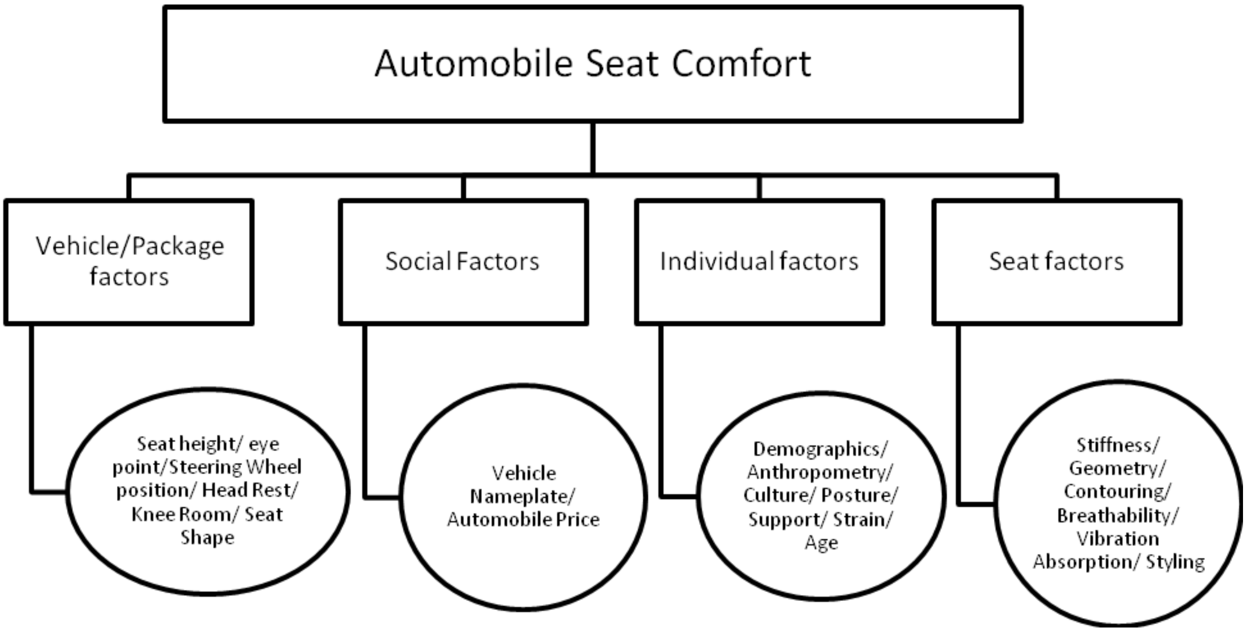

Figure 3 Factors defining automobile seat comfort

2.3 Survey Assessment for Car Seats

In the assessment procedure, it requires participation from a group of personnel with either varied interests and aspects or similar traits to each other. Numerous subjective rating strategies have been explored to establish the most appropriate scheme for designing and evaluating car seats. Participants (n=30) aged in the range of 22-57 having driving experience not less than 6 months were interviewed. Seats of varied families of cars were utilized for the survey process and the ratings for each was obtained based on their features appeal to the drivers as well as separate measures of comfort and discomfort of the whole body and the local body parts. Survey questionnaire was based on how the car features affect seat comfort for each of the drivers. The questionnaire data set is classified under two categories:

(i) Assessment of seat features
(ii) Assessment of pain perception in body parts

The seat features and afflicted areas of the body that endure the maximum pain are defined as follows:

Seat Features considered for Assessment

- Distance from steering wheel
- Height of seat
- Cushion softness
- Shape of Seat
- Adjustment Features
- Armrest
- Backrest Inclination

Body Parts Pain perception assessment

- Buttock
- Lower back
- Upper leg
- Shoulder
- Neck
- Upper back
- Shoulder
- Calves
- Arms
- Head
- Limb Joints

Figure 4 Features and afflicted areas of the human body

2.3.1 Assessment of Seat Features

The questionnaire for obtaining ratings on the seat features of the various car models has been featured in Appendix 1. This feedback was obtained by using an open-end survey questionnaire from the consumers of 10 different car models. Their responses were recorded and weightage was added to their ratings. The questionnaire was formulated putting stress on the clarity of the questions for the layman.

2.3.2 Assessment of Pain Perception in Body Parts

For obtaining the ratings on the pain concentration in various affected regions of the human body while driving for long hours, a diagram with the affected regions marked was presented to the participants. The visual questionnaire helps to accurately rate the pain in these areas and hence gives a more accurate data. Presenting the questionnaire in a picture format saves us from formatting question which usually can be confusing to the layman. Providing the population with a picture and pictorial form of rating helps them to analyse their discomfort and comfort while in the seat more accurately than in case of asking a numerical rating for their emotions (Figure 5).

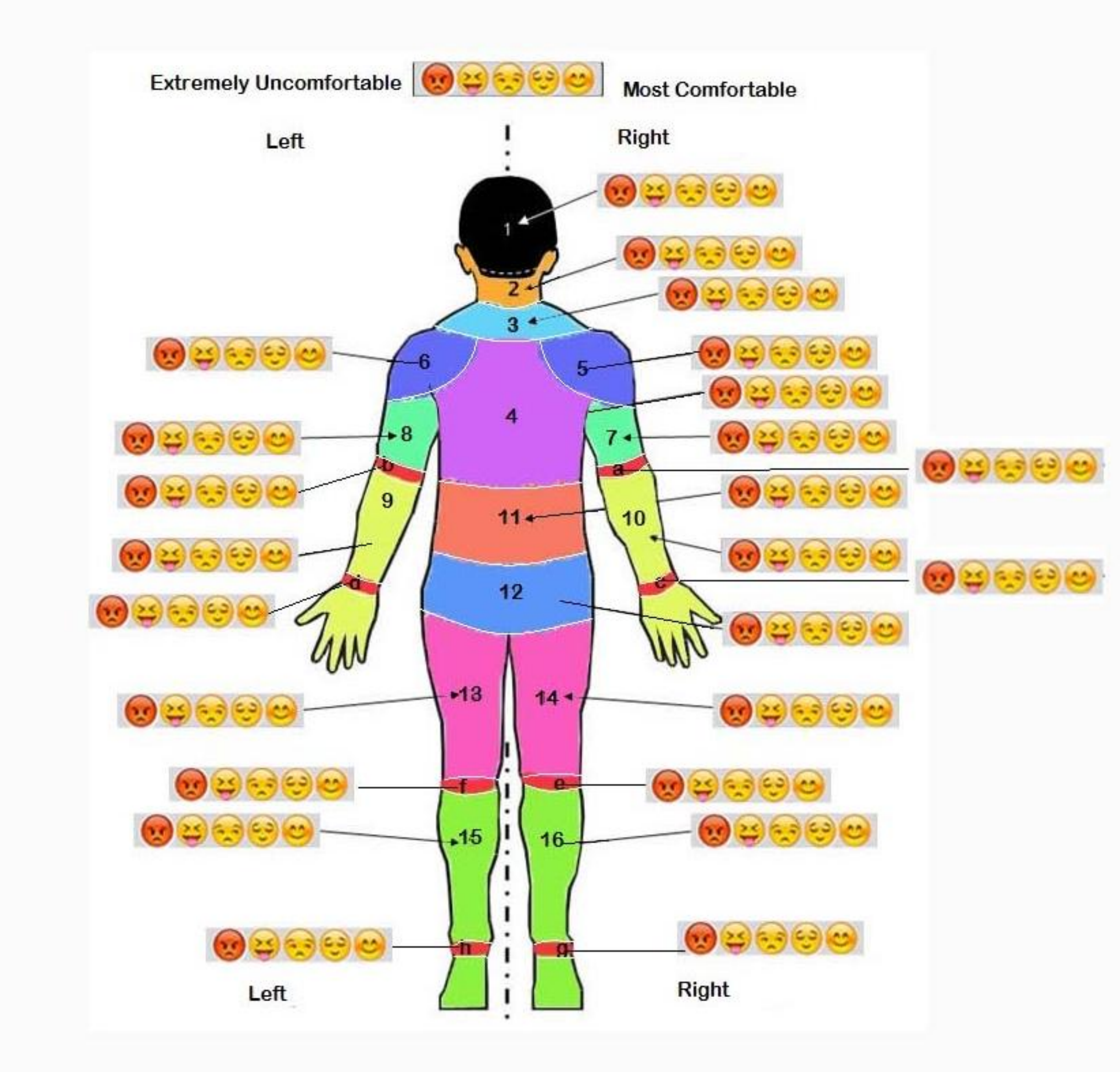

Figure 5 Picture and pictorial form of rating used in the survey conducted

2.4 Data Collection

The survey papers from the participants were collected and collaborated into an Excel sheet. The ratings for both, seat features and pain concentration was calculated and result rating for each car model for each participant was recorded. The Recordings of the survey have been featured in Appendix 2.

CHAPTER 3

Statistical Analysis

3.1 Introduction

Statistical analysis involves a collection of methods used to evaluate large bulk of data and report the general trends obtained with highest scores. It is useful mainly while dealing with loud data. Statistical analysis provides ways to objectively report on how unusual an event is based on historical data. The various types of statistical analysis result include Candlesticks, point and figure charts, Pie-charts, bar figures and scatter plots. They are specifically created for users using large data inputs. The various statistical methods that are put into use to collate data inputs are:

- Descriptive statistics includes mainly Cross tabulation, Frequencies, Descriptives, Explore, Ratio Statistics
- Bivariate statistics comprises of Means, T-Test, ANOVA, Non-Parametric, Correlation (Bivariate, partial, distances)
- Linear regression is useful for prediction for numerical outcomes
- Factor analysis, cluster analysis (two-step, K-means, hierarchical), Discriminant analysis are used for prediction of identifying groups

3.2 Statistical Assessment for Car Seat

Statistical Package for the Social Sciences (SPSS) is a software package owned by IBM since 2009 that is utilised for statistical analysis in this project. The version used in this work is IBM SPSS Statistics 20.0 which supports base, regression and advanced type of analysis. The data recorded in the excel sheet is copied to the SPSS workbench. Then through the use of graphs, scatter plot and histogram, the best features and least pain concentration attributes of car seat models are obtained.

3.2.1 Analysis of Seat Features

The different car models which were surveyed had numerous features that were satisfactory to various individuals depending on their perception of comfort. The cumulative result by adding the weightage and ratings given to the various features by the participants is analyzed. The graphs and histograms are plotted for various features against the height and car models so as to obtain the car models having the features which give the optimum level of comfort.

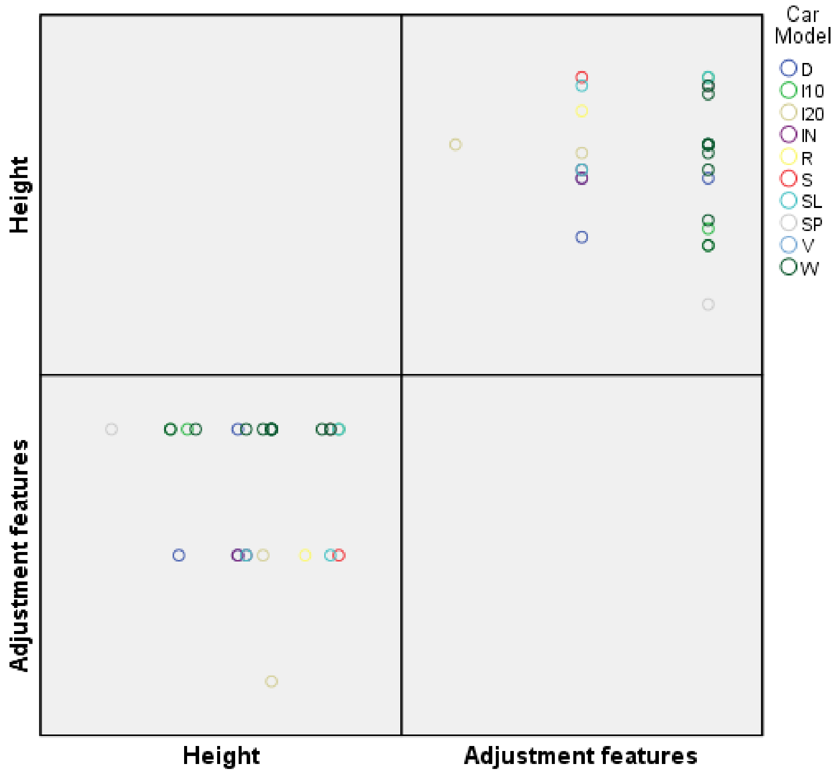

Figure 6 Scatter plot graph for adjustment features versus Height setting markers as car models

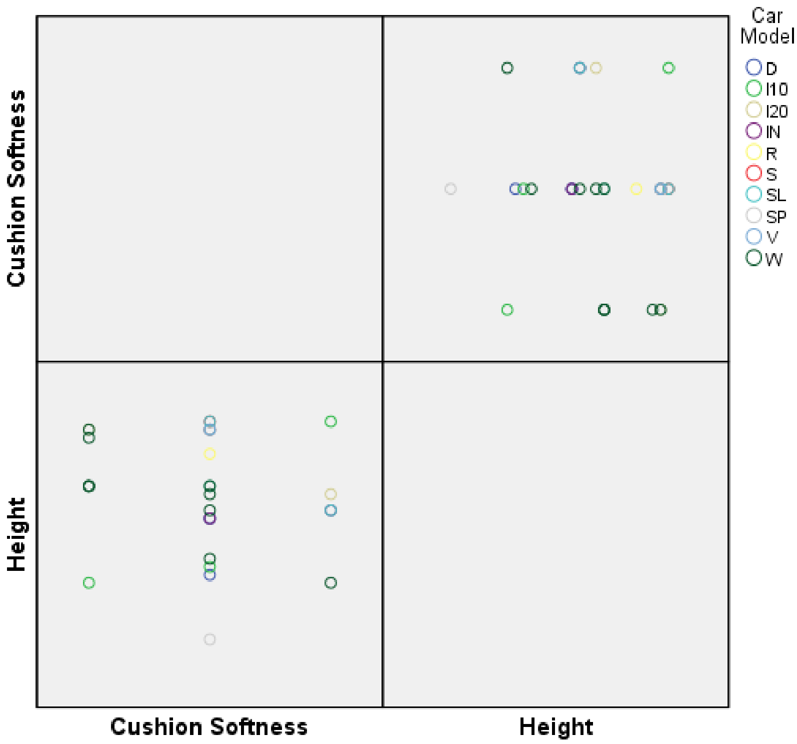

Figure 7 Scatter Plot graph for cushion softness versus Height setting markers as car models

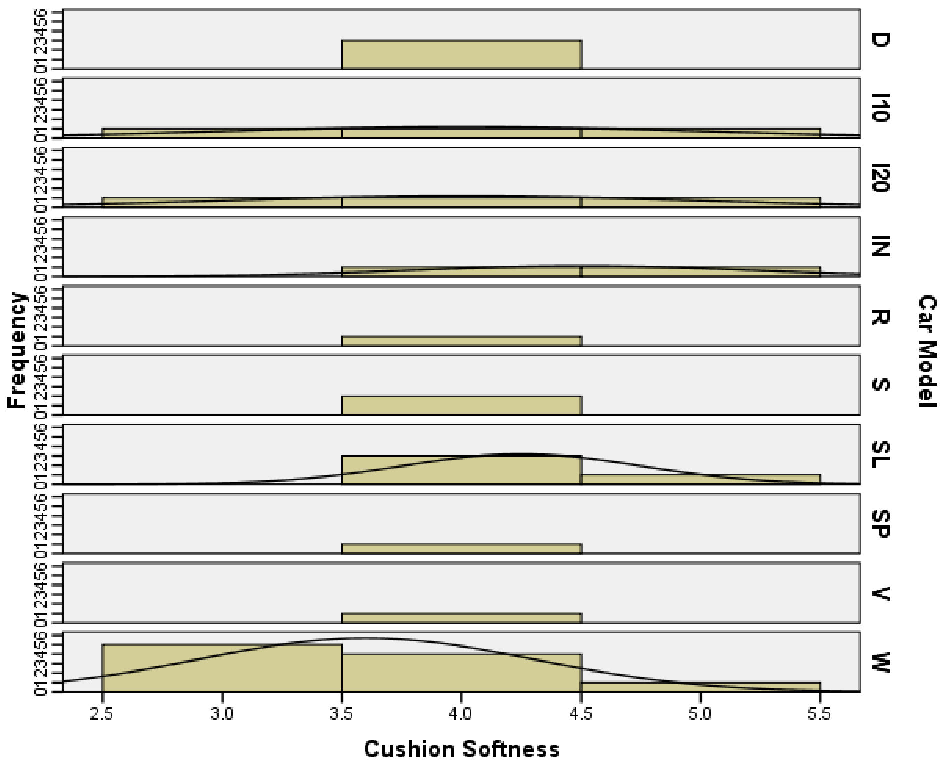

Figure 8 Histogram of Cushion Softness versus cars

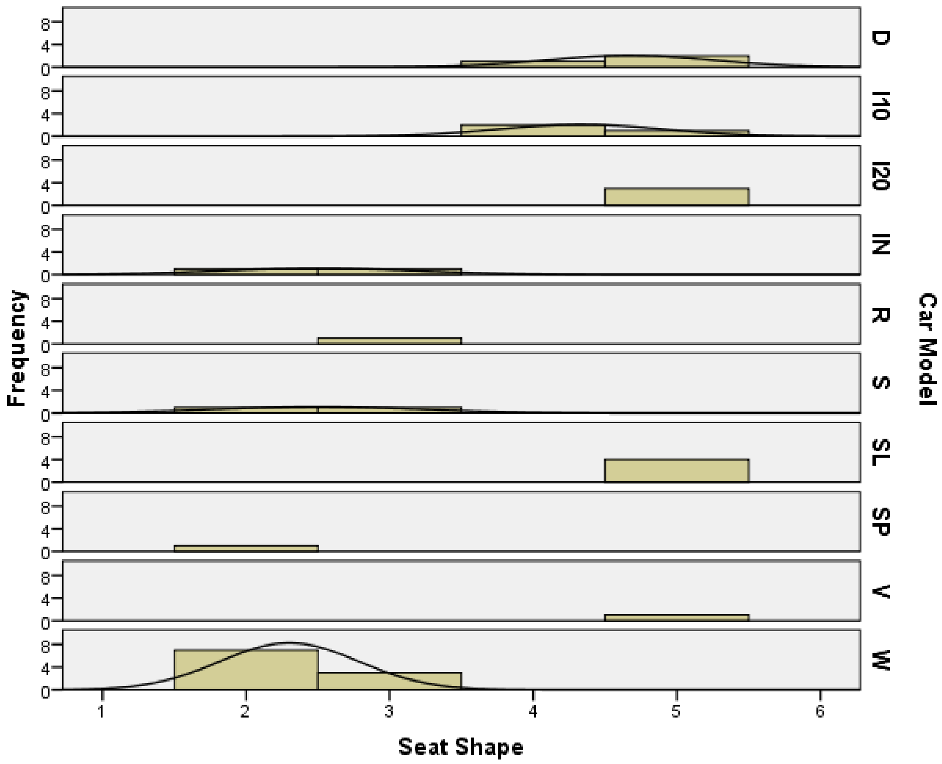

Figure 9 Histogram of Seat Shape versus Car Model

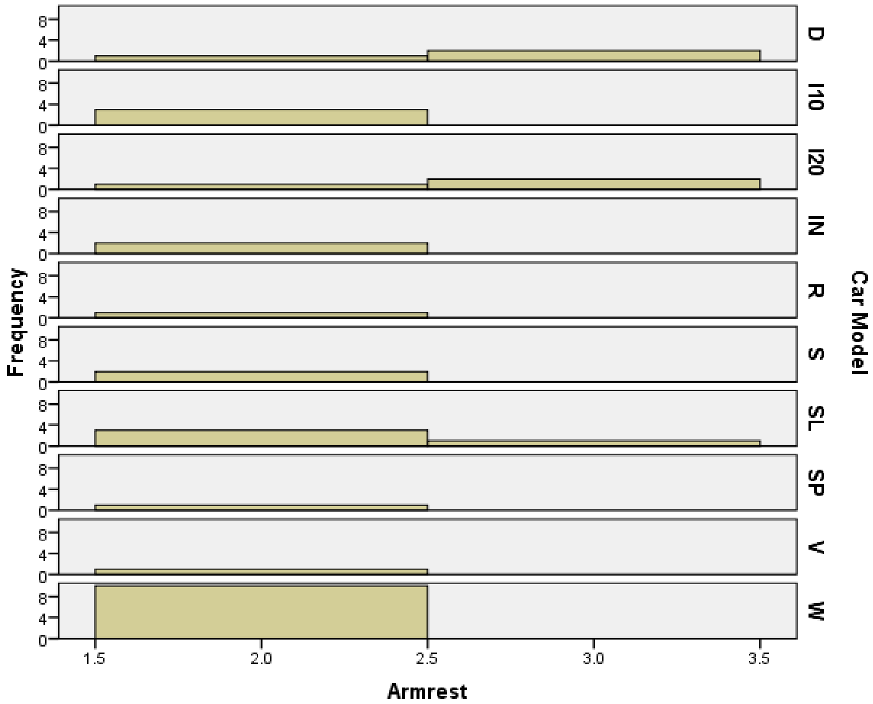

Figure 10 Histogram of Armrest versus Car Model

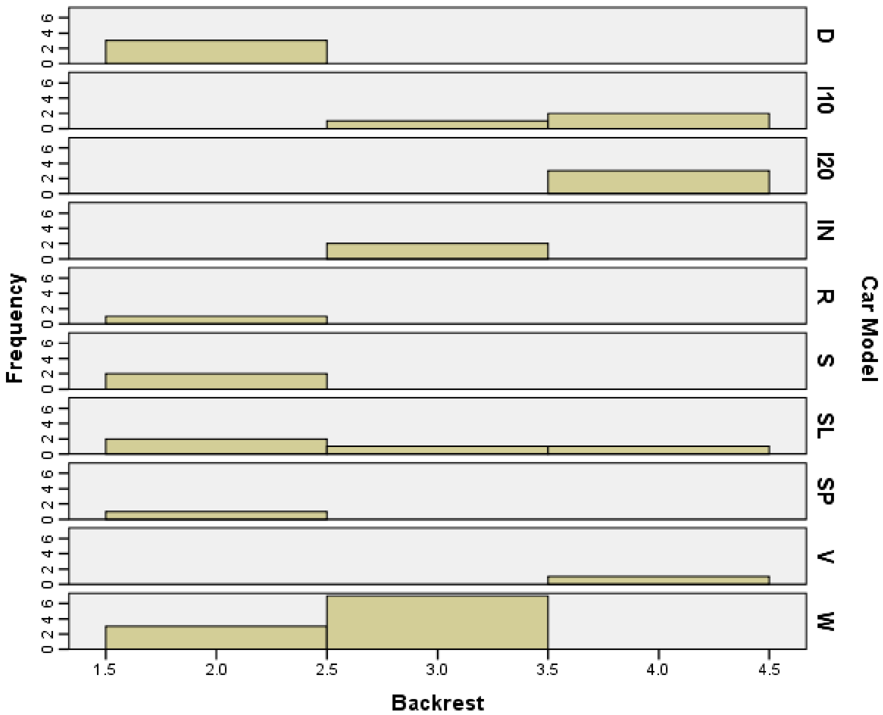

Figure 11 Histogram of Backrest versus Car Model

The various graphs and histograms were analyzed and deliberated upon. Rating-5 is taken as the marker for consideration as best feature in the car seat model. Taking into account all the graphs, Car-i20 and Car-i10 is considered as the cars with best features. Car-i10 has the best seat shape and cushion softness while Car-i20 has the best adjustment features, armrest and backrest.

3.2.2 Analysis of Pain Perception in Body Parts

The various major body parts that experience pain such as the knee, ankle, upper shoulder, left elbow, lumbar region and the neck are considered according to the survey and recordings collected. The attributes those are responsible in a car seat for applying strain on the pain concentrated parts are the backrest, shoulder area of the seat, headrest and the curvature angle of the seat width.

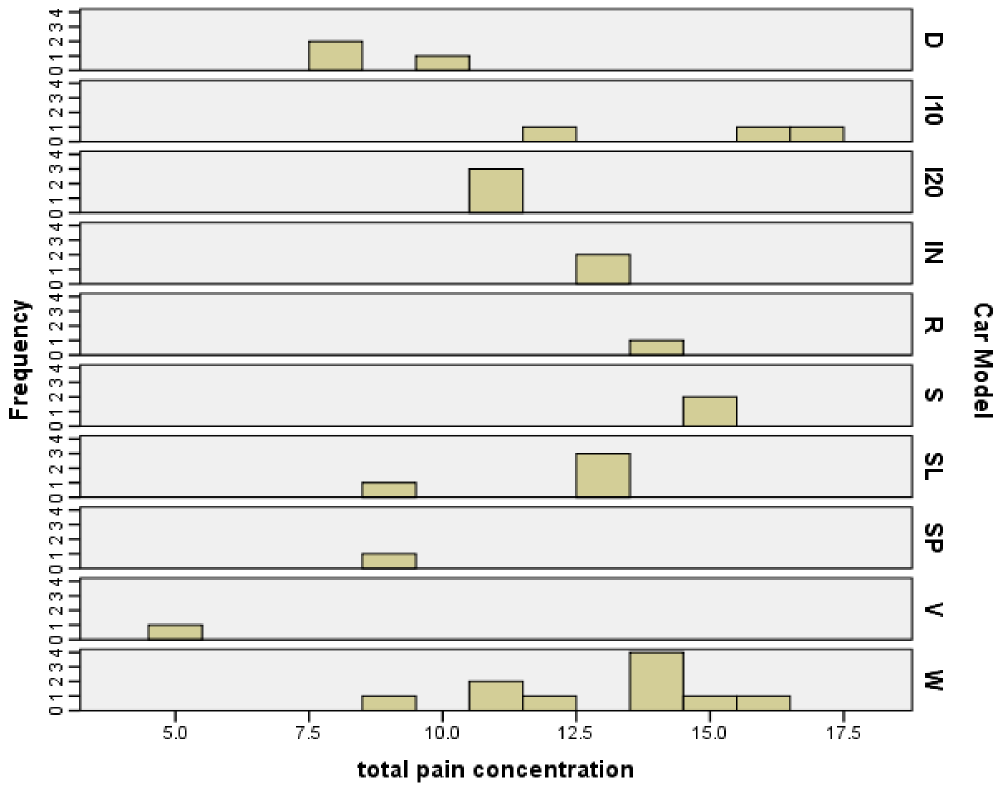

Figure 12 Histogram of the total pain concentration versus the car models

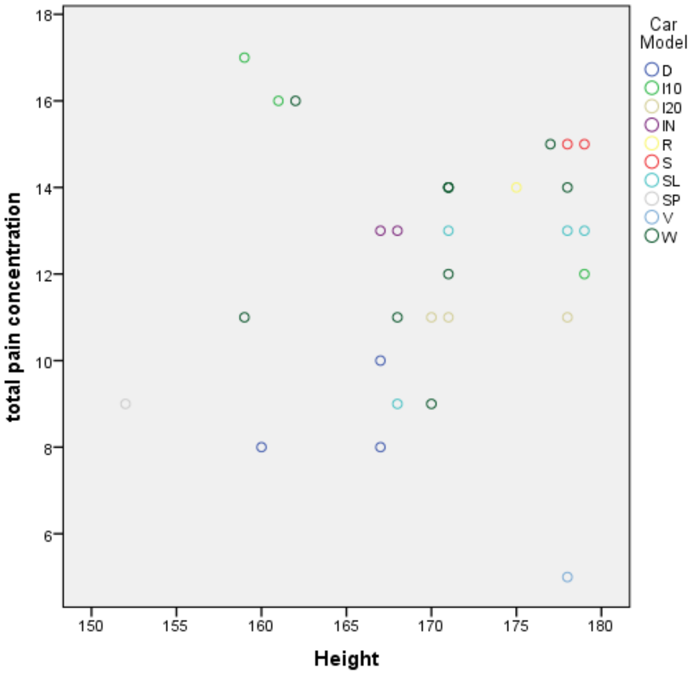

Figure 13 Scatter plot of total pain concentration versus height with car models as markers

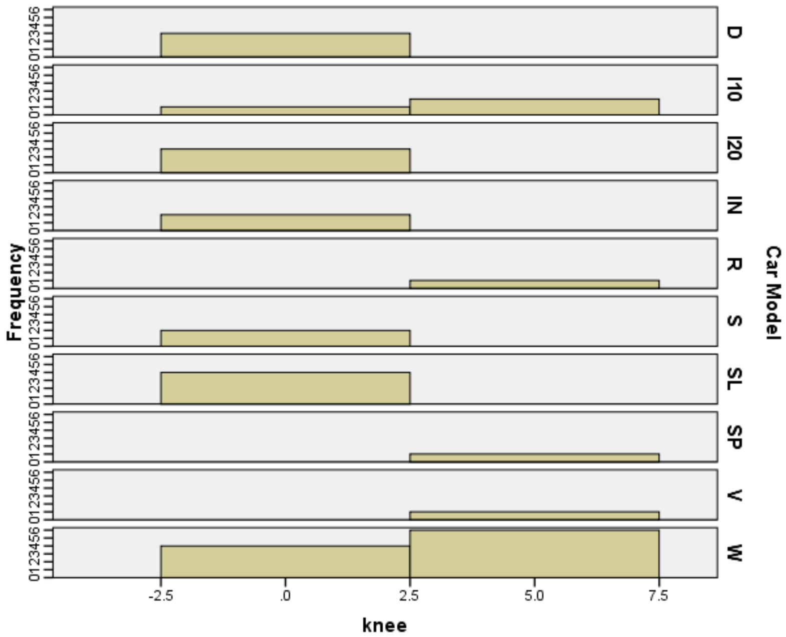

Figure 14 Histogram of knee versus car models

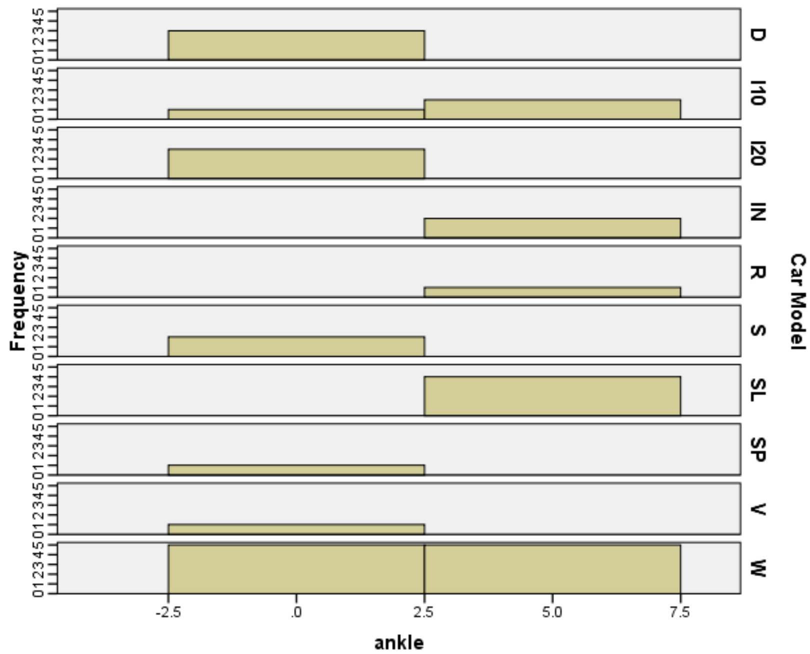

Figure 15 Histogram of ankle pain versus car models

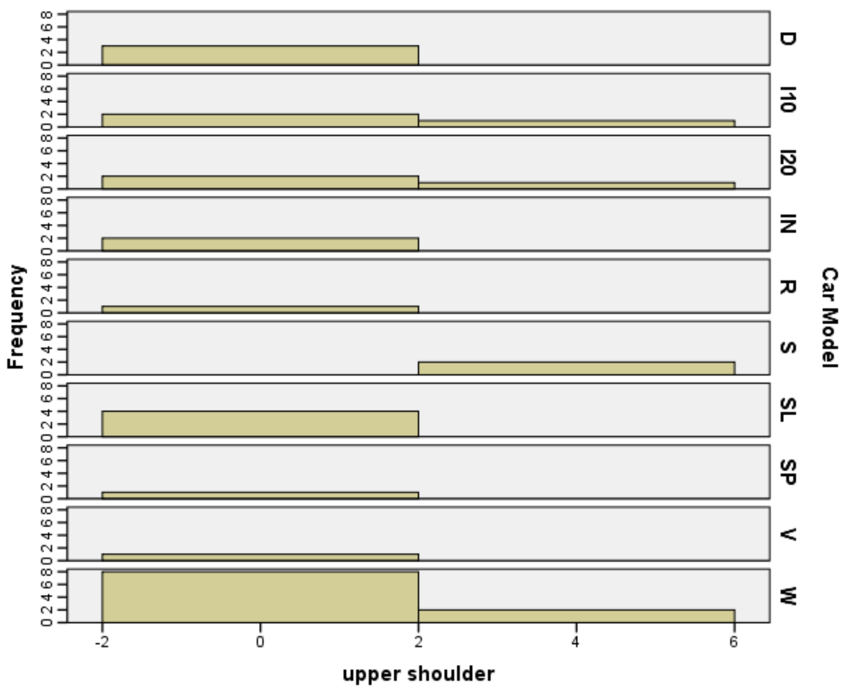

Figure 16 Histogram of Upper Shoulder versus Car Models

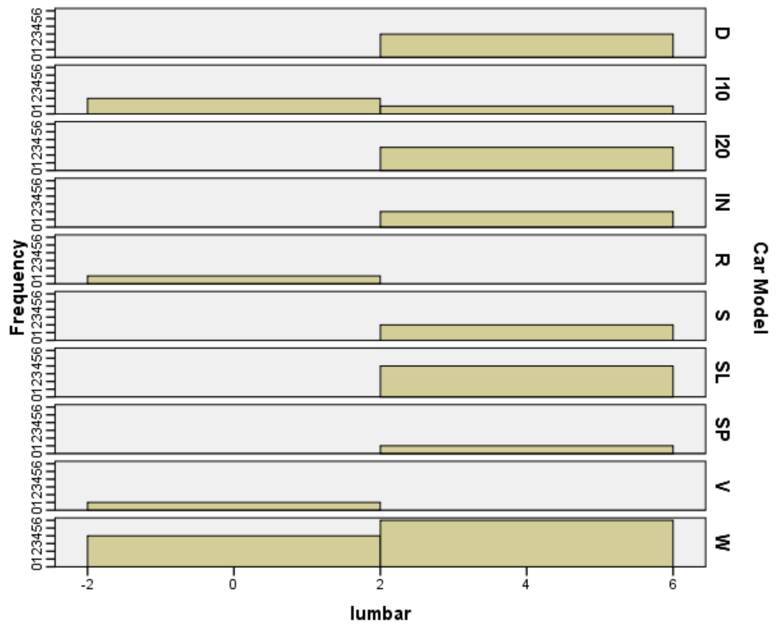

Figure 17 Histogram of Lumbar Region versus Car Models

The different graphs and histogram provide the result the users of Car-i20 experience least pain in the knee and ankle while the users of Car-i10 experience complete support in the lumbar region, shoulder and neck regions. Car-SL and Car-W provide the least comfort while driving as the pain concentration in these cars is the highest.

CHAPTER 4

Capturing Three Dimensional Digitized Data of Car Seats

4.1 Introduction

Reverse engineering is one of the fast growing discipline, which encases a large amount of actions. Reverse engineering is a distinct process of achieving a geometric Computer-Aided Design(CAD) model extracted from 3-D points which are gathered using scanning or digitizing existing parts and products. The process of digitally capturing the physical entities of a module, referred to as reverse engineering (RE), is often defined by researchers regarding their specific task (Motavalli & Shamsaasef, 1996) [28]. Abella et al. (1994) [29] described RE as the fundamental hypothesis of fabricating a part built on an primary or physical model devoid of the use of an engineering drawing. Yau et al.(1993) [30] has described RE, as the method of recovering new geometry from a manufactured part by digitizing and altering an existing CAD model.

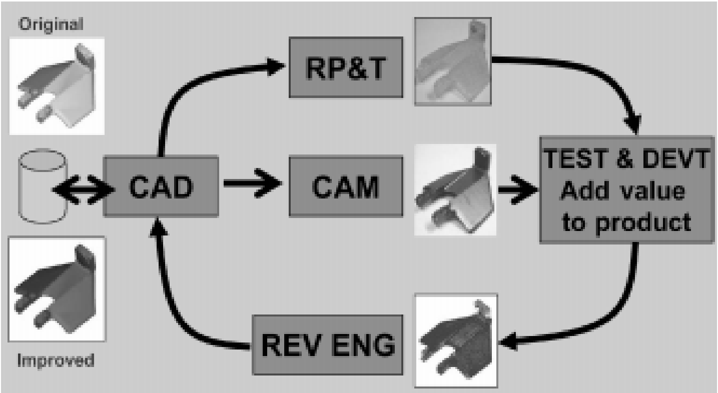

Figure 18 Product development cycle

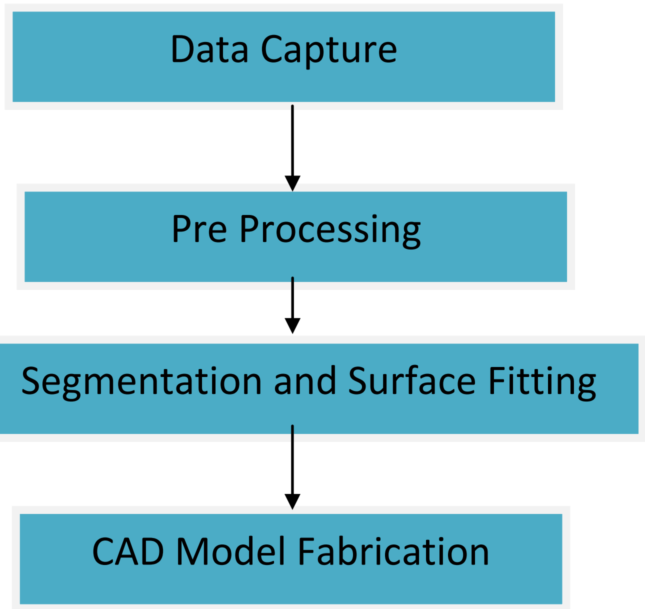

Figure 19 Reverse Engineering process consists of the following procedures

4.2 3D Scanning of Driver's Car Seat

4.2.1 Data Capturing

There are many methods for obtaining shape data, *contact methods* where the surface is touched by means of mechanical probes at the end of a robotic arm like CMM while in non contact method, light, sound or magnetic fields are employed to interact with the surface or the volume of the object.

Depending on the size of the part scrutinized, contact methods can be lengthy because each point is produced one after the other at the tip of the probe.

Optical methods of shape gathering are the most widespread and have relatively fast attainment rates. Noncontact devices utilize light within the data capture process. There are five significant categories of optical methods: triangulation, ranging, interferometry, structured lighting and image analysis. In *Laser Triangulation* method the scanners use either a laser line or just one laser point to scan across an object. A sensor grasps the laser light that is imitated off the object using trigonometric triangulation; the system then analyze the distance from the object to the scanner. *Ranging* is a method where the distance is sensed by time-of-flight of light beams; *Interferometry* determines the distance in terms of wavelengths via interference pattern. Structured Lighting makes use of projecting patterns of light upon a plane of the object and captures an image of the consequential pattern as reflected by the surface. Data can be attained using auditory methods which comprises sound (SONAR) and magnetic field.

4.2.2 Preprocessing

This stage include importing the point cloud data to a point cloud data managing software, registering, removal of the noise and data reduction steps.

In case of complex shape, the scanner cannot capture the complete surface data from a single scanned direction. By varying the object orientation, the object must be scanned multiple times from different directions. A portion of point cloud data is obtained every time the object is scanned. A procedure to combine all fragmented point cloud data into a single coordinate system is called registration.

In order to create a smooth and accurate surface model, noise free point cloud data is important. Data Reduction is a process to reduce the number of point clouds while keeping the sharpness of the part.

4.2.3 Segmentation and Surface Fitting

The process of converting point clouds to freeform surfaces can be divided into two: curved based modeling and polygon based modelling. In the curved based modeling, the point clouds are rearranged into a regular pattern (series of cross sections). These are further subdivided into simpler shapes of point sets, after which surface fitting is performed. Skinning function is used to fit curves to an approximated NURBS (Non Uniform Rational B-Spline) surface model which are combined to make a valid CAD model.

4.2.4 CAD model Reconstruction

The creation of CAD mock-up from point data is the most complex action within RE because effective surface fitting algorithms are essential to produce surfaces that accurately symbolize the three-dimensional data illustrated by the point cloud data. Enlargement in the use of rapid prototyping and tooling technologies have helped to shorten noticeably the time taken to make physical illustrations from CAD models. The entirely parametric final 3D CAD model could then be used by the customer for countless purposes including designing moulds and tooling, redesigning of the seat, or additional engineering analysis.

4.3 Measuring Devices Used for Car Seat Scanning

The data acquisition machine used in our project is of non contact type which uses optical triangulation method to scan the surface. The laser scanner consists of the laser probe which emits a laser beam to the part and the CCD (Charged Coupled Device) cameras then capture 2D image of the projected beam. The 3D coordinates of the part can be obtained by applying the triangulation method. The laser probe is usually mounted on the end effector of a robotic arm. In our case it was called *FARO arm*.

FARO's assortment of transportable coordinate measuring machines (CMMs) consist of measuring arms, laser trackers, 3D laser scanners and 3D imagers. These handy CMMs can be used for both contact and non-contact measurement. The FARO Arm is an efficient coordinate measuring machine (CMM) that allows maker easy substantiation of artifact quality by performing 3D assessment, tool certifications, CAD estimation, dimensional examination, reverse engineering, etc. The ScanArm, in addition to the FARO Laser Line Probe of the FaroArm put in matchless non-contact 3D scanning capacity for thorough measurement of surface form, making the ScanArm the ideal amalgamation of a contact and non-contact portable CMM.

Figure 20 FARO Arm

4.3.1 Scanning Set-Up

FARO arm is a multiple axis articulated robot arm with a spherical work volume. It has got six degrees of freedom and high mobility due to its small size, light weight, and the integrated quick charge battery. Two handle buttons are provided on the arm for data collecting. Front button, which is near probe, is for data collection and back button, which is near the handle, is for data acceptance. Auxiliary Port is a six pin connector which allows two channels of analog input into the FARO arm signal processing board. The FARO arm was placed on a wooden stool with a granite surface to vacuum it properly and it remains fixed. The legs of the stool were provided with adjustable features to make it stable on an even ground surface.

Figure 21 FARO arm placed on a granite surface

Figure 22 FARO arm connected to the laptop having RE Software

4.3.2 Precautions

This is a precision-measuring instrument, while using FARO arm, proper care must be taken in operating environment. Proper operation includes avoiding the following;

- Neglect (dropping, twisting at the end stops etc.)
- It has got six degrees of freedom. If any of the degree of freedom is locked it will not collect the data this can be checked on controller box.
- Moisture and high humidity
- Excessive temperature changes without suitable elapsed time.

4.4 Scanning of Car Models

Car models were selected from the results of the subjective analysis. The driver's car seats of these two cars were scanned using the laser scanner of the FARO arm. The FARO Arm the fastest way to capture the complex shape of a car seat. Other methods could easily take many hours. The scanned data was collected in the form of point cloud. This laser-line scanner is the ideal solution for organic shapes of this size. The physical seat was digitized an accuracy of approximately +/-0.002" (50 microns) in about an hour.

CHAPTER 5

Re-design of Car Seat

5.1 Introduction

The resultant dense set of raw 3D points is called a “point cloud,” which is then processed using *Geomagic 3D software from 3D Systems* (reverse engineering software). Geomagic Capture facilitates designers and engineers to include real-world objects into CAD as a flawless part of their engineering workflow. Geomagic Studio’s magnanimous collection of point cloud and polygon controlling features along with influential surfacing tools that helps to create premium 3D models more rapidly. Geomagic Studio also gathers design objective from any profile and can impeccably transmit parametric models to several external CAD packages.

Chief Characteristics of RE software are :

- It supports a extensive range of non-contact and probe devices, 3D scanners and digitizers.
- Transfers accurately 3D data directly into parametric CAD systems and exports polygonal models in many file formats including: STL, OBJ, VRML, DXF, PLY and 3DS.

- Powerful, computerized point cloud data clean up, mesh analysis and repair, remeshing tools and patch functionality.
- It optimizes digital scan data (outlier detection, noise reduction, overlap removal) and it can process large and denser point cloud data efficiently.
- It can both automatically or physically register and merges multiple scan data sets.
- Handles bulky 3D point cloud and probe data sets
- It can alter, edit, clean, detect and correct errors in the polygon models
- It can automatically fill holes in the model.

5.2 Processing of Digitized Data in Geomagic Software

- After connecting the FARO arm USB to the Dell Precision laptop, Geomagic2012 software is opened.
- Feature icon is selected and then click on Capture. Capture takes the scanned image by the laser.
- Each time the scanning is done and the data is accepted using the 'red' button on the FARO gun.
- Data is collected from different orientations and then registered into one coordinate plane.
- The point data is then edited and cleaned.
- Points option in the menu gives the various features to reduce noise, fill holes, delete unwanted geometry and join points to form polygons.

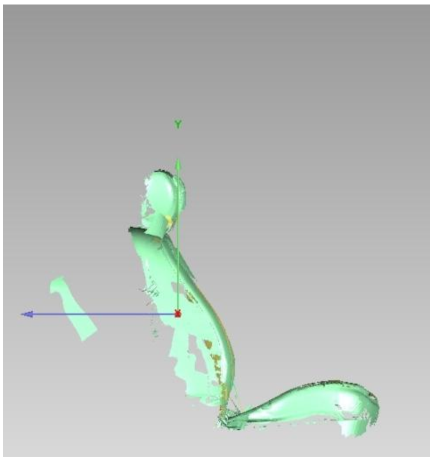

Figure 23 side view of the point cloud data of the scanned seat

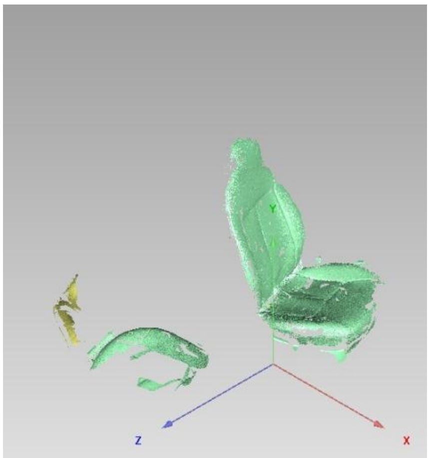

Figure 25 Point cloud data at different orientations

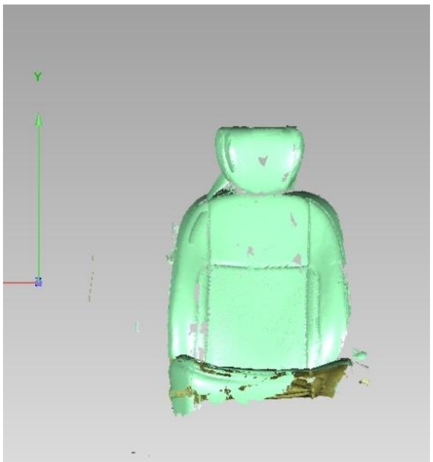

Figure 24 Front view of the scanned point cloud data

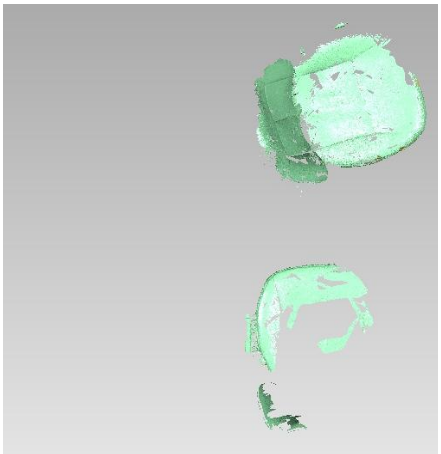

Figure 26 the point cloud data of the scanned seat at different orientations

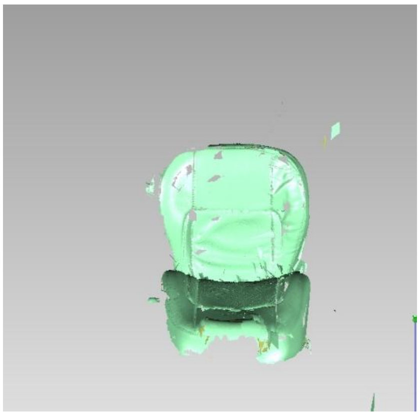

Figure 27 Top view of the scanned point cloud data

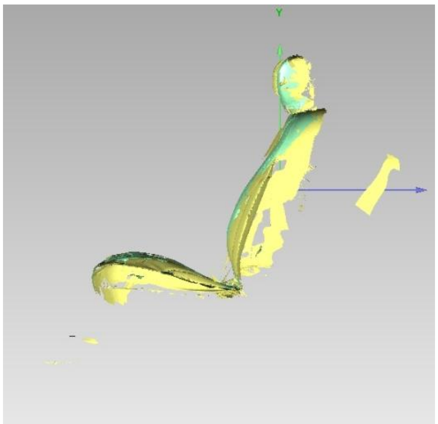

Figure 28 Point cloud data after noise reduction

5.3 Contours extraction from Reverse Engineering Model

Reverse engineering using 3D scan data is the most proficient way to generate a CAD model from a physical object that has any kind of complex or freeform shape. While using traditional measurement techniques such as calipers to reverse engineer these complex surfaces can be tricky or even impossible. Through the reverse engineering process, the extract digital shape of physical objects that may have insufficient design documentation or it may require CAD data for modern manufacturing methods. CAD software, *Catia V6 by Dassault Systemes* is used in our project to create curves and surfaces. With a highly elastic approach to reverse engineering, Catia helps to reduce the time required to develop CAD models from physical objects.

Rendering of the Car Seat Contours

Real Time Rendering in the CATIA workbench allows significant material specifications that can be shared through the entire product enhancement process as well as for mapping materials onto parts so as to produce photo-realistic images. Catia directly imports polygon facet data acquired by scanning physical objects, and helps you evaluate and prepare it for subsequent use. With real time rendering tools in Catia, we fitted curves, splines and surfaces to the photographic image, creating precise CAD geometry for subsequent design engineering. An accurate 3D surface and line and models of what you want to detect in the camera image is required. The line model is what is used to determine the correct pose in the camera image. The more distinctively the lines of the model can be found as edges in the image.

A product is created in the Real time rendering workbench and a part is inserted in it. This part is opened in a Generative Shape Design workbench and a plane is created by extruding a line. The product is again opened in real time rendering and a sticker (of the photograph/captured image) is placed on this planed surface.

The desired curves from the images of the car seat are extracted. The selection these curves is based on the survey conducted and user comfort ratings. The contours extracted were on three orthographic planes. The results from the subjective analysis were used to select curves which represent the best car feature. These features were further modified as per survey candidates' suggestions to get a novel car seat design.

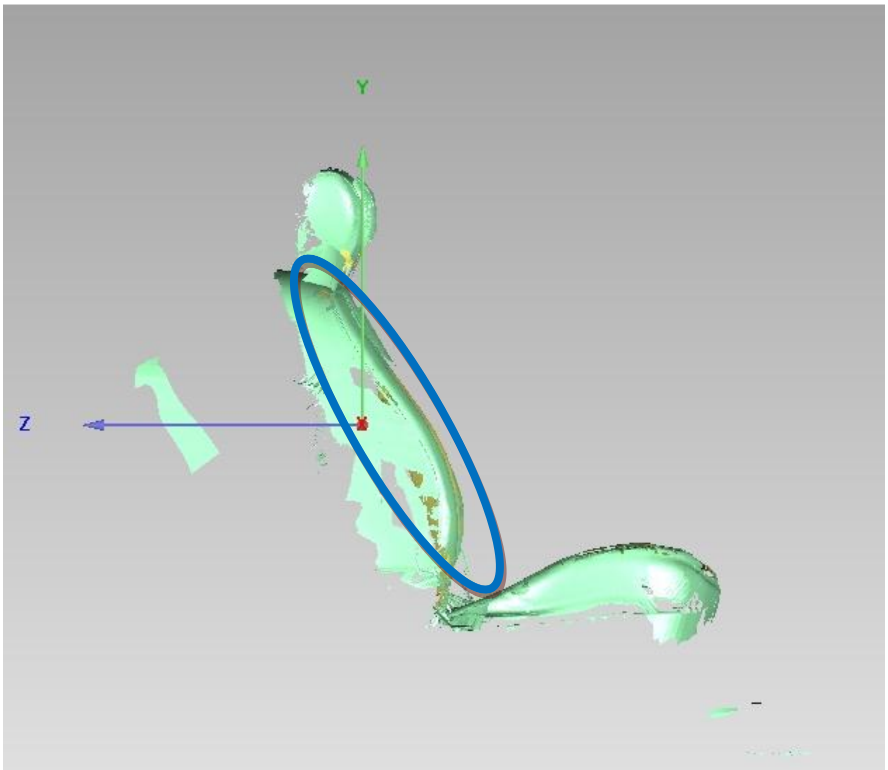

Figure 29 the enclosed contour was extracted from this car seat model based on its rating in subjective analysis

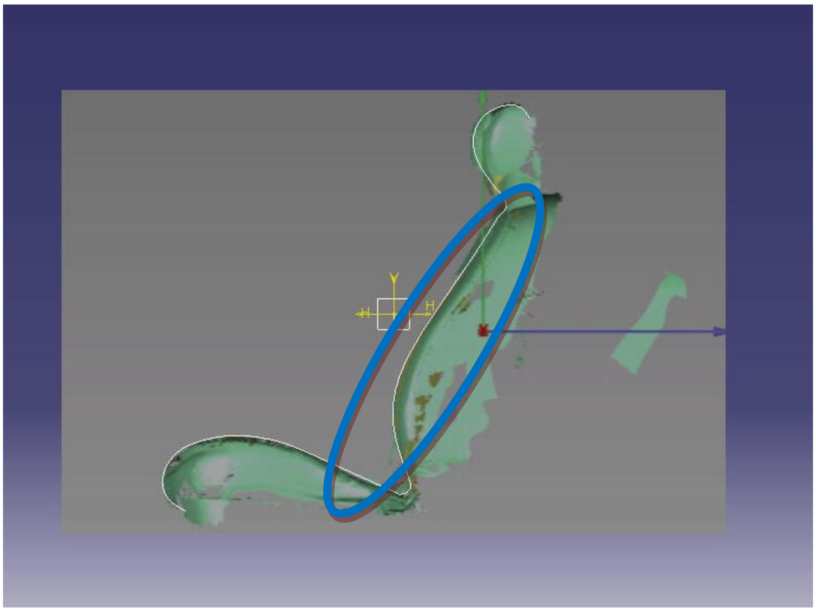

Figure 30 A profile is generated along the chosen contour in real time rendering workbench

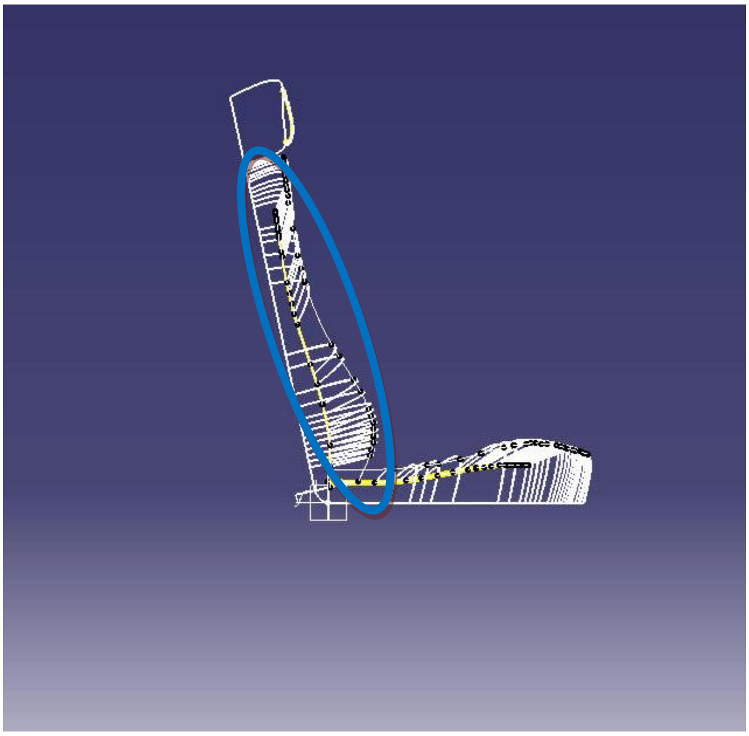

Figure 31 similarly other contours are also extracted from the chosen car models and a wireframe model consisting of all these different curves is made. These contours are also modified as mentioned by users in survey (the enclosed area shows the contour extracted from figure 29)

5.4 Development of Surface model of Car Seat

Surface is created by sweeping a profile curve along multiple guides. Some of these complex surfaces are created from a set of contours and a set of path way guides which resulted in nice continuous curvature with references. For the different needs for profiled surface creation mainly: Simple Sweep, Sweep and Snap, Sweep and Fit, Sweep near profiles was used.

The surfaces were modified to reduce pain concentration areas and provide maximum comfort to the driver.

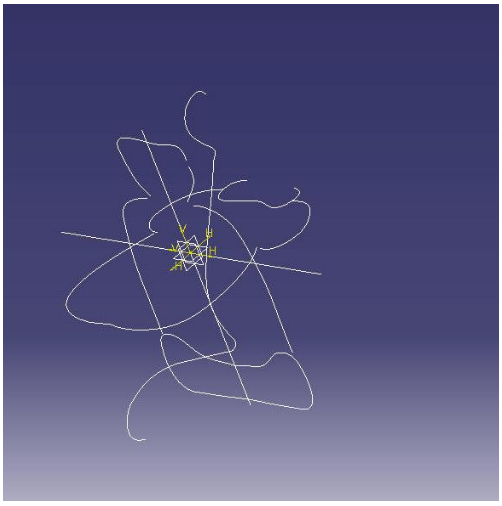

Figure 32 Contours extracted from different car seat models

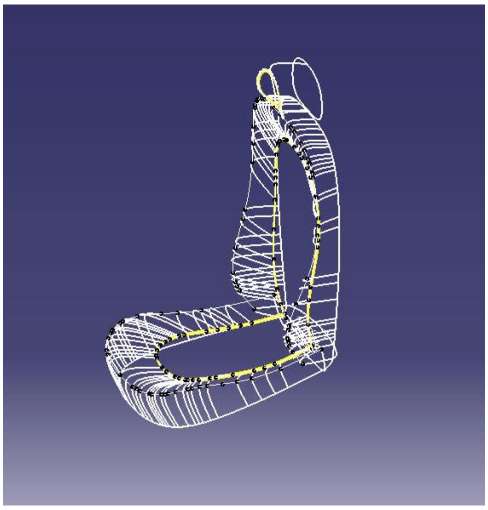

Figure 34 Wireframe model from the extracted and modified contours

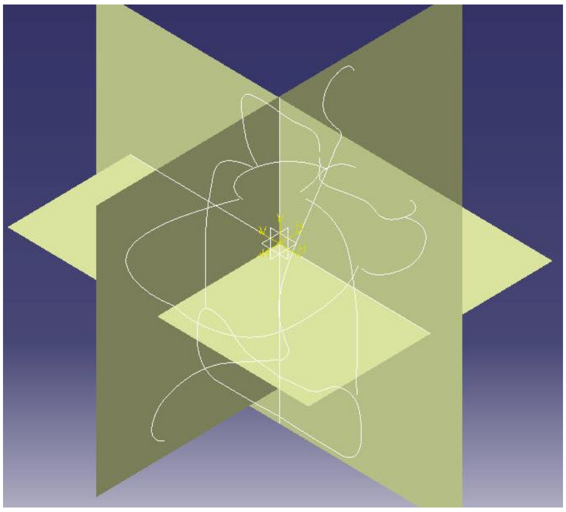

Figure 33 The contours in three orthogonal planes

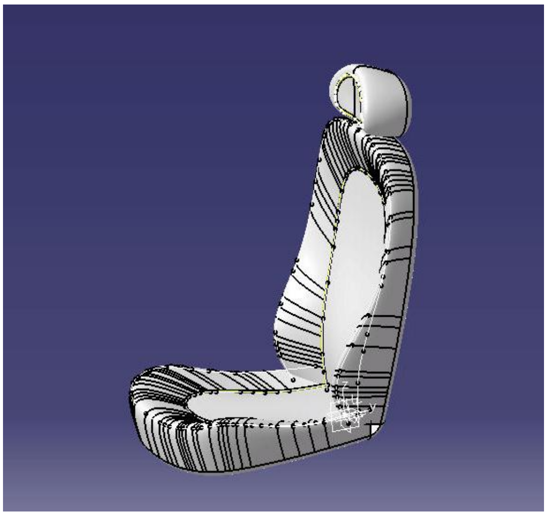

Figure 35 Surface generated through the curves in figure 34

5.5 Results

5.5.1 Redesigning of the car seat

The next task is to apply pre-defined materials. Select the part geometry on which the material should be applied and in our case for our redesigned seat we chose beige leather fabric. The curves of the best car features were taken to reconstruct a new surface, incorporating the best features (curves) of the car model and some modifications. The surface was constructed and rendered.

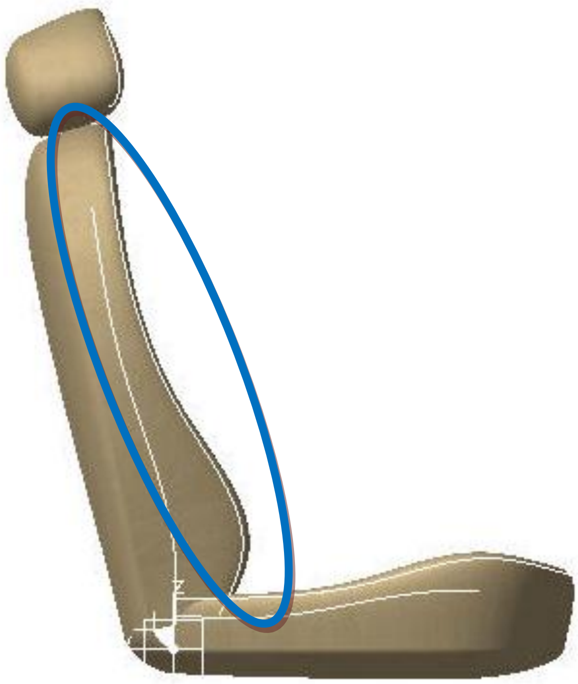

Figure 36 Side view of the re-designed car seat (the enclosed area shows the surface on the contour in figure 30 and 31and its modification)

Figure 37 The 3D view of the re-designed seat

Figure 38 Front view of the re-designed car seat

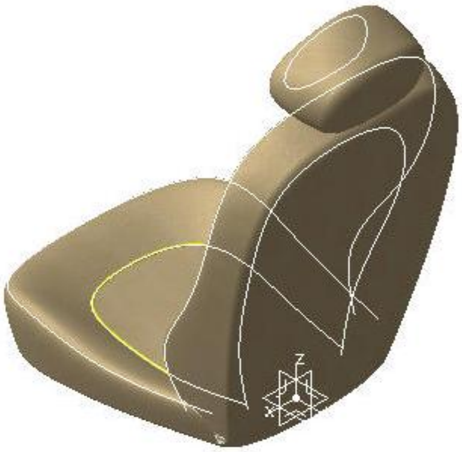

Figure 39 Orthogonal view of the re-designed car seat

5.5.2 Physical Prototype of the Car Seat Structure

The final reconstructed model was scaled by factor 0.2 and fabricated. The file was converted into .stl file format and the data was transmitted to Rapid Prototyping Machine software where it is sliced. The model is oriented in such a way that uses optimum support material. The support structures are generated automatically by the software MOJO Print Wizard 1.1.The material used for model construction is ABS (acrylonitrile butadiene styrene) .The building of the prototype was done in the 3D Printer by Stratasys (which uses FDM technology) at Creative Automation Laboratory of Industrial Design Department of National Institute of Technology Rourkela.

CHAPTER 6

Conclusions and Future Directions

This chapter concludes the technical sum-up of the thesis work on Redesign of a Drivers' Car Seat Using Three Dimensional Reverse Engineering Techniques, which is followed by directions for future work.

6.1 Concluding Remarks

The re-evaluation of the design of car seats based on the comfort and discomfort factors is of utmost importance especially from the consumers' point of view. The method for evaluation of design used in this task used mostly the subjective reporting techniques. Participants are interviewed in this process to obtain data ratings regarding the various seat features of the 10 car models. The feedback data for both the seat features and pain perception of the consumers is collaborated and imported into the analytical workbench of SPSS. The analysis of the feedback data provides the features of the different car seat models that are responsible for providing the most comfortable driving experience to its consumers. The features that are highly responsible for providing long-term comfort are categorized based on the ratings for the seat features as:

- Neck rest
- Lumbar support
- Thigh angle
- Cushion width

This work compared the selected car seats' features and compared them to the pain perception results of the same car seat models. This comparison provided the seat attributes that could be re-designed or enhanced in some manner according to the consumer's suggestions so as to lessen the pain concentration in the affected areas. The car seat models chosen for the process of redesign are imported after scanning by a CMM device into a three dimensional CAD environment as point cloud or digitized data for the extraction of the profile and amalgamation of the best features of the selected car models. The modifications specified based on the consumer suggestions and ratings for pain concentration are added so as to obtain the new redesigned version of the car seat model.

6.2 Future Scopes

This work can be further enhanced by applying objective analysis to corroborate the findings of the subjective analysis. Analysis of body pressure distribution (BPD) at the human-seat contact interface would help in the proper justification of the comfort level of the new improved seat design. The effects of localized pressure and strain due to inadequate structural support can be analysed with the help of BPD instruments like pressure mats and thermal sensors. The contact forces and peak pressure of the crucial anatomical zones is experimented on for the new seat design in a virtual environment by using a digitized human model also known as a manikin. The sitting posture of a human body can also be investigated in a virtual environment to obtain the back rest angle, seat height and knee angle for a relaxed and comfortable driving without putting strain on the major body joints. The total body seat interface contact force can also be investigated with the use of BPD devices to gain knowledge on the pressure loading for the design proposed and the postural factors responsible for the uneven pressure distribution.

Material consideration can also be investigated for providing the cushion vibration absorption, breathability and stiffness to the seat model. Currently, Polyurethane Foam (PUF) is the cushion material choice largely due to its lightweight and ease of manufacturability characteristics. The PUF cushion is designed to provide sufficient cushioning for a wide range of occupants of varying weights. The material concentration for the seat should be such that it must be soft enough to deflect lighter subjects and stiff enough so as not to bottom out under heavier subjects. The materials endurance for vibration absorption while driving should be of optimum level so as to provide a comfortable ride to its occupants.

Analysis of the seat-pan pressure distribution for the proposed design can be conducted and the measured responses can be compared and analyzed against that of the selected car seat models. The significant variations in the force and pressure applied on the occupant can be compared for the new design and the selected car models.

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Appendix 1

SURVEY QUESTIONNAIRE

Car Seat Comfort Survey

Thank You for Your Participation

Name: ______________________________ Phone: ____________________

Occupation: __________________________ Area: ____________________

Age: ________________________________ Gender: ____________________

Weight: ______________________________ Height: ____________________

How many years have you been driving a car? __________ Years

How many hours per day do you drive a computer? __________ Hrs.

How often do you take breaks per hour of driving time? __________

Percentage of driving time utilized in relaxing? __________ %

Feel parameters	1	2	3	4	5
Does the car seat feel uncomfortable with change in temperature?					
Does the car seat stick to you due to perspiration?					
Does your body appear warmer after a long continuous drive?					
Does the seat feel too scratchy to you?					
Does your seat feel too hard for you?					
Does the seat position make you feel congested?					
Accessibility of gear change					
Field of view from the driver's seat					

Is driver seat comfortable wrt vehicle Vibrations?					

Are the symptoms lessened or eliminated during less traffic? o Yes o No

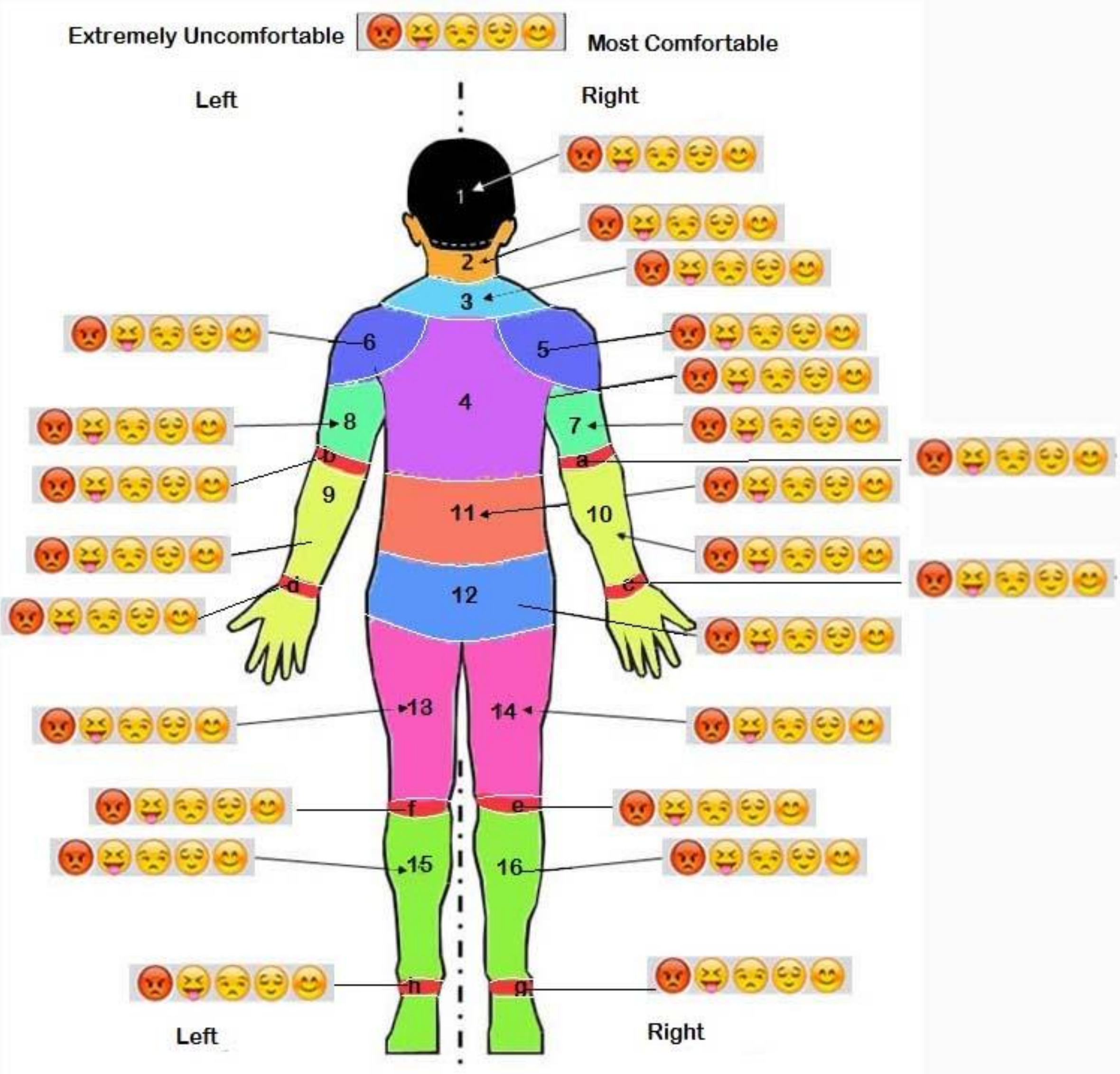
Which areas of your body get the most tired or feel the most discomfort (list)? o None

Answer the following questions about your seat:	1	2	3	4	5
Is the seat comfortable?					
Does the backrest give you low back support?					
Does it allow your feet to fully rest on the floor or footrest?					
Does it have adjustments to allow you to assume different positions?					
If present, are these adjustment mechanisms easy to use?					
Other seat comments:					
NOTE: 5=extreme limit and 1=least limit					

Type of geographic location in which you live:

(1) Urban (2) Suburban (3) Rural

(4) Other (please specify):____________________


Extremely Uncomfortable
Most Comfortable
Left
Right
1
2
3
4
5
6
7
8
a
b
9
10
11
c
d
12
13
14
e
f
15
16
h
g
Left
Right

Appendix 2

RECORDED DATA

Serial No	Gender	w/h	Age	Car Model	Seat Features rated above 3	Weightage	Pain concentration after long driving hours
1	Male	82/171	22	WagnoR	Seat Adjustment Features	5	knee
							Ankle
							left elbow
2	Male	75/168	27	Maruti	Seat Adjustment Features	5	knee
					Seat cushion Softness	4	calves
							left elbow
3	Male	87/168	45	Skoda laura	Seat shape	2	ankles
					Seat Adjustment Features	5	lower back
					Seat cushion softness	4	
4	Male	80/171	28	WagonR	Seat Adjustment Features	5	lower back
							ankle
							neck
							upper shoulder
5	Male	78/170	45	WagonR	Seat Cushion	4	Waist
					Seat Adjustment Features	5	Lumbar Region
							Knee
6	Male	65/160	57	Dzire(Maruti)	Seat Shape	2	left forearm
					Seat Adjustment features	5	lower back
					Seat Cushion Softness	4	left elbow
7	Male	75/175	58	Ritz(Maruti)	Seat Adjustment features	5	left elbow
					Seat Cushion Softness	4	knee
							ankles
8	Female	60/159	25	WagonR	Seat Cushion Softness	4	lower back
					Seat Adjustment Features	5	ankles

							calves
9	Male	71/167	57	Indigo	Seat Adjustment Features	5	ankles
					Seat Cushion Softness	4	lower back
							left elbow
10	Male	68/152	51	Spark	Seat adjustment features	5	waist
					seat cushion softness	4	knee
11	Male	74/178	37	WagonR	Seat adjustment features	5	knee
							neck
							calves
							waist
12	Male	74/178	54	Vento(Volkswagen)	Seat adjustment features	5	knee
					Seat shape	2	
13	Male	67/177	22	WagonR	Seat adjustment features	5	shoulder
							neck
							waist
							left elbow
14	Male	77/178	51	i20 hyundai	seat adjustmet features	5	lower back
					seat shape	2	neck
							shoulder
15	Male	75/179	50	Santro Hyundai	seat cushion softness	4	lower back
					seat adjustment features	5	left elbow
							neck
							shoulder
16	Male	84/179	51	i10 Hyundai	seat adjustment features	5	neck
					seat cushion softness	4	shoulder

					seat shape	2	knee
17	Male	65/159	27	i10 Hyundai	seat adjustment features	5	neck
					seat shape	2	left elbow
							knee
							ankles
18	Male	79/178	49	Skoda Laura	seat shape	2	ankles
					seat adjustment features	5	left elbow
							waist
19	Male	65/167	54	Dzire(Maruti)	Seat Shape	2	left forearm
					Seat Adjustment features	5	lower back
					Seat Cushion Softness	4	left elbow
20	Female	55/161	23	i10 Hyundai	Seat adjustment features	5	left elbow
					Seat Shape	2	ankles
							lower back
							neck
21	Male	67/171	22	i20 Hyundai	Seat shape	2	neck
					Seat cushion softness	4	left elbow
							lower back
22	Male	75/179	49	Skoda Laura	seat shape	2	ankles
					seat adjustment features	5	left elbow
							waist
23	Male	65/167	54	Dzire(Maruti)	Seat Shape	2	left forearm
					Seat Adjustment features	5	lower back
					Seat Cushion Softness	4	left elbow
24	Male	79/171	37	WagonR	Seat adjustment features	5	knee
							neck

							calves
							waist
25	Female	65/162	47	WagonR	Seat Adjustment Features	5	lower back
					Seat cushion softness	4	ankle
							neck
							left elbow
26	Male	69/170	27	i20 Hyundai	Seat shape	2	neck
					Seat cushion softness	4	left elbow
							lower back
27	Male	72/168	55	Indigo	Seat Adjustment Features	5	ankles
					Seat Cushion Softness	4	lower back
							left elbow
28	Male	76/178	50	Santro Hyundai	seat cushion softness	4	lower back
					seat adjustment features	5	left elbow
							neck
							shoulder
29	Male	82/171	22	WagnoR	Seat Adjustment Features	5	knee
							Ankle
							left elbow
30	Male	78/171	46	Skoda Laura	seat shape	2	ankles
					seat adjustment features		left elbow
							waist