Decision Making Using Fuzzy Logic

Lecture 7

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Issues Related to Term-paper

- Select one or more papers/ Based on own work
- Structure of the paper
  - Abstract
  - Problem Definition
  - Conceptual Aspects/Details
  - Implementation
  - Results and Discussion
  - Future Projections
  - Summary
  - References
- Plagiarism check – Turnitin, plagscan report
- Important: Follow Guidelines

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Submission Norms

- .pdf version ONLY
- By email to ***skbarai@rediffmail.com***
- Rollno_TP1.pdf file
- Example: **08CE3000_TP1.pdf**
- Before deadline

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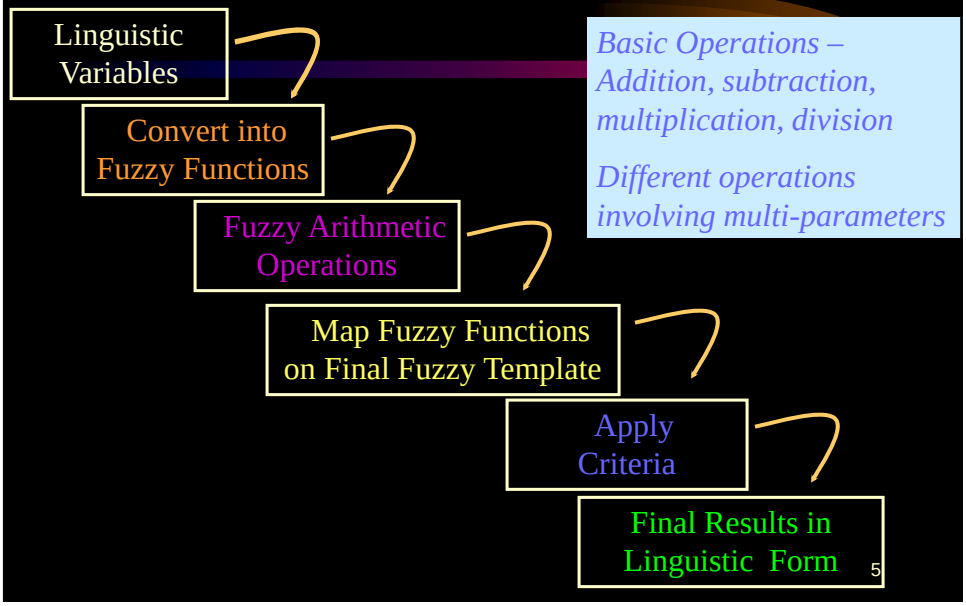
General Approach



List of Criteria

- The pseudo-expectation criterion
- The gravity center criterion
- The most possible criterion
- The pessimistic criterion
- The optimistic criterion
- The α-pessimistic criterion
- The α-optimistic criterion
- The average mean criterion
- The nearest to the ideal optimum criterion
- The dominance criterion
- The classification criterion
- The four point average criterion

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Relationship between operation mode and feature values

Mode (Pattern)	Pressure	Temperature	Flow Rate
Autoclaving	High	High	Zero
Annealing	High	Low	Zero
Sintering	Low	Zero	Low
Transport	Zero	Zero	High

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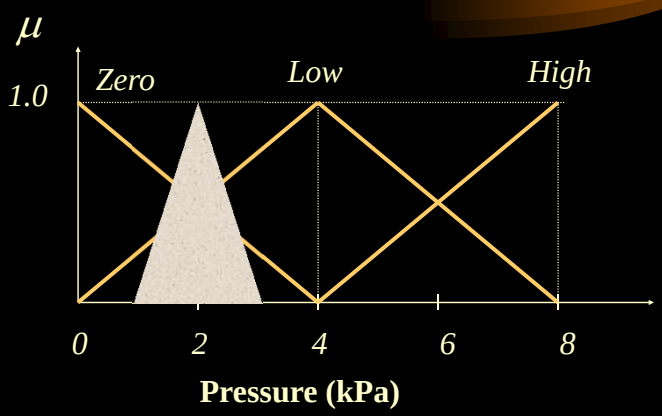
Pressure



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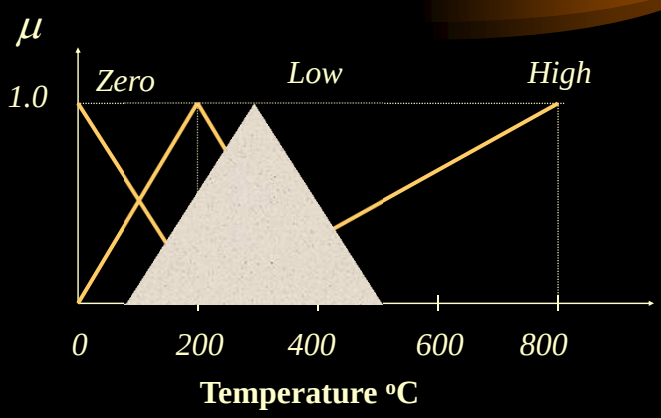
Temperature



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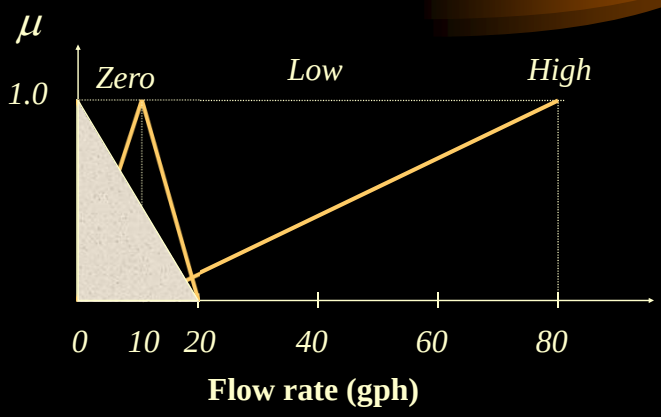
Flow rate



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Assumption

- $W_{pressure} = 0.5$
- $W_{temperature} = 0.25$
- $W_{flow} = 0.25$

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Background

- Decision making in multi parameters systems
- Example: degree of damage in system
- Take into account the **condition of component** and **importance of the component**

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Fuzzy Weighted Expression

$$Y = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}$$

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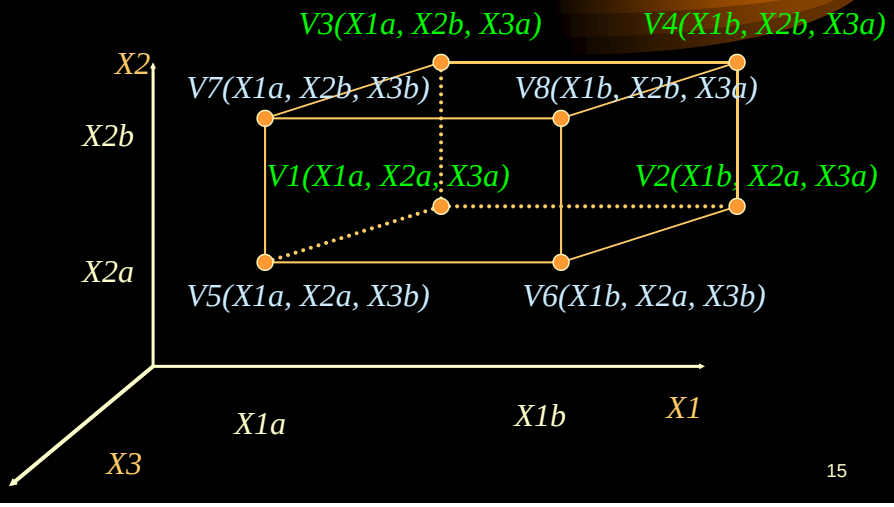
Illustration of Vertices

- Vertices with 3 attributes
- (Number of vertices =$2^n = 2^3 = 8$



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How do you attack the problem?

- Simplified procedure based on interval arithmetic and α - cut fuzzy sets
- Proposed by Dong and Shah (1987)
- Known as ***Vertex Method***

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Vertex Method

- Let all input values x_i's of a continuous function $y = f(x_1, x_2, ..., x_n)$ be interval estimates $x_i = [a_i, b_i], i= 1,n$
- Y be the function of interval variables X_i, such as $Y = f(X_1, X_2, ...X_n), x_1 \in X_1, x_2 \in X_2 .....x_n \in X_n$

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- With intervals given as extreme points of fuzzy sets as

$X_1 : [a_1, b_1]$
$X_2 : [a_2, b_2]$
.. :
.....
.. : .....
$X_i : [a_i, b_i]$
.. : .....
.. : .....
$X_n : [a_n, b_n]$

2n points which can be combined in 2^n distinct ways of n-ary array $(X_1, X_2, ...X_n)$, *where* X_i*'s can have extreme values* **ai's or bi's**

Let these distinct combination be denoted by $V_1, V_2, ...V_2^n$

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Distinct Combination

$V_1 : (a_1, a_2, \ldots\ldots\ldots\ldots, a_n)$
$V_2 : (b_1, a_2, \ldots\ldots\ldots\ldots, a_n)$
…:……..
…:……..
…:……..
…:……..
…:……..
$V_2^n : (b_1, b_2, \ldots\ldots\ldots\ldots, b_n)$

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Output Function Y

- $Y = f(X_1, X_2, \ldots X_n) = [Y_a, Y_b]$
- $[Y_a, Y_b] = [\min\{f(V_1), f(V_2), \ldots., f(V_2^n)\}, \max\{f(V_1), f(V_2), \ldots., f(V_2^n)\}$
- $[Y_a, Y_b] = [\ \Lambda\ \{ f(V_j) \}, \vee \{ f(V_j)],$

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Fuzzy Weighted Expression

$$Y = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}$$

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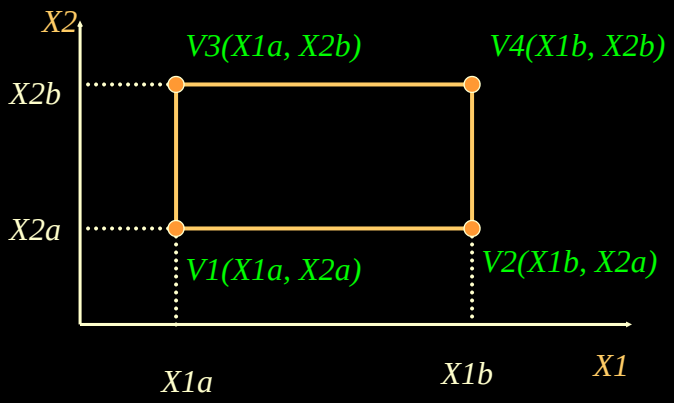
Illustration of Vertices

- Vertices with 2 attributes
- (Number of vertices $=2^n = 2^2 = 4$



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- ***Cartesian Product***

$$\begin{bmatrix} X1a \\ X1b \end{bmatrix} [X2a, X2b]$$

- ***Vertices***

$$\begin{bmatrix} V1 \\ V2 \\ V3 \\ V4 \end{bmatrix} = \begin{bmatrix} (X1a, X2a) \\ (X1b, X2a) \\ (X1a, X2b) \\ (X1b, X2b) \end{bmatrix}$$

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- ***Cartesian Product***

$$\begin{bmatrix} X1a & X2a \\ X1b & X2a \\ X1a & X2b \\ X1b & X2b \end{bmatrix} [X3a, X3b]$$

- ***Vertices***

$$\begin{bmatrix} V1 \\ V2 \\ V3 \\ V4 \\ V5 \\ V6 \\ V7 \\ V8 \end{bmatrix} = \begin{bmatrix} (X1a, X2a, X3a) \\ (X1b, X2a, X3a) \\ (X1a, X2b, X3a) \\ (X1b, X2b, X3a) \\ (X1a, X2a, X3b) \\ (X1b, X2a, X3b) \\ (X1a, X2b, X3b) \\ (X1b, X2b, X3b) \end{bmatrix}$$

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Illustration of Vertices

- Vertices with 4 attributes
- (Number of vertices $=2^n = 2^4 = 16$

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- ***Cartesian Product***

$$\begin{bmatrix} X1a\ X2a\ X3a \\ X1b\ X2a\ X3a \\ X1a\ X2b\ X3a \\ X1b\ X2b\ X3a \\ X1a\ X2a\ X3b \\ X1b\ X2a\ X3b \\ X1a\ X2b\ X3b \\ X1b\ X2b\ X3b \end{bmatrix} [X4a, X4b]$$

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-
- *Vertices*

V1		*(X1a, X2a, X3a, X4a)*
V2		*(X1b, X2a, X3a, X4a)*
V3		*(X1a, X2b, X3a, X4a)*
V4		*(X1b, X2b, X3a, X4a)*
V5		*(X1a, X2a, X3b, X4a)*
V6		*(X1b, X2a, X3b, X4a)*
V7		*(X1a, X2b, X3b, X4a)*
V8		*(X1b, X2b,X3b, X4a)*
V9		*(X1a, X2a, X3a, X4b)*
V10		*(X1b, X2a, X3a, X4b)*
V11	=	*(X1a, X2b, X3a, X4b)*
V12		*(X1b, X2b, X3a, X4b)*
V13		*(X1a, X2a, X3b, X4b)*
V14		*(X1b, X2a, X3b, X4b)*
V15		*(X1a, X2b, X3b, X4b)*
V16		*(X1b, X2b,X3b, X4b)*

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Vertices with n attributes

V1 = (X1a, X2a, X3a, ……., Xia, ……., Xna)

V2 = (X1b, X2a, X3a, ……., Xia, ……., Xna)

…….

…….

…….

$V2^n$ = (X1a, X2b, X3b, ……., Xib, ……., Xnb)

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Vertices for Weighted Average

- Let us consider the interval based weighted average function for four attributes (n=4)
- *X = [X1, X2, X3, X4], Xi = [Xia, Xib]*
- *W= [W1, W2, W3, W4], Wi= [Wia, Wib]*

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Vertices for X

$$[Vx] = \begin{bmatrix} Vx1 \\ Vx2 \\ Vx3 \\ Vx4 \\ Vx5 \\ Vx6 \\ Vx7 \\ Vx8 \\ Vx9 \\ Vx10 \\ Vx11 \\ Vx12 \\ Vx13 \\ Vx14 \\ Vx15 \\ Vx16 \end{bmatrix} = \begin{bmatrix} (X1a, X2a, X3a, X4a) \\ (X1b, X2a, X3a, X4a) \\ (X1a, X2b, X3a, X4a) \\ (X1b, X2b, X3a, X4a) \\ (X1a, X2a, X3b, X4a) \\ (X1b, X2a, X3b, X4a) \\ (X1a, X2b, X3b, X4a) \\ (X1b, X2b,X3b, X4a) \\ (X1a, X2a, X3a, X4b) \\ (X1b, X2a, X3a, X4b) \\ (X1a, X2b, X3a, X4b) \\ (X1b, X2b, X3a, X4b) \\ (X1a, X2a, X3b, X4b) \\ (X1b, X2a, X3b, X4b) \\ (X1a, X2b, X3b, X4b) \\ (X1b, X2b,X3b, X4b) \end{bmatrix}$$

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Vertices for W

$$[Vw] = \begin{bmatrix} Vw1 \\ Vw2 \\ Vw3 \\ Vw4 \\ Vw5 \\ Vw6 \\ Vw7 \\ Vw8 \\ Vw9 \\ Vw10 \\ Vw11 \\ Vw12 \\ Vw13 \\ Vw14 \\ Vw15 \\ Vw16 \end{bmatrix} = \begin{bmatrix} (W1a, W2a, W3a, W4a) \\ (W1b, W2a, W3a, W4a) \\ (W1a, W2b, W3a, W4a) \\ (W1b, W2b, W3a, W4a) \\ (W1a, W2a, W3b, W4a) \\ (W1b, W2a, W3b, W4a) \\ (W1a, W2b, W3b, W4a) \\ (W1b, W2b, W3b, W4a) \\ (W1a, W2a, W3a, W4b) \\ (W1b, W2a, W3a, W4b) \\ (W1a, W2b, W3a, W4b) \\ (W1b, W2b, W3a, W4b) \\ (W1a, W2a, W3b, W4b) \\ (W1b, W2a, W3b, W4b) \\ (W1a, W2b, W3b, W4b) \\ (W1b, W2b, W3b, W4b) \end{bmatrix}$$

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[X][W]

- The combined vertices of *[X][W]* will be $2^{2.4} = 256$, which can be obtained again by taking Cartesian products of *[Vx] and [Vw].*
- Some typical vertices are

V1 = (X1a, X2a, X3a, X4a, W1a, W2a, W3a, W4a)

V2 = (X1b, X2a, X3a, X4a, W1a, W2a, W3a, W4a)

… ……

… ……

V255= (X1a, X2b, X3b, X4b, W1b, W2b, W3b, W4b)

V256 = (X1b, X2b, X3b, X4b, W1b, W2b, W3b, W4b)

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[Y] = [X][W]

- The value of the interval function Y in general can be expressed as Y = f(X1, X2, …, Xn, W1, W2, …, Wn) and is given by
- $Y = [Y_a, Y_b] = [\Lambda \{ f(V_j) \}, V \{ f(V_j)], j = 1, 2^{2n}$
- $Y = [Y_a, Y_b] = \Sigma Wij.\ Xij / \Sigma Wij$
- Here i = 1, n and j = a or b
- Vj is the ordinate of the jth vertex

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Evaluation of Y

$Y(V_{j=1}) = f(V1) =$
$[(W1a.X1a) + (w2a.\ X2a) + (W3a.X3a) + (W4a.X4a)] / [W1a + W2a + W3a + W4a]$

$Y(V_{j=2}) = f(V2) =$
$[(W1a.X1b) + (w2a.\ X2a) + (W3a.X3a) + (W4a.X4a)] / [W1a + W2a + W3a + W4a]$

…… ……..
…… ..

$Y(V_{j=255}) = f(V255) =$
$[(W1b.X1a) + (w2b.\ X2b) + (W3b.X3b) + (W4b.X4b)] / [W1b + W2b + W3b + W4b]$

$Y(V_{j=256}) = f(V256) =$
$[(W1b.X1b) + (w2b.\ X2b) + (W3b.X3b) + (W4b,X4b)] / [W1b + W2b + W3b + W4b]$

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Evaluation of Y

- Having computed 256 functional values, the minimum and maximum remains to be picked up in order to obtain the interval.

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Take Home Problem

	[Xia, Xib]	*[Wia, Wib]*
Attribute 1	[0.4, 0.6]	[0.8,1.0]
Attribute 2	[0.7,0.96]	[0.5,0.9]
Attribute 3	[0.1,0.3]	[0.8,1.0]
Attribute 4	[0.0,0.2]	[0.5,0.9]

Find Y

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MATLAB
Fuzzy Logic Tool Box

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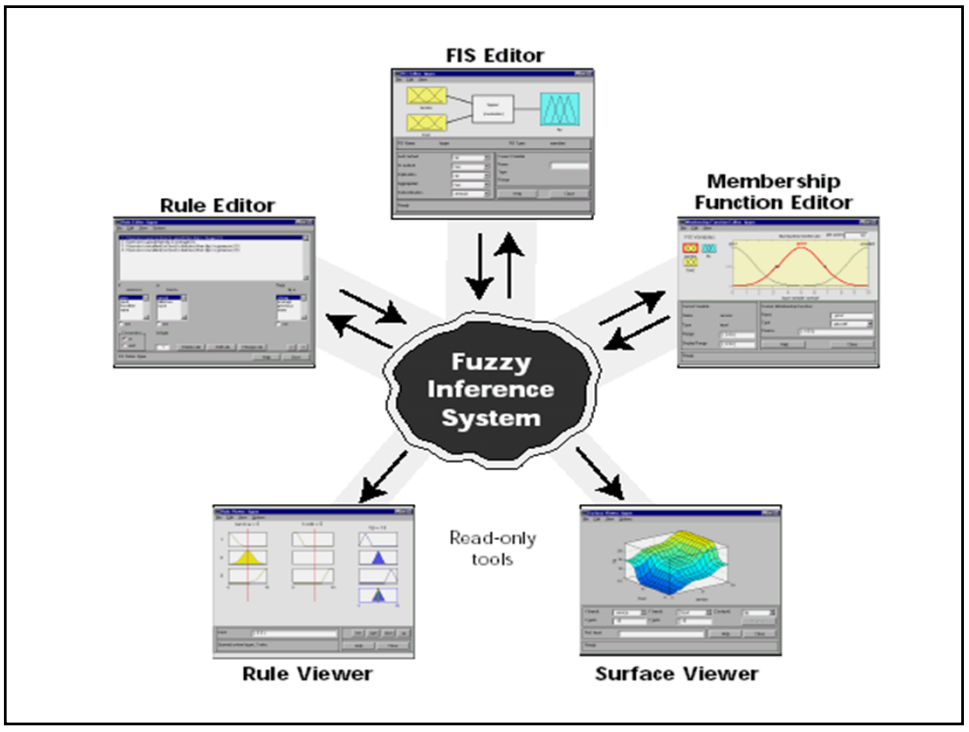

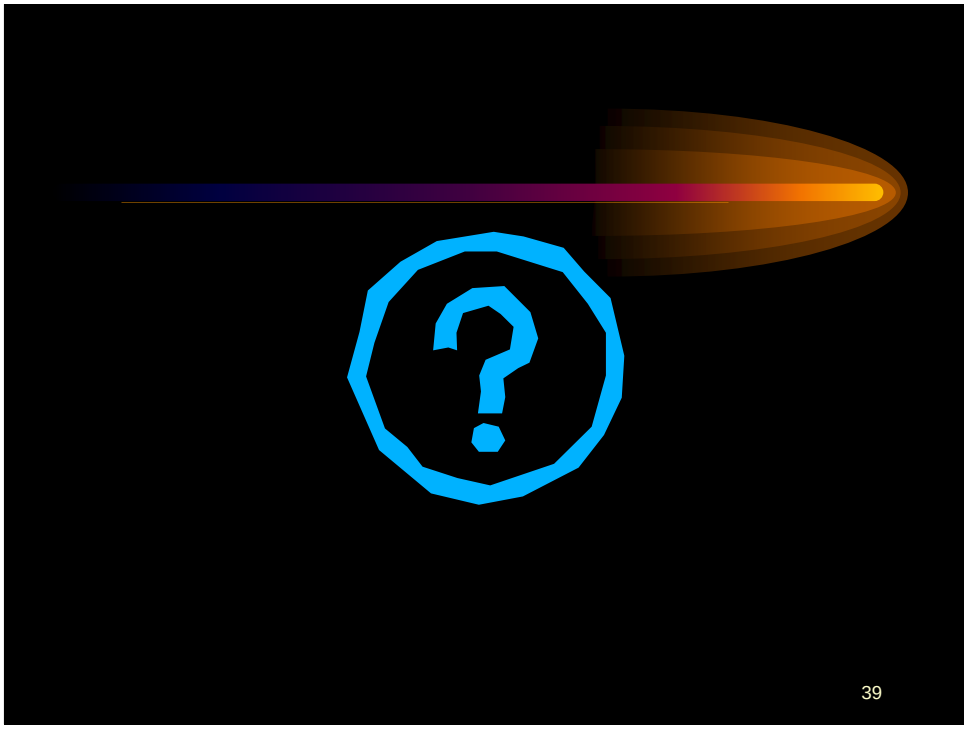

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Civil Engineering Application
Damage Assessment of Bridges

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Background

- 1,11,500 Bridges in Indian Railways
- Small culverts of @ 0.6 m to 100-120 m multiple span bridges
- Most of the steel bridges in India are railway bridges

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Present Visual Inspection Procedure followed by the Indian Railways

Table 1: Typical form from bridge inspection register (IRBIR, 1990)

	Date and year of inspection	
Components	Condition of the bridge at the time of inspection	Rating
1	Foundation and flooring (Extent of scour and damage and sitting if any.)	
2	Masonry - Condition and defects noticed (including arches)	
3	Foundation and flooring (Extent of scours, slips or settlement and waterway obstruction	
4	Bed blocks - condition and defects noticed	
5	Bearing and expansion arrangements condition and defects noticed	
6	(1) Steel work - structural condition and defects noticed (inclusive of painting) or (2) P.S.C./ R.C.C. girders / slabs - condition and defects noticed (Score out whichever does not apply)	
7	(1) Track, sleepers and fastenings - condition and renewals required (2) Track defects in line - level and creep (3) Track - condition at approaches	
	Action Taken	
	Initials of inspecting officials	

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Limitations in Current Bridge Inspection Procedure

- Damage quantification – Based on Visual Inspection
- Importance of deteriorated members – Imprecisely defined
- Evaluation of bridges – Personal Judgment
- Relationship between the extent of deterioration and the assignment of their rating not clearly defined
- Lack of special forms for different kinds of bridges in India

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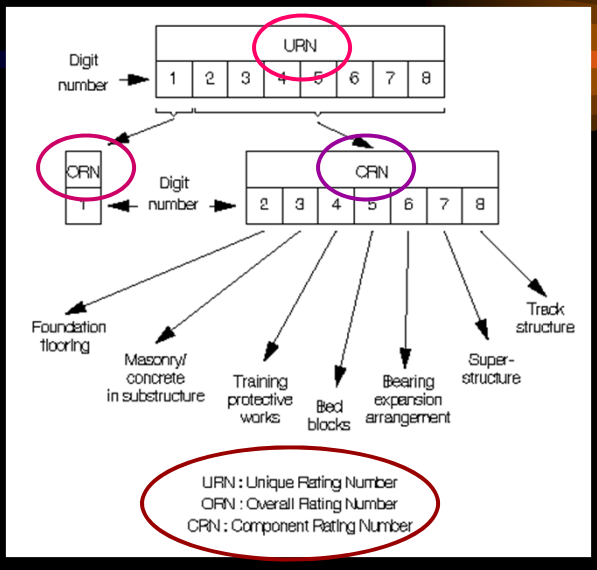
Improved Rating Procedure proposed by Indian Railways



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Improved Rating Procedure proposed by Indian Railways

Table 2: Description of Component Rating Number (CRN)

Condition Rating Number (CRN)	Explanation
1	Warrants rebuilding / rehabilitation (Distress bridge category I)
2	Requires rebuilding / rehabilitation (Distress bridge category II)
3	Requires major / special repairs
4	Requires routine maintenance
5	Sound condition
6	Not applicable (not existing in bridge)
0	Not inspected

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Improved Rating Procedure proposed by Indian Railways

Table 3 : Entries of rating number in bridge inspection form as per new Numerical Rating System (NRS)

		Rating
Components	Condition of the bridge at the time of inspection (ORN)	3
(1)	Foundation and flooring (Extent of scour and damage and sitting if any.)	4
(2)	Masonry- Condition and defects noticed (including arches)	3
(3)	Protective works - condition scours, slips or settlement and waterway obstruction	6
(4)	Bed blocks - condition and defects noticed	5
(5)	Bearing and expansion arrangements condition and defects noticed	5
(6)	(1) Steel work - structural condition and defects noticed (inclusive of painting) or (2) P.S.C./ R.C.C. girders / slabs - condition and defects noticed (Score out whichever does not apply)	4 -
(7)	(1) Track, sleepers and fastenings - condition and renewals required (2) Track defects in line - level and creep (3) Track - condition at approaches	5 - -

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Improved Rating Procedure proposed by Indian Railways

Table 4 : Implications of Unique Rating Number 34365544

Digit Number	Rating	Indication
1 (ORN)	3	The bridge or more of its components require major or special repair
2	4	Foundation and flooring require routine maintenance
3	3	Masonry and concrete in substructure require major repairs
4	6	Training and protective works are not existing
5	5	Bed blocks are in sound condition
6	5	Bearing and expansion arrangements are in good condition
7	4	Super structure requires routine maintenance
8	4	Track structure requires routine maintenance

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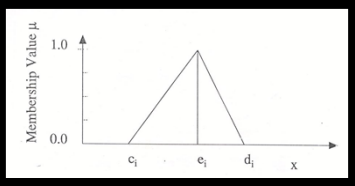
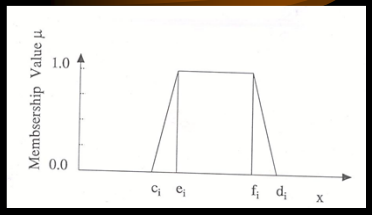
Various Fuzzy Models





$$\mu_{Ai}(x) = \begin{cases} (x-ci)/(ei-ci) & ei \geq x \geq ci \\ (x-di)/(ei-di) & di \geq x \geq ei \\ 0 & \text{otherwise} \end{cases}$$

$$\mu_{Ai}(x) = \begin{cases} (x-ci)/(ei-ci) & ei \geq x \geq ci \\ 1 & fi \geq x \geq ei \\ (x-di)/(fi-di) & di \geq x \geq fi \\ 0 & \text{otherwise} \end{cases}$$

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Condition and Importance Ratings

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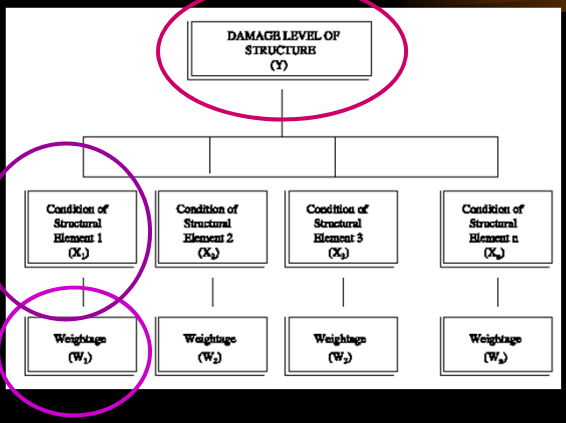
Global Damage Level Computation



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Fuzzy Weighted Expression

$$Y = \frac{\sum_{i=1}^{n} W_i X_i}{\sum_{i=1}^{n} W_i}$$

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Proposed Algorithm for Visual Inspection Data Evaluation

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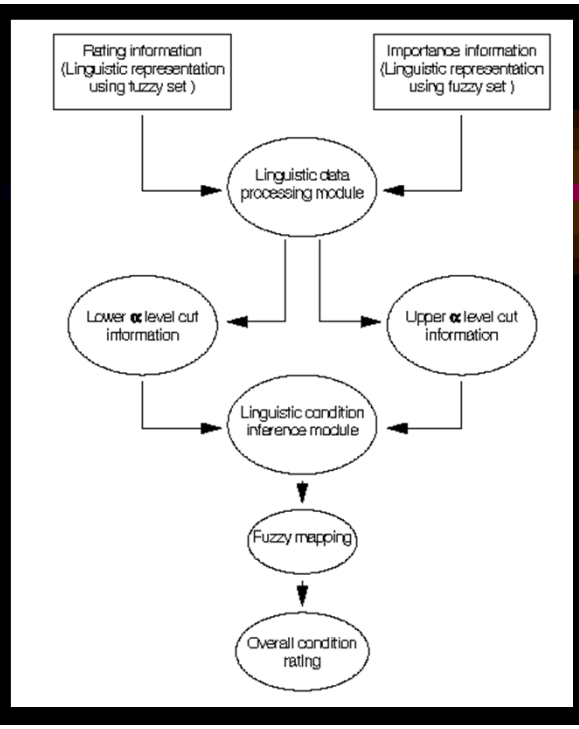

Overall condition rating

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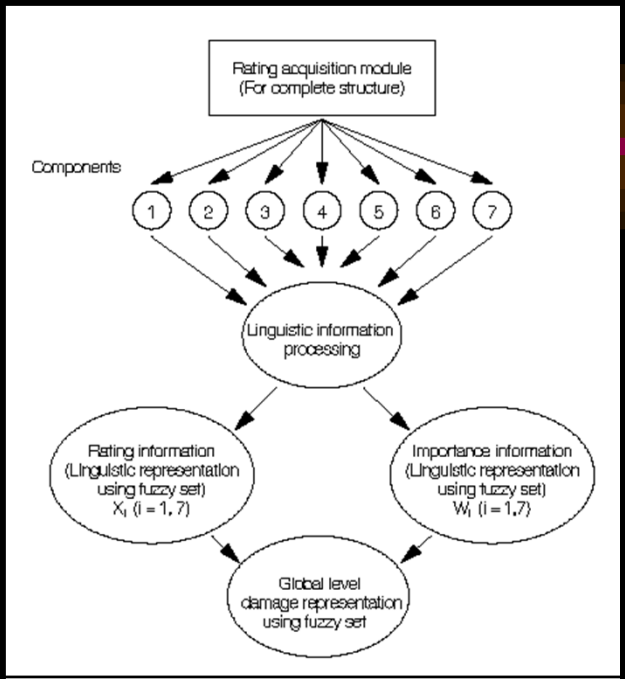

At Component Level

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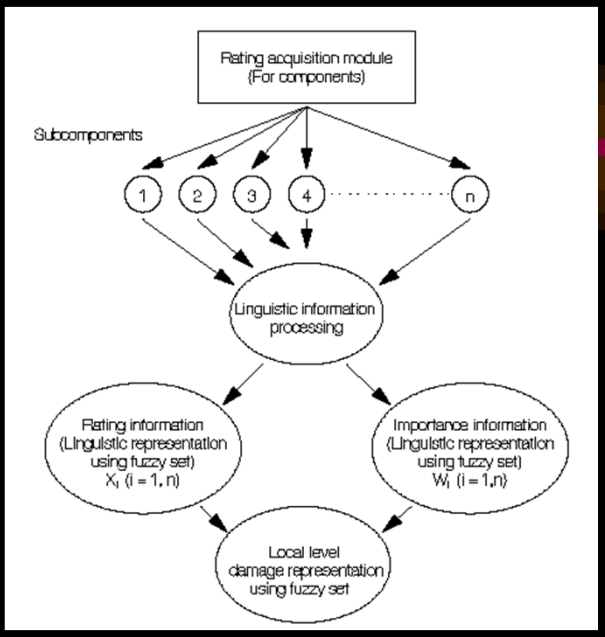

At sub-component Level

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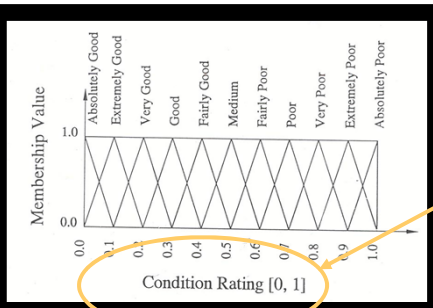
Table 5: Typical condition assessment of steel bridge components : Proposed visual inspection form and entries

	Component of Bridge	Importance (w) and condition rating(x)				Overall Structural Condition
(1)	Foundation and Flooring	w^{local}	x^{local}	w^{global}	x^{global}	
	1 Foundation	AIMP	VGD	IMP	VGD	
	2 Flooring	VIMP	VGD			
(2)	Substructure: Masonry/concrete	w^{local}	x^{local}	w^{global}	x^{global}	
	1. Piers	VIMP	GD	VIMP	FGD	
	2. Abutments	VIMP	FGD			
	3. Retaining Walls	VIMP	GD			
	4. Wing Walls	IMP	FGD			
	5. Ballast Walls	IMP	MED			
(3)	Training and Protective works	w^{local}	x^{local}	w^{global}	x^{global}	
	1 Pitching	IMP	GD	IMP	FGD	
	2 Toe walls	IMP	FGD			
	3 Apron	IMP	MED			
	4 Earth work section of guide bund/spur	IMP	GD			FGD
(4)	Bed Blocks			w^{global}	x^{global}	
				IMP	MED	
(5)	Bearing Girders	w^{local}	x^{local}	w^{global}	x^{global}	
	1 Sliding Bearing	IMP	GD	VIMP	FGD	
	2 Roller and Rocker Bearing	VIMP	MED			
	3 Elastomeric Bearing	IMP	MED			
	4 Bearing	IMP	GD			
(6)	Superstructure	w^{local}	x^{local}	w^{global}	x^{global}	
	1 Deck Type Plate Girder /			VIMP	MED	
	2 Half Through Type Plate Girder/	VIMP	MED			
	3 Open Web Girder					
(7)	Track Structures	w^{local}	x^{local}	w^{global}	x^{global}	
	1 Guard Rails	LIMP	FPR	VIMP	MED	
	2 Timber	MIMP	PR			
	3 Hook Bolts	MIMP	GD			
	4 Track Geometry	IMP	FGD			
	5 Ballast Cushion	IMP	PR			

Acronym used for various qualitative information (Refer Figure 4)

Importance Rating (w)		Condition Rating (x)	
(1) Always Important	AIMP	(1) Absolutely Good	AGD
(2) Very Important	VIMP	(2) Extremely Good	EGD
(3) Important	IMP	(3) Very Good	VGD
(4) Moderately Important	MIMP	(4) Good	GD
(5)Low Important	LIMP	(5) Fairly Good	FGD
(6)Very Low Important	VLIMP	(6) Medium	MED
(7)Not Important	NOTIMP	(7) Fairly Poor	FPR
		(8) Poor	PR
		(9) Very Poor	VPR
		(10) Extremely Poor	EPR
		(11) Absolutely Poor	APR



Overall Condition Rating

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Prototype Development of Internet Based Fuzzy Inference Driven Bridge Management System

Deepesh Yadav
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IIT Kharagpur

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Bridge Structure Discretization

- **Guidelines given by IRC SP-35 (1990) a bridge can be divided into 13 components**

- Approaches
- Protective Works
- Waterway
- Foundation
- Substructure
- Bearings
- Superstructure
- Expansion Joints
- Wearing Coat
- Drainage Spouts and Vent Holes
- Handrails and Parapets
- Footpaths
- Utilities.

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Identification of Linguistic Terms

	Fuzzy Variable	Fuzzy Terms
1	Condition Level	Extremely Good, Very good, Good, Medium, Poor, Very poor
2	Damage Level	Highly damaged, Significantly damaged, Moderately, Less, Slightly, Not damaged at all
3	Abnormalities Level	Very high, High, Reasonable, Little, Very little, None
4	Functioning level	Completely satisfactory, Quite satisfactory, Reasonably satisfactory, Barely satisfactory, Unsatisfactory, Highly unsatisfactory
5	Importance Level	Very Important, Important, Moderately Important, Less Important, Very less Important, Not Important

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System Development Process

- Implementation of the forms for various components and subcomponents of bridge structure.
- Implementation of the vertex method
- Integration of all the forms and the vertex method to get the unified system.

- A typical form has following features: (i) Graphical User Interface. (ii) The guidelines to inspect various components. (iii) An exhaustive list of options according to the kind of assessment. (iv) Means of acquiring and storing the Data.
- All these features are implemented using Java environment.

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Demonstration

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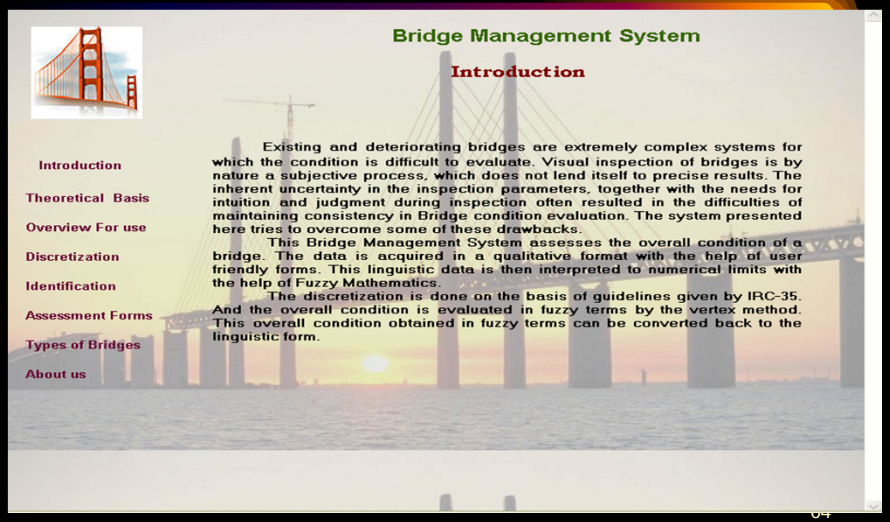
Welcome Screen



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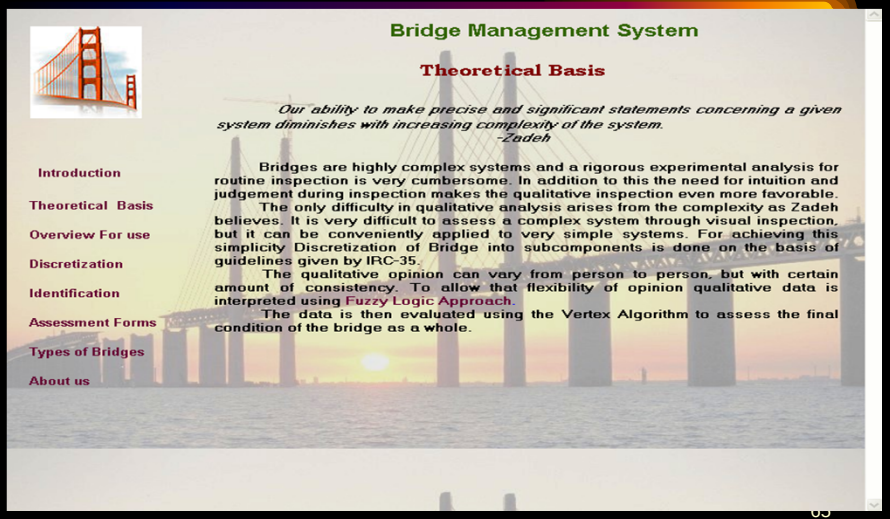
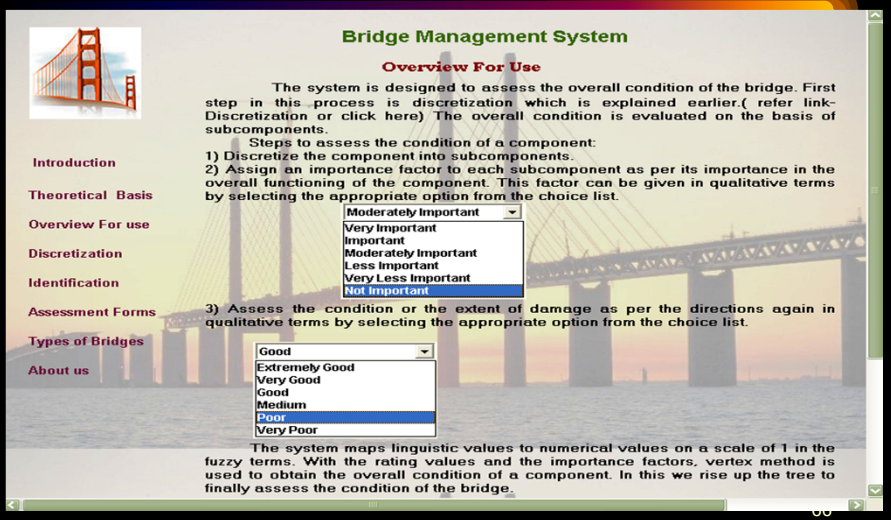
Theoretical Basis

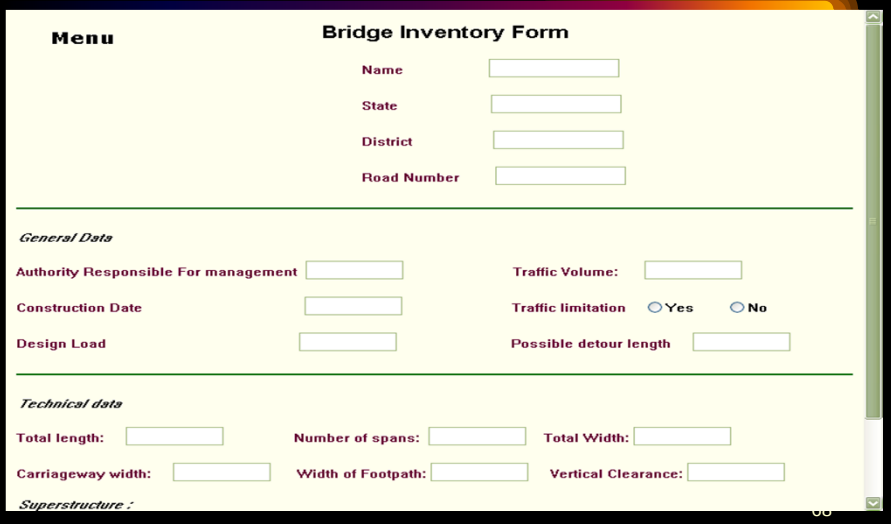


Overview for Use

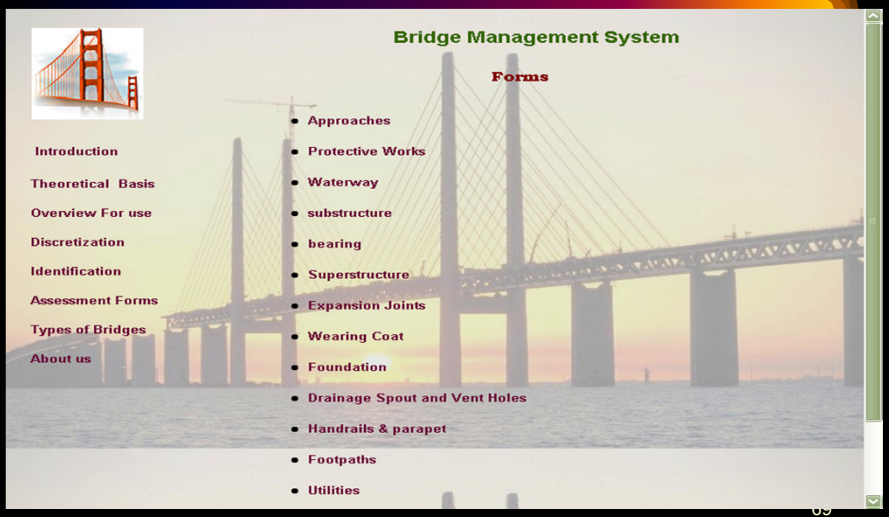


Discretization

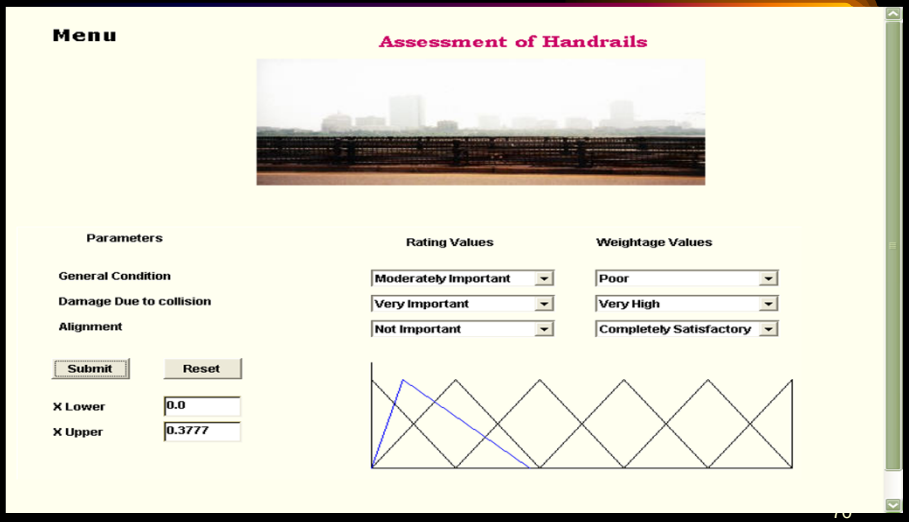
Identification Page



Forms page



Assessment of Handrails and Parapets



Assessment of Wearing Coat

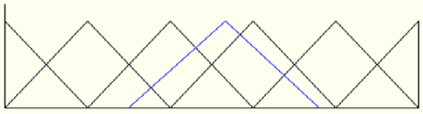
Menu
Introduction
Theoretical basis
Overview For Use
Discretization
Assessment Forms
Types of Bridges
About Us

Assessment of Wearing Coat

Parameters	Rating Values	Weightage Values
Surface Condition	Moderately Important	Good
Evidence of Wear	Moderately Important	Reasonable
Design Thickness wrt Kerb Height	Moderately Important	Reasonably Satisfactory

Submit Reset

X Lower 0.3
X Upper 0.76



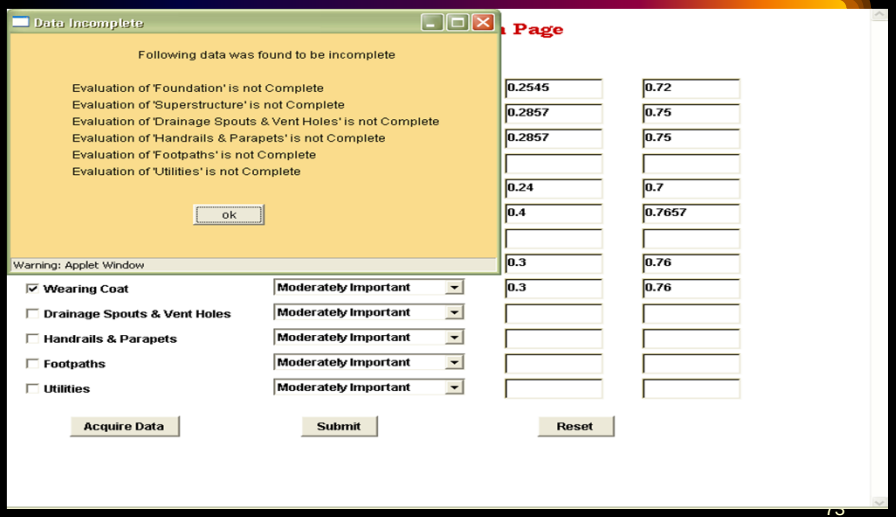
Final Evaluation Form

Final Evaluation Page

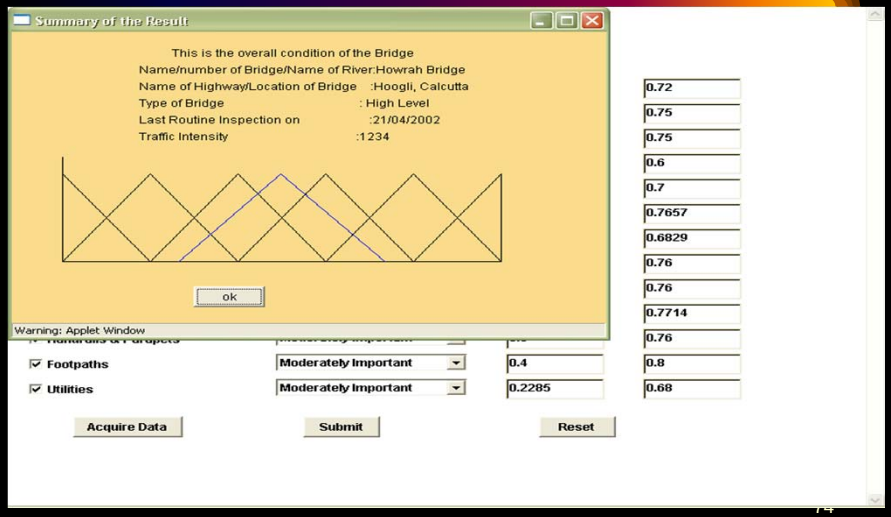
☑ Approaches	Moderately Important	0.2545	0.72
☑ Protective Works	Moderately Important	0.2857	0.75
☑ Waterway	Moderately Important	0.2857	0.75
☐ Foundation	Moderately Important		
☑ Substructure	Moderately Important	0.24	0.7
☑ Bearings	Moderately Important	0.4	0.7657
☐ Superstructure	Very Less Important		
☑ Expansion Joints	Not Important	0.3	0.76
☑ Wearing Coat	Moderately Important	0.3	0.76
☐ Drainage Spouts & Vent Holes	Moderately Important		
☐ Handrails & Parapets	Moderately Important		
☐ Footpaths	Moderately Important		
☐ Utilities	Moderately Important		

Acquire Data Submit Reset

Final Page with Error



Final Result



Salient Features

- Global Coverage
- Interactive
- Quick Result Generation
- User Friendly
- Error Trapping Mechanism

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Limitations

- Bias Opinion
- Discretization of Structure

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Summary

- The choice of the *Internet* Based Bridge Management System stems from the wide accessibility that the internet is capable of providing.
- The system has been developed using fuzzy weighted approach.
- With advancement of IT, there is a scope to develop the system on wireless communication based Personal Digital Assistants (PDAs), Laptops and other **mobile computers**

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Fuzzy Logic based Bridge Management System on Handheld Devices

B. Tech Project

under

Dr. Sudhirkumar Barai

by

Deepak Pushpakar

03CE3006

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Technology

- Implementing the proposed technique
  - As a computer application?
- On a Handheld Device
  - Locational constraints overcome
  - Much easier to carry a phone in the pocket than a computer
- Which Handheld Device?
  - Easy to use

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Technology

  - Easily available
  - Low in cost – Carrying features just sufficient for the application
  - Reliable
  - Good support for developers
- Series 60 Mobile Phones
  - C++ based Symbian Operating System
    - Optimized for low resource conditions
    - SDK supplied by Symbian Inc.
    - Application made in C++

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Technology

- Limitations
  - Low processing power of such devices
  - Limited memory available – Vertex Method is expensive
  - Limited User Interface
- Requirements
  - A friendly, easy, just sufficient User Interface
  - Efficient programming for working in constrained memory environment

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Technology

- Efforts
  - Graphical User interface made very easy to use and convenient, with most code reusable, and simple controls
  - Vertex method coded with a modification, now runs with constant memory, regardless of number of nodes in the vertex methods and number of layers in the discretization
  - Over Seven Thousand Lines of C++ code, into a 15 KB Application

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Demonstration

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Screenshots

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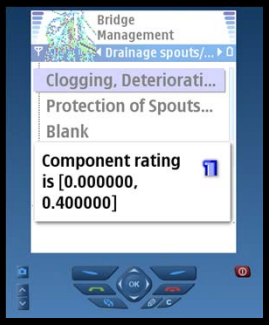
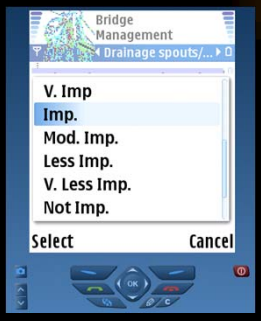
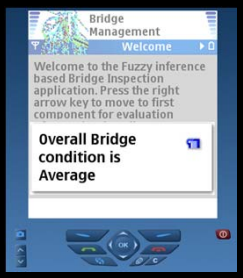
Screenshots







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Mobile Technology

- Widespread use in today's world for varied purposes
- Convenient and handy
- Essential
  - Personal and constant information retrieval
    - Recommender Systems
  - Location and time critical information systems
    - Tourism information system – location aware mobility support for users
    - Current system in consideration

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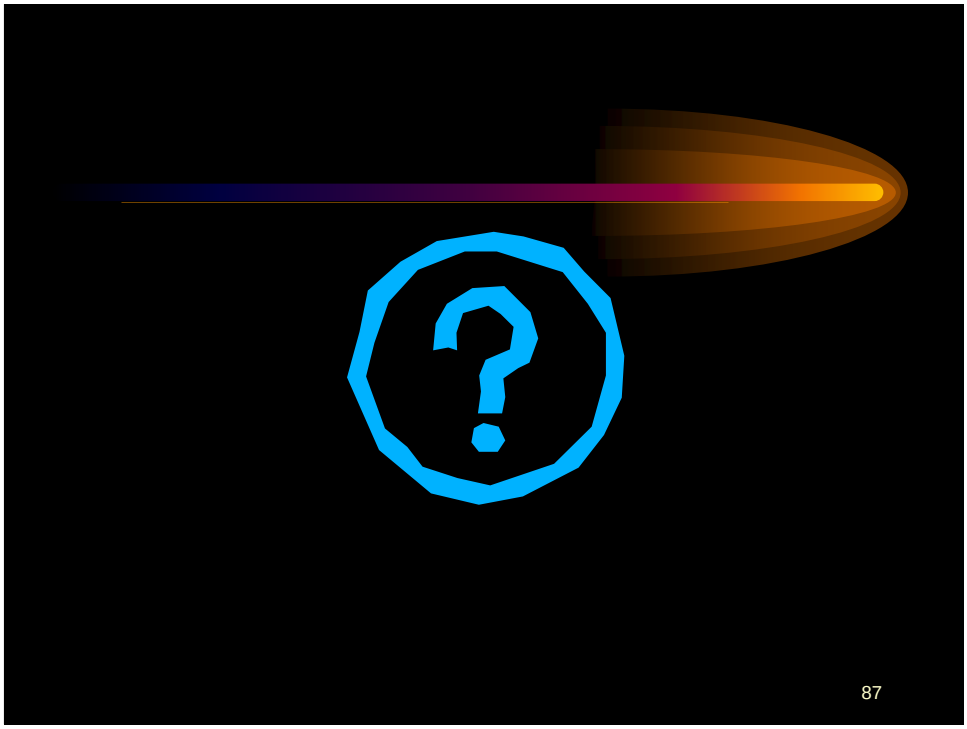
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