

**DESIGNING NEW SCHEMES FOR THE SOLUTION OF PORTFOLIO OPTIMIZATION
PROBLEM USING FUZZY SETS & CLOUD COMPUTING TECHNIQUES**

B.Tech. Final Year Report

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TABLE OF CONTENT

CHAPTER NO.	TITLE	PAGE NO.
1	<u>ABSTRACT</u>	
2	<u>INTRODUCTION</u>	1
2.1	Scope and Objective	2
2.2	Modules and its Description	3
3	<u>PURPOSE</u>	6
4	<u>PROBLEM STATEMENT</u>	7
		7
5	<u>SOLUTION</u>	<u>18</u>
6	<u>PROPOSED MODEL</u>	28
6.1	Project Implementation Technology	28
6.2	Feasibility Report	38
7	<u>IMPLEMENTATION</u>	42
		42
8	<u>CONCLUSION</u>	65
8.1	Project Snapshots	65
9	<u>REFERENCES</u>	70

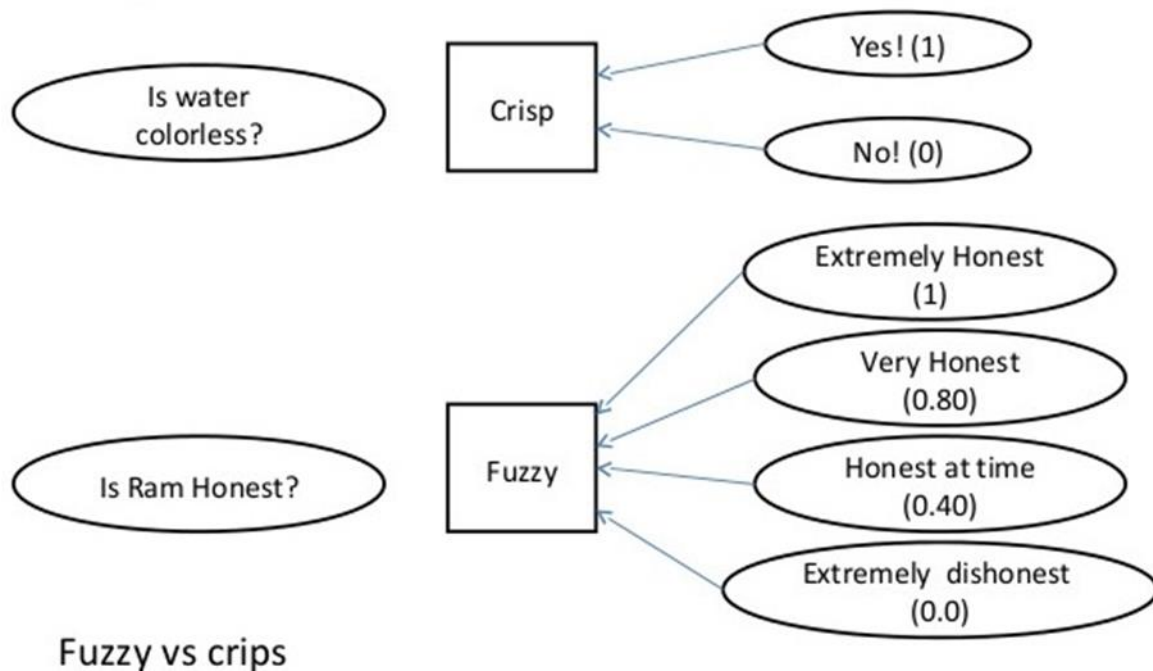
ABSTRACT

- A BIOBJECTIVE FUZZY PORTFOLIO SELECTION MODEL THAT MAXIMIZES THE PORTFOLIO RETURN AND MINIMIZES THE PORTFOLIO RISK
- WE USE AN FUZZY INTERACTIVE APPROACH TO SOLVE THE MODEL SO THAT THE DESIRED ASPIRITIION LEVEL OF THE DECISION MAKER WITH REGARD TO RETURN AND RISK OBJECTIVES ARE ACHIEVED AS CLOSELY AS POSSIBLE.
- MAX RETURNS
- MINIMIZE RISK
- DESIGN OF NEW SCHEMES FOR COMPUTING THE VALUES OF THE RISK AND EXPLORING THE IMPLICATION OF SUCH CHANGE

Introduction

- The word “fuzzy” means “vagueness (ambiguity)”.
- Fuzziness occurs when the boundary of a piece of information is not clear-cut.
- Fuzzy sets - 1965 Lotfi Zadeh as an extension of classical notation set.
- Classical set theory allows the membership of the elements in the set in **binary terms**.
- Fuzzy set theory permits membership function valued in the interval $[0,1]$.
- In real world, there exist much fuzzy knowledge (i.e. vague, uncertain inexact etc).
- Human **thinking** and **reasoning** (analysis, logic, interpretation) frequently involved **fuzzy** information.
- Human can give satisfactory answers, which are probably true.
- Our systems are unable to answer many question because the systems are designed based upon classical set theory (Unreliable and incomplete).
- We want, our system should be able to cope with unreliable and incomplete information.
- Fuzzy system have been provide solution.

Example



Fuzzy Sets

- Fuzzy sets theory is an extension of classical set theory.
- Elements have varying degree of membership. A logic based on two truth values,
- **True** and **False** is sometimes insufficient when describing human reasoning.
- Fuzzy Logic uses the whole interval between 0 (false) and 1 (true) to describe human reasoning.
- A Fuzzy Set is any set that allows its members to have different degree of membership, called **membership function**, having interval $[0,1]$.

- **Fuzzy Logic** is derived from fuzzy set theory
- Many degree of membership (between 0 to 1) are allowed.
- Thus a membership function $\mu_{\tilde{A}}^{(x)}$ is associated with a fuzzy sets \tilde{A} such that the function maps every element of universe of discourse X to the interval $[0,1]$.
- The mapping is written as: $\mu_{\tilde{A}}(x): X \rightarrow [0,1]$.
- Fuzzy Logic is capable of handing inherently imprecise (vague or inexact or rough or inaccurate) concepts
- **Fuzzy set** is defined as follows:
- If X is an universe of discourse and x is a particular element of X , then a fuzzy set A defined on X and can be written as a collection of ordered pairs

$$A = \{(x, \mu_{\tilde{A}}(x)), x \in X\}$$

PURPOSE

- In the increasingly dynamic economic environment, especially the ever changing stock markets, estimation of the covariance matrix seems to be unreliable and faces big challenges.

- Returns based roughly on historical data are somewhat unconvincing since they are ex-ante rather than ex-post.
- The more dynamic the financial situations, the stock returns tend to be more uncertain and vague. There is an imperative to consider returns as fuzzy random variables in portfolio optimization.

Example

- Let $X = \{g_1, g_2, g_3, g_4, g_5\}$ be the reference set of students.
- Let \tilde{A} be the fuzzy set of “smart” students, where “smart” is fuzzy term.

$$\tilde{A} = \{(g_1, 0.4)(g_2, 0.5)(g_3, 1)(g_4, 0.9)(g_5, 0.8)\}$$

Here \tilde{A} indicates that the smartness of g_1 is 0.4 and so on

Membership Function

- The membership function fully defines the fuzzy set
- A membership function provides a measure of *the degree of similarity* of an element to a fuzzy set

Membership functions can

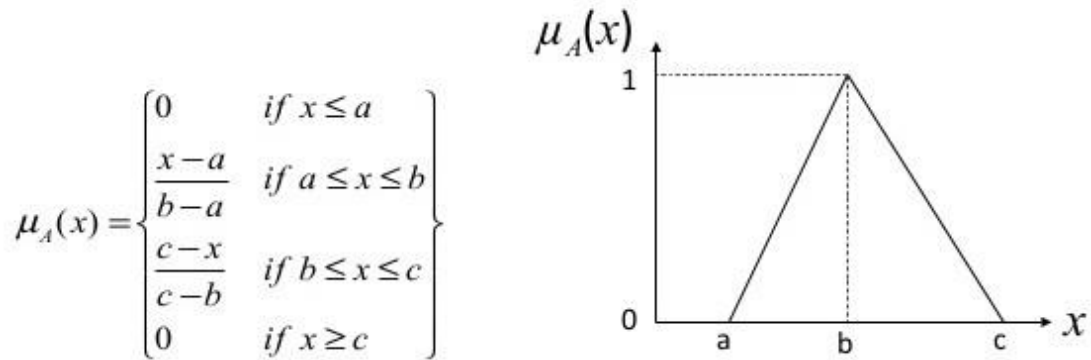
- either be chosen by the user arbitrarily, based on the user's experience (MF chosen by two users could be different depending upon their experiences, perspectives, etc.)
- Or be designed using machine learning methods (e.g., artificial neural networks, genetic algorithms, etc.)

There are different shapes of membership functions;

- **Triangular,**
- **Trapezoidal,**
- **Gaussian, etc**

- **Triangular membership function**

A *triangular* membership function is specified by three parameters {a, b, c} a, b and c represent the x coordinates of the three vertices of $\mu_A(x)$ in a fuzzy set A (a: lower boundary and c: upper boundary where membership degree is zero, b: the centre where membership degree is 1)



- **Trapezoid membership function**

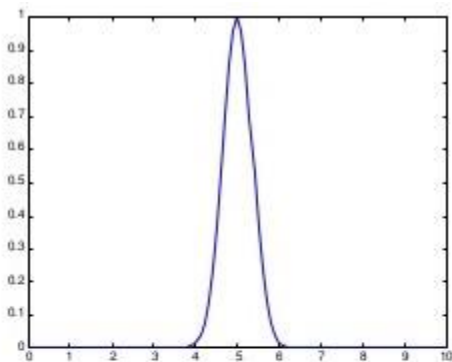
- A *trapezoidal* membership function is specified by four parameters {a, b, c, d} as follows:

$$\mu_A(x) = \begin{cases} 0 & \text{if } x \leq a \\ \frac{x-a}{b-a} & \text{if } a \leq x \leq b \\ 1 & \text{if } b \leq x \leq c \\ \frac{d-x}{d-c} & \text{if } c \leq x \leq d \\ 0 & \text{if } d \leq x \end{cases}$$

- **Trapezoid membership function**

- A *trapezoidal* membership function is specified by four parameters {a, b, c, d} as follows:

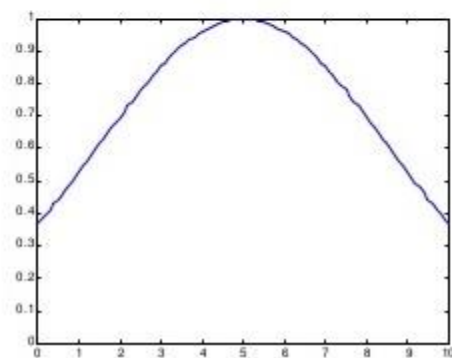
$$\mu_A(x) = \left\{ \begin{array}{ll} 0 & \text{if } x \leq a \\ \frac{x-a}{b-a} & \text{if } a \leq x \leq b \\ 1 & \text{if } b \leq x \leq c \\ \frac{d-x}{d-c} & \text{if } c \leq x \leq d \\ 0 & \text{if } d \leq x \end{array} \right.$$



$$c=5$$

$$s=0.5$$

$$m=2$$



$$c=5$$

$$s=5$$

$$m=2$$

Fuzzy Set Operation

Given X to be the universe of discourse and \tilde{A} and \tilde{B} to be fuzzy sets with $\mu_A(x)$ and $\mu_B(x)$ are their respective membership function, the fuzzy set operations are as follows:

Union:

$$\mu_{A \cup B}(x) = \max(\mu_A(x), \mu_B(x))$$

Intersection:

$$\mu_{A \cap B}(x) = \min(\mu_A(x), \mu_B(x))$$

Complement:

$$\mu_{\tilde{A}}(x) = 1 - \mu_A(x)$$

Example:

$$A = \{(x_1, 0.5), (x_2, 0.7), (x_3, 0)\} \quad B = \{(x_1, 0.8), (x_2, 0.2), (x_3, 1)\}$$

Union:

$$A \cup B = \{(x_1, 0.8), (x_2, 0.7), (x_3, 1)\}$$

Because

$$\begin{aligned} \mu_{A \cup B}(x_1) &= \max(\mu_A(x_1), \mu_B(x_1)) \\ &= \max(0.5, 0.8) \\ &= 0.8 \end{aligned}$$

$$\mu_{A \cup B}(x_2) = 0.7 \quad \text{and} \quad \mu_{A \cup B}(x_3) = 1$$

PROBLEM STATEMENT

We consider a bi-objective portfolio optimization model based on mean variance framework proposed by Markowitz. The model simultaneously maximize the portfolio return ($f_1(x)$) and minimize the portfolio risk ($f_2(x)$) and is formulated as follows:

$$\begin{aligned} \max \quad & f_1(x) = \sum_{i=1}^n r_i x_i \\ \min \quad & f_2(x) = \sum_{i=1}^n \sum_{j=1}^n \sigma_{ij} x_i x_j \\ \text{subject to} \quad & \\ & \sum_{i=1}^n x_i = 1, \\ & x_i \geq 0, \quad i = 1, 2, \dots, n, \end{aligned}$$

where $r_i = E[R_i]$, $\sigma_{ij} = E[(R_i - r_i)(R_j - r_j)]$, i.e., the covariance between assets i and j . The problem is a quadratic programming problem. Considering that in the real-world applications of portfolio selection, decisions are often structured around vague aspirations about the desired portfolio return and risk, we present a fuzzy framework for accommodating approximate linguistic-type information in the portfolio selection problem.

We formulate a fuzzy bi-objective portfolio selection problem based on vague aspiration levels of investors regarding

portfolio return and risk to determine a satisfying portfolio selection strategy. It is assumed that investors indicate aspiration levels on the basis of their prior experience and knowledge and linear membership functions are used to express such vague aspiration levels of the investors. A linear membership function is most commonly used because it is simple and it is defined by fixing two points: the upper and lower levels of acceptability

SOLUTION

Step 1: We formulate the model A1 using the input data from a sample set of data values of 10 assets as follows [11]:

$$\begin{aligned} \text{Objective 1 [11]:} \quad & \text{Max } f_1(x) = \\ & 0.19278x_1 + 0.13587x_2 + 0.40086x_3 + 0.29892x_4 + 0.14921x_5 \\ & + 0.30107x_6 + 0.23818x_7 + 0.23114x_8 + 0.26122x_9 + 0.56246x_{10} \end{aligned}$$

Equation 1.0

Objective 2: The objective is formulated using covariance matrix values for the 10 assets [11].

$\min f_2(x) =$

$$\begin{aligned} &0.14010x_1x_1 + 0.08682x_2x_2 + 0.42326x_3x_3 + 0.23027x_4x_4 \\ &+0.07587x_5x_5 + 0.18957x_6x_6 + 0.16280x_7x_7 + 0.11891x_8x_8 \\ &+0.18988x_9x_9 + 0.58191x_{10}x_{10} + 0.10078x_1x_2 + 0.18711x_1x_3 \\ &+0.19250x_1x_4 + 0.08633x_1x_5 + 0.12689x_1x_6 + 0.13209x_1x_7 \\ &+0.06919x_1x_8 + 0.21966x_1x_9 + 0.02598x_1x_{10} + 0.20718x_2x_3 \\ &+0.15458x_2x_4 + 0.05175x_2x_5 + 0.14749x_2x_6 + 0.08768x_2x_7 \\ &+0.03790x_2x_8 + 0.14741x_2x_9 + 0.10203x_2x_{10} + 0.35904x_3x_4 \\ &+0.09484x_3x_5 + 0.26475x_3x_6 + 0.05923x_3x_7 + 0.11967x_3x_8 \\ &+0.30827x_3x_9 + 0.08954x_3x_{10} + 0.05233x_4x_5 + 0.18741x_4x_6 \\ &+0.02499x_4x_7 + 0.00701x_4x_8 + 0.23510x_4x_9 + 0.09450x_4x_{10} \\ &+0.06021x_5x_6 + 0.11656x_5x_7 + 0.12379x_5x_8 + 0.11404x_5x_9 \\ &-0.03522x_5x_{10} + 0.09074x_6x_7 + 0.05367x_6x_8 + 0.20890x_6x_9 \\ &-0.01913x_6x_{10} + 0.18631x_7x_8 + 0.15498x_7x_9 + 0.14058x_7x_{10} \\ &+0.10665x_8x_9 -0.02910x_8x_{10} + 0.13128x_9x_{10} \end{aligned}$$

Equation 1.1

subject to:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 1$$

$$x_i \geq 0, i = 1, 2, \dots, 10.$$

Step 2: To determine the worst lower (upper) bound and best upper (lower) bound for return and risk objective functions,

respectively, the above problem is solved as a single-objective problem as follows:

$$\max f_1(x) = 0.19278x_1 + 0.13587x_2 + 0.40086x_3 + 0.29892x_4 + 0.14921x_5 + 0.30107x_6 + 0.23818x_7 + 0.23114x_8 + 0.26122x_9 + 0.56246x_{10}$$

subject to:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 1$$

$$x_i \geq 0 \quad i = 1, 2, \dots, 10.$$

Solution is obtained using MATLAB built-in functions.

Output obtained is value of objective-1 $f_1(\text{set1})$

Second objective $f_2(\text{set1})$ is calculated using the values of x_i obtained above.

For risk objective function

$$\begin{aligned} \min f_2(x) = & 0.14010x_1x_1 + 0.08682x_2x_2 + 0.42326x_3x_3 + \\ & 0.23027x_4x_4 + 0.07587x_5x_5 + 0.18957x_6x_6 + 0.16280x_7x_7 + \\ & 0.11891x_8x_8 + 0.18988x_9x_9 + 0.58191x_{10}x_{10} + 0.10078x_1x_2 + \\ & 0.18711x_1x_3 + 0.19250x_1x_4 + 0.08633x_1x_5 + 0.12689x_1x_6 + \\ & 0.13209x_1x_7 + 0.06919x_1x_8 + 0.21966x_1x_9 + 0.02598x_1x_{10} + \\ & 0.20718x_2x_3 + 0.15458x_2x_4 + 0.05175x_2x_5 + 0.14749x_2x_6 + \\ & 0.08768x_2x_7 + 0.03790x_2x_8 + 0.14741x_2x_9 + 0.10203x_2x_{10} + \end{aligned}$$

$$\begin{aligned}
&0.35904x_3x_4 + 0.09484x_3x_5 + 0.26475x_3x_6 + 0.05923x_3x_7 + \\
&0.11967x_3x_8 + 0.30827x_3x_9 + 0.08954x_3x_{10} + 0.05233x_4x_5 + \\
&0.18741x_4x_6 + 0.02499x_4x_7 + 0.00701x_4x_8 + 0.23510x_4x_9 + \\
&0.09450x_4x_{10} + 0.06021x_5x_6 + 0.11656x_5x_7 + 0.12379x_5x_8 + \\
&0.11404x_5x_9 - 0.03522x_5x_{10} + 0.09074x_6x_7 + 0.05367x_6x_8 + \\
&0.20890x_6x_9 - 0.01913x_6x_{10} + 0.18631x_7x_8 + 0.15498x_7x_9 + \\
&0.14058x_7x_{10} + 0.10665x_8x_9 - 0.02910x_8x_{10} + 0.13128x_9x_{10}
\end{aligned}$$

subject to:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = 1$$

$$x_i \geq 0, \quad i = 1, 2, \dots, 10.$$

The solution is obtained using MATLAB built-in functions.

The output obtained is the value of the second objective $F_2(\text{set2})$.

Using the values obtained for x_i the value of first objective is obtained = $F_1(\text{set2})$

The coding is done using MATLAB and a sample program is given below:

MATLAB CODE:

`X1=optimvar('X1')`

`X2=optimvar('X2')`

...

```
X10=optimvar('X10')
```

```
prob.objective = Formula using equation 1.0 or equation 1.1
```

```
prob.Constraints.cons1 =
```

$$x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10} == 1$$

```
prob.Constraints.cons2= x1 >= 0
```

```
.....
```

```
prob.Constraints.cons11= x10 >= 0
```

```
show(prob)
```

```
sol= solve(prob)
```

The output values obtained for x_i are used.

The solution obtained is:

S.No	Objective-1=F1	Objective-2=F2
1	F1(set1)	F2(set1)
2	F1(set2)	F2(set2)

Membership functions are formulated for return and risk, which are described below:

Membership function used for return:

$$\begin{aligned}
 u_1(F_1) &= 1 && \text{if } f_1(x) \geq F_1(\text{set1}) \\
 & && (f_1(x) - F_1(\text{set2})) / (F_1(\text{set1}) - F_1(\text{set2})) \\
 & && \text{if } F_1(\text{set2}) < f_1(x) < F_1(\text{set1}) \\
 &= 0 && \text{if } f_1(x) \leq F_1(\text{set2})
 \end{aligned}$$

Membership function used for risk is $u_2(F_2)$ which is defined similarly.

PROPOSED MODEL

The problem model B1 is formulated using membership functions u_1 and u_2 . An auxiliary variable λ is introduced in the model [11].

Problem formulation B1:

Maximize λ

Subject to

$$\lambda \leq u_1(f_1)$$

$$\lambda \leq u_2(f_2)$$

$$x_1 + x_2 + \dots + x_{10} = 1$$

$$x_i \geq 0 \quad i=1, 2, \dots, 10$$

$$0 \leq \lambda \leq 1$$

The solution is obtained using MATLAB built-in functions.

Now, if the risk level and return are not acceptable to a user, there is need to focus on designing new schemes for calculating risk levels by modifying the above models and provide new set of solutions to the user.

Each time a new risk level would be generated and model A1 and model B1 would be formulated using membership functions and a new set of solution would be generated. This process would be iterated till a satisfactory solution which meets the expectations of the investor is found.

Thus, the focus of this project is to build new schemes for computing risk parameters. Using this value, models A1 and B1 would be formulated and the solution found would be checked by the investor.

The project concentrates on the following dimensions:

- (i) Designing new algorithms to compute the values of risk used in the portfolio optimization.
- (ii) Designing new schemes to represent risk in the model
- (iii) Using cloud computing algorithms for processing data used in problem and their implementation in Python

IMPLEMENTATION

The screenshot shows a MATLAB Live Editor window titled "SolveLinearProgrammingProblemExample.mlx". The window is divided into three panes: "LIVE EDITOR", "INSERT", and "VIEW". The "LIVE EDITOR" pane contains the following code:

```
1 x1=optimvar('x1');
2 x2=optimvar('x2');
3 x3=optimvar('x3');
4 w1=optimvar('w1');
5 w2=optimvar('w2');
6 w3=optimvar('w3');
7 % x1, x2 and x3 are known from P3.2 solution
8 x1=0.54;
9 x2=0.3;
10 x3=0.16;
11 prob = optimproblem;
12 prob.Objective = w1*x1 + w2*x2 + w3*x3;
13 prob.Constraints.cons1 = w1 >= 0.13;
14 prob.Constraints.cons2 = w2 >= 0.12;
15 prob.Constraints.cons3 = w3 >= 0.11;
16 prob.Constraints.cons4 = w1 + w2 + w3 == 1;
17 prob.Constraints.cons5 = w1 + w2 <= 0.8;
18 prob.Constraints.cons6 = w3 <= 0.7;
19
20 show(prob)
```

The "VIEW" pane shows the output of the code, which is "OptimizationProblem :". The window also features a toolbar with various editing and execution tools, and a sidebar with navigation options.

in.mathworks.com/help/optim/ug/optim.problemdef.optimizationproblem.solve.html?tid=srchtitle

Help Center

CONTENTS

- Documentation Home
- Optimization Toolbox
- Problem-Based Optimization
- Optimization Toolbox
- Nonlinear Optimization
- Problem-Based Nonlinear Optimization
- Optimization Toolbox
- Linear Programming
- Linear Programming

more...

solve

ON THIS PAGE

- Syntax
- Description
- Examples
- Input Arguments
- Output Arguments
- Algorithms

LIVE EDITOR

INSERT VIEW

Go To Find

Normal Text

B I U M

Code Task Control Refactor

Run Section Run and Advance Run to End

Run Step Stop

SolveLinearProgrammingProblemExample.mlx

```
OptimizationProblem :  
  
Solve for:  
w1, w2, w3  
  
minimize :  
0.54*w1 + 0.3*w2 + 0.16*w3  
  
subject to cons1:  
w1 >= 0.13  
  
subject to cons2:  
w2 >= 0.12  
  
subject to cons3:  
w3 >= 0.11  
  
subject to cons4:  
w1 + w2 + w3 == 1  
  
subject to cons5:  
w1 + w2 <= 0.8  
  
subject to cons6:  
w3 <= 0.7
```

21 sol = solve(prob)

in.mathworks.com/help/optim/ug/optim.problemdef.optimizationproblem.solve.html?tid=srchtitle

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- Problem-Based Optimization
- Optimization Toolbox
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- Optimization Toolbox
- Linear Programming
- Linear Programming

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LIVE EDITOR

INSERT VIEW

Go To Find

Normal Text

B I U M

Code Task Control Refactor

Run Section Run and Advance Run to End

Run Step Stop

SolveLinearProgrammingProblemExample.mlx

```
w3 >= 0.11  
  
subject to cons4:  
w1 + w2 + w3 == 1  
  
subject to cons5:  
w1 + w2 <= 0.8  
  
subject to cons6:  
w3 <= 0.7
```

21 sol = solve(prob)

Solving problem using linprog.

Optimal solution found.

sol = struct with fields:
w1: 0.1300
w2: 0.1700
w3: 0.7000

22 objective3 = 0.13 * x1 + 0.17 * x2 + 0.7 * x3;
23 disp(objective3)

0.2332

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CONCLUSION

An investor can validate a solution based on values of

Objective 1 Max Expected return

Objective 2 Min Risk

And Objective 3 Uncertainty level in modeling the membership function and selecting range .

If the user is satisfied with these values solution is finally accepted based of objective 1,objective 2,auxillary variable (λ) and objective 3

Otherwise,we need to frame P 3.1,P 3.2 and objective 3 again and take investor choice of accepting or not accepting a viable solution.

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