

STATISTICAL AND
MATHEMATICAL METHODS
USED IN
PRODUCT DESIGN

SPECIAL PROJECT

BY

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856104

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Seminar Project

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Guide

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APPROVAL SHEET

Seminar project entitled 'Statistical and Mathematical Methods used in Product Design' submitted by K.P.Chandran is approved for the partial fulfilment of the requirements for the award of postgraduate degree in Industrial Design.

Guide *N. Sarin*

Introduction

There are various statistical and mathematical methods to design and to assist design. They are : -

1. Designing using one's own dimensions
2. Designing using percentile values
3. Design methodologies using statistics
4. Paired comparisons tests.
5. INDSCAL
6. Computer Aided Design

1. Designing using one's own dimensions

This is a simple mathematical method. In this the designer uses his own dimensions for designing the product.

2. Designing using percentile values

The most useful statistics for the equipment design is percentiles. The need for statistics in product design is imposed due to variability of human dimensions.

Designing for the average man will be no way practical depending upon the equipment to be designed either people above 50th percentile or those who are below that value will find the design unfit for their dimensions. Also the range of persons to be accommodated cannot spread from the

least value to the greatest value of that group because the group may consist of people having abnormal dimensions whose values will be irrelevant for the design. So the concept of percentile gives a more practical range of dimensions to be incorporated in the design.

3. Design methodologies

3.1 Interaction of factors

Many factors affecting design may interact one another to make a complicated situations. Interaction matrices can be used to find the relationships between factors.

Factors	1	2	3	4	5
1			X		
2				X	X
3					
4					X
5					

eg. 1. Discovering all factors influencing an existing design by taking all parts in the design and all elements with which it has contact.

eg.2 When the design problem involves linking of many elements as in the case of pipe works, circuits building

layout etc.

3.2 Design evaluation

First establish sequences and orders of importance of design factors by using interaction matrices.

Factors	1	2	3	4	5	6
1		X	X			X
2						
3		X				X
4	X	X	X		X	X
5	X	X	X			X
6		X				
Total	2	5	3	0	1	4
	C	F	D	A	B	E

Each cross denote the factor in the row is more important than the factor in the column. So the most important factor will have least total where as the least important will have the maximum total (A → F)

Then make another matrix with design requirements and design concepts. Assign some weightage to each concept in each column depending upon how effectively the design requirement is fulfilled by that concept.

Finally the total score of each concept is found out and one can reach on a final conclusion keeping in mind the relative importance of all the requirements.

4. Paired comparison test

Paired comparison test is used to study the likes and dislikes of people towards different product attributes.

Any two stimuli is taken at a time and subjects are asked to compare them on a rating scale, required product attribute to be assessed. The experiment is repeated for all combinations of the stimuli on all subjects. The results are then tabulated and analysed.

For example, the study conducted by Prof. Iida on tooth brushes is as follows.

No. of tooth brushes studied (No. of stimuli) = 6

No. of subjects = 5

Product attributes	-	Length	-	L
		Colour	-	C
		Shape	-	S
		Hardness	-	H

Let the tooth brushes be A,B,C,D and E

and Subjects 1,2,3,4 and 5

and then possible combinations of paired stimuli are

- | | |
|-------|--------|
| 1. AB | 6. BD |
| 2. AC | 7. BE |
| 3. AD | 8. CD |
| 4. AE | 9. CE |
| 5. BC | 10. DE |

Each subject is asked to rate all the pairs of stimuli in a 7 step rating scale.

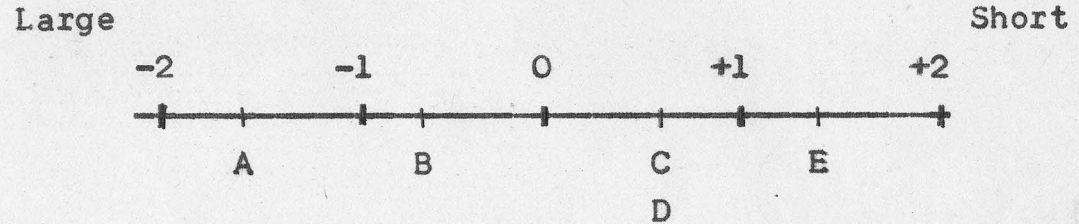
Sample tabulation of results

Subject 1

	L	C	S	H
AB	-1	-3	-2	-1
AC	-3	0	-1	-2
AD	-1	-3	-3	-1
AE	-2	-3	-2	-2
BC	-3	-2	-2	-1
BD	-1	0	-1	-1
BE	-1	-2	-2	0
CD	0	-2	0	1
CE	-2	2	1	1
DE	1	2	-1	-2

Values for all the subjects are tabulated like this.
 Analysis of the data give the following result.

Length (sample~~x~~ result)



5. INDSCAL

INDSCAL is a programme for Individual Differences multidimensional Scaling. The experiment is illustrated by the following example.

Two subjects A and B are presented with all possible distinct pairs of three cups of black coffee, designated by 1,2, and 3. Assume that the cups of coffee have the following physical properties

Stimulus	Temperature (^o F)	Sugar (tea spoon)
1	150	2
2	110	3
3	70	1

Upon presenting the cups to the subjects, they will respond to the dissimilarities between each pair. The responses are represented by the artificial dissimilarities data shown below.

Subject A

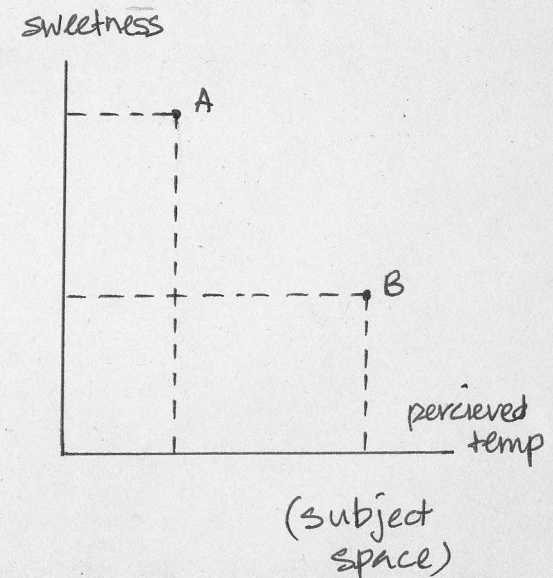
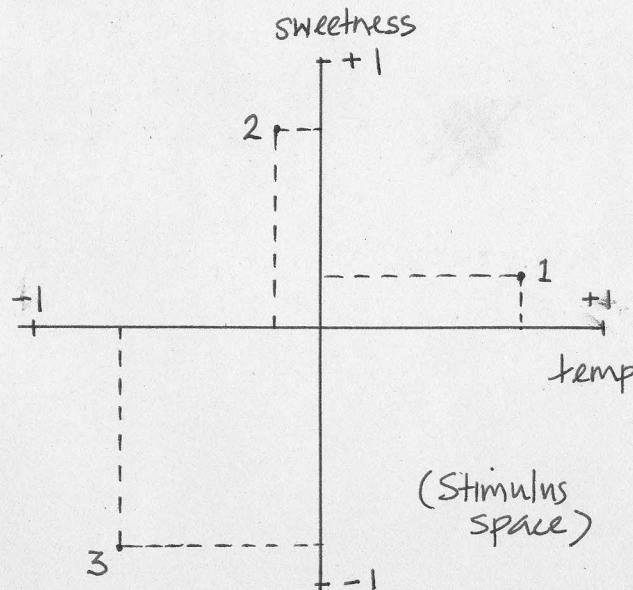
2	.84	
3	1.22	1.38
	1	2

Subject B

2	.88	
3	1.42	1.15
	1	2

Each value indicates the subjects assessment of the difference between the stimulus in the row label to that in the column label.

On analysing this data by INDSCAL, we get the following results.



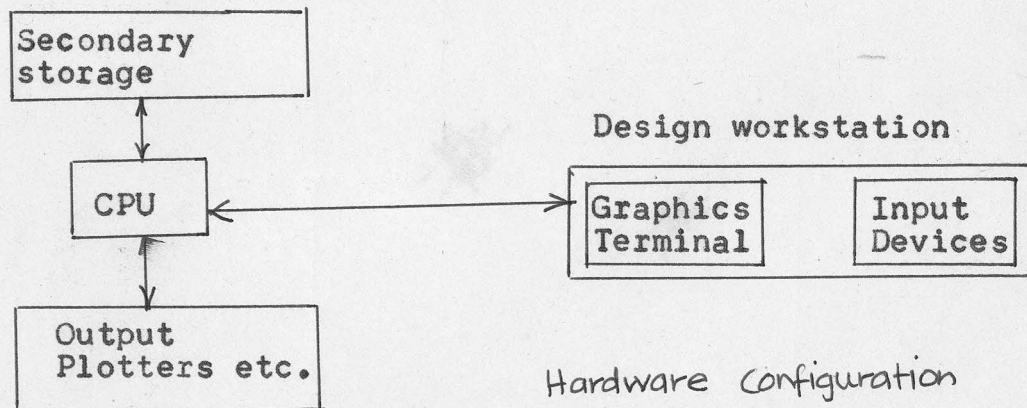
6. Computer Aided Design (CAD)

CAD can be defined as the use of computer system to assist the creation, modification, analysis or optimization of design.

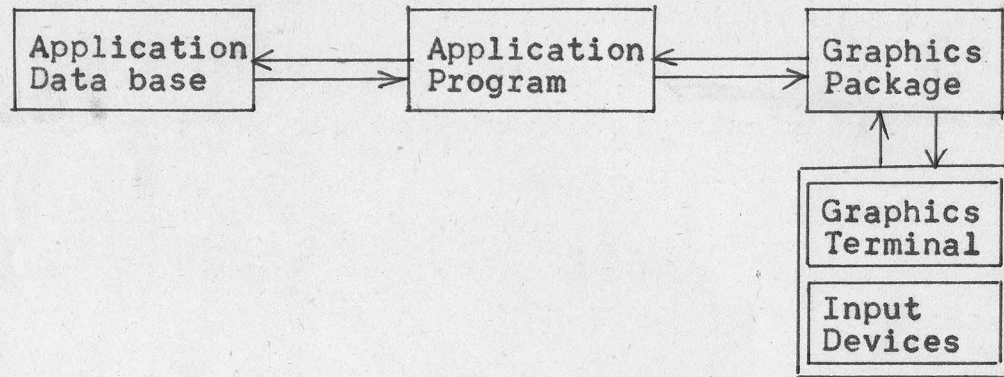
Modern CAD systems are based on interactive computer graphics (ICG). ICG is a user oriented system where the computer is employed to create, transform and display data in the form of pictures or symbols.

A typical ICG system is a combination of hardware and software.

The hardware consists of a design workstation output devices, CPU and secondary storage.

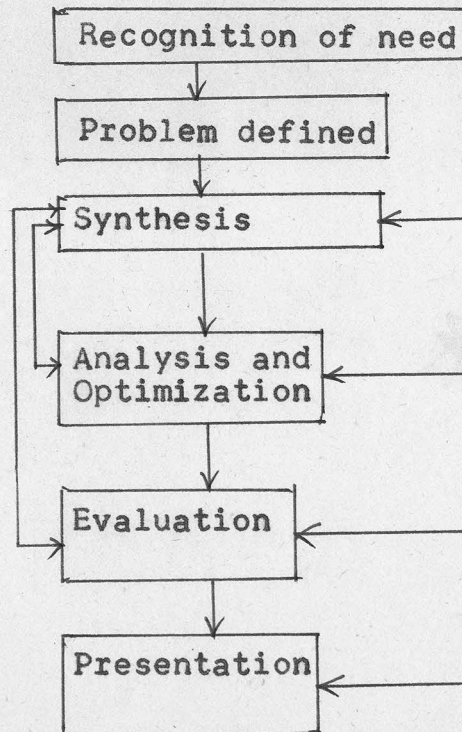


Software configuration

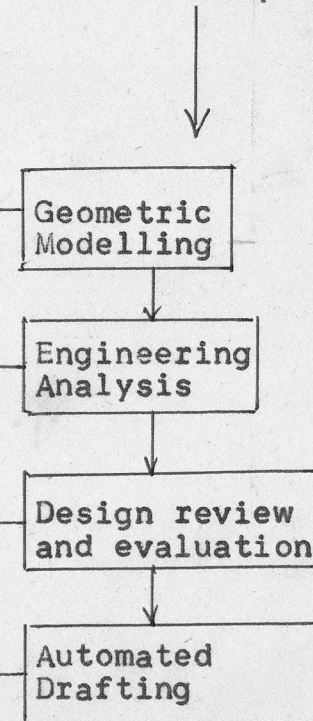


Design workstation

Design Process



Rele of computer



Geometric Modelling

.Constructing the geometry

This involves defining points lines, arcs and circles, conics surfaces and editing them to get the required figure.

Some of the common editing features are

1. Move an item
2. Duplicate an item
3. Rotation of an item
4. Mirror image
5. Delete a selected portion
6. Trim a line or other component.
7. Create a cell out of graphic elements
8. Scale an item in X,Y and Z direction.

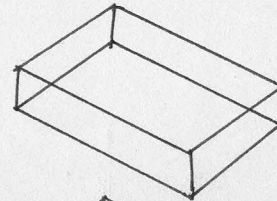
Concatenation

Any of the above transformation can be combined together as a sequence of transformations. This combined transformation is called concatenation.

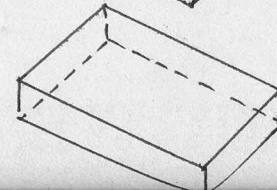
Depending on the capabilities of the ICG system, there are many types of geometric modelling.

Wire frame models

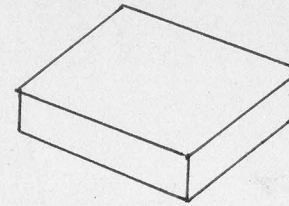
1. All corners visible



2. Hidden lines dotted



3. Hidden lines removed



Solid modelling

In this, the models are displayed as solid objects to the viewer. There are two basic approaches to the problem of solid modelling.

1. Constructive solid geometry (CSG).
2. Boundary representation (B-rep).

CSG uses solid geometric shapes such as cubes, sphere, cylinders, pyramids etc for building models.

B-rep uses electronic tablet and pen or analogous procedure to draw the boundary of the object in as many as number of use as necessary and then combining them together.

There is another system called Hybrid system which is the combination of both CSG and B-rep.

Engineering Analysis

This includes analysis pertaining to surface area, weight volume, centre of gravity, Moment of inertia, stress, strain heat transfer etc.

Design review and evaluation

1. Zoom any desired part and magnify the image for close scrutiny.
2. Layering: e.g. Overlaying the geometric image of the final shape of the machined part on top of the image of the rough casting, to ensure availability of enough material.
3. Interference checking : This involves analysis of an assembled structure in which there is a risk that the components may occupy the same space.
4. Kinematics : This can animate motion of a mechanism such as hinged components and linkages. This capability enhances the designer's visualization of the operation of mechanisms and help to ensure against interference of other components. Thus analysis is possible without building a physical model.

Automated Drafting

Automated drafting system can increase productivity in the drafting function by roughly 5 to 10 times over manual drafting. These drafting systems can perform

1. Automatic dimensioning
2. Generation of cross hatching
3. Scaling of the drawing
4. Sectional views and enlarged views of particular parts.

Integrated CAD-CAM :

Creating a data base for manufacturing

In the conventional manufacturing cycle, engineering drawings are prepared by the design draftsman and used by manufacturing engineers to develop the process plan. Thus a two step procedure is employed for design and manufacturing.

By using CAD systems for design the data base needed for manufacture is also developed with the design process, which can be fed directly to the NC machine for manufacturing.

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