Workshop5. Financial planning system

System Design

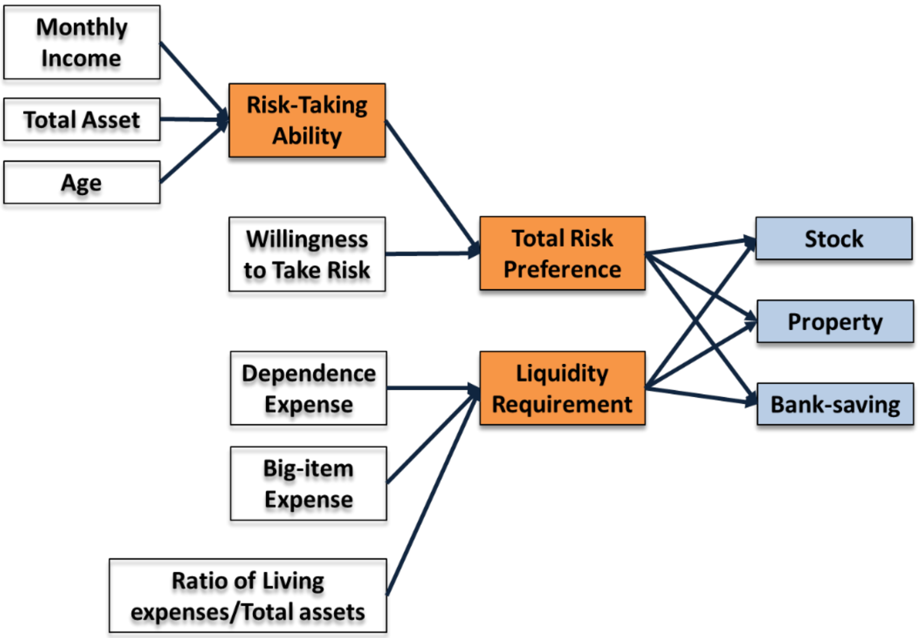

Figure 1: System Diagram

The system is to generate the optimal asset combination based on user's input. "Risk-taking Ability", "Total Risk Preference" and "Liquidity Requirement" are sub-goals which help to infer final outputs.

Input partition and Description

Inputs	low	medium	high
Monthly income	< $3,000	$2,000~$8,000	> $7,000
Total assets	< $500,000	$300,000~$1,000,000	> $800,000
Age	20~40	30~60	> 50
Willingness to take risk	< 0.4	0.3~0.7	> 0.6
Dependence expense	< 3 yrs from now	2~6 yrs from now	> 5 yrs from now
Big-item expenses	< 3 yrs from now	2~6 yrs from now	> 5 yrs from now
Ratio of Living expenses/Total assets	< 5%	3%~12%	> 10%

Table 1. Input Fuzzy Partition

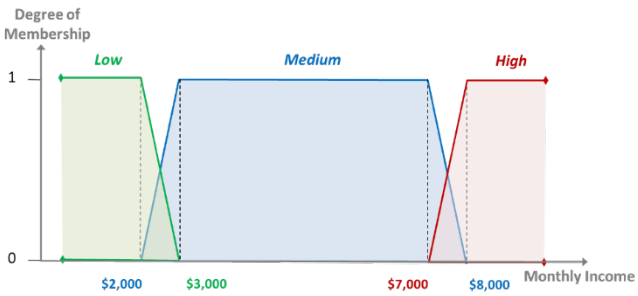

Figure 2. Membership Function of "Monthly Income"

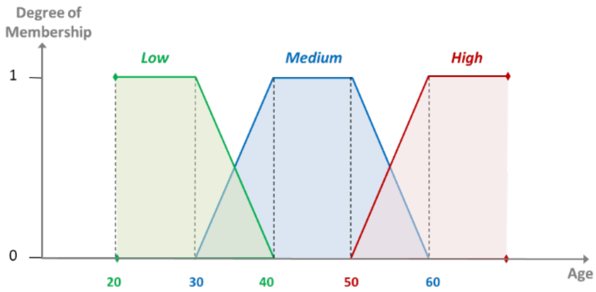

Figure 3. Membership Function of “Age”

The partition of input variables is demonstrated in table 1. Throughout the whole system, we use trapezoidal membership function for all fuzzy variables like in figure 2 and 3. At the same time, we use “Low”, “Medium” and “High” linguistic terms for the fuzzy subsets of different variables. It is noted, however, that they may have different meanings for different variables.

1) Monthly Income: It reflects the level of user’s monthly income.

2) Total Asset: Value of all assets including: real estate, security, cash or other forms of investment.

3) Age: It reflects time horizon.

4) Willingness to Take Risk: The user’s willingness to take risk is subjective. The higher the value is, the more risk user would like to take.

5) Dependence Expense: User will estimate when his/her dependents will need a large amount of money. For example, user’s son is already 15 year’s old and college tuition fee will be needed in 3 years. Another example is that user’s father was recently diagnosed with cancer and a large amount of money will be needed immediately.

6) Big-item expense: User will estimate when he/she will need a large amount of money. For example, user is planning to go to USA to read MBA in 5 years.

7) Ratio of Living expenses/Total assets: It reflects user’s level of living expense relative to his total assets.

Sub-goal Logic and Rules

Subgoals	Low	Medium	High
Risk-taking ability	< 0.4	0.3~0.7	0.6~1.0
Total risk preference	< 0.4	0.3~0.7	0.6~1.0
Liquidity requirement	< 0.4	0.3~0.7	0.6~1.0

Table 2. Subgoal Fuzzy Partition

Risk-taking ability↑	Monthly income↑	Total assets↑	Age↓
Total risk preference	min(Risk-taking ability,Willingness to take risk)		
Liquidity requirement↑	Dependents' expenses↓	Big-item expenses↓	Living expenses/Total asset↑

Table 3. Key Factors Determining Subgoals

We have 3 sub-goals in our system:

- Risk-taking ability
- Total risk preference
- Liquidity requirement

"Risk-taking ability" is the ability of user to sustain losses without putting user's living in jeopardy. It is significantly affected by the investor's time horizon ("Age") and assets he/she owns (including "Total assets" and "Monthly income"). Generally, if assets are relatively large, user has an increased ability to take risk. Likewise, if time horizon is considered long (young age), user also has an increased ability to take risk. Therefore, "Risk-taking ability" tends to increase as "Monthly income" and "Total assets" increase and "Age" decreases.

We assume the same weight on "Monthly income" and "Total assets", which means without considering "Age", user having high "Monthly income" and medium "Total assets" has the same "Risk-taking ability" with user having medium "Monthly income" and high "Total assets". Based on the logic above, we designed our rules below:

Risk-taking Ability

(Monthly Income)			
High	Medium	High	High
Medium	Low	Medium	High
Low	Low	Low	Medium
Age = Low	Low	Medium	High (Total Asset)

Risk-taking Ability

(Monthly Income)			
High	Low	Medium	High
Medium	Low	Low	Medium
Low	Low	Low	Low
Age = Medium	Low	Medium	High (Total Asset)

Risk-taking Ability

(Monthly Income)			
High	Low	Low	Medium
Medium	Low	Low	Low
Low	Low	Low	Low
Age = High	Low	Medium	High (Total Asset)

Figure 4. Rule tables for "Risk-taking Ability"

"Total Risk Preference" combines "Risk-taking ability" calculated from above and "Willingness to take risk". "Willingness to take risk" is subjective and inputted by user. Higher value means user is more likely to take risk and it is usually not conform to user's ability to take risk. We designed rules that "Total Risk Preference" goes with the more conservative of the two in Figure 5.

Total Risk Preference

(Risk-taking ability) \ (Willingness to take risk)	Low	Medium	High
High	Low	Medium	High
Medium	Low	Medium	Medium
Low	Low	Low	Low

Figure 5. Rule table for "Total Risk Preference"

"Liquidity Requirement" includes "Living expense/Total Assets" which reflects ongoing needs for distributions and "Big-item expense" and "Dependence Expense" which is one-time or infrequent negative liquidity events requiring irregular distributions. Nearer "Big-item expense" and "Dependence Expense" which we treat equally and Bigger "living expense/Total Assets" lead to higher "Liquidity Requirement". We designed rules below based on logic above.

Liquidity Requirement — Living expenses/Total assets = Low

(Big-itme Expense) \ (Dependence Expense)	Low	Medium	High
High	Mediun	Low	Low
Medium	Mediun	Medium	Low
Low	High	Medium	Medium

Liquidity Requirement — Living expenses/Total assets = Medium

(Big-itme Expense) \ (Dependence Expense)	Low	Medium	High
High	Mediun	Medium	Low
Medium	High	Medium	Medium
Low	High	High	Medium

Liquidity Requirement — Living expenses/Total assets = High

(Big-itme Expense) \ (Dependence Expense)	Low	Medium	High
High	High	Medium	Medium
Medium	High	High	Medium
Low	High	High	High

Figure 6. Rule table for "Liquidity Requirement"

Output Logic and Rules

The output of our system will be the investment percentage in each financial instrument. The attributes of each instrument are listed in Table 4 based on our research on Internet. Instrument which has higher risk will have higher return and "Properties" has the lowest liquidity.

Each instrument proportion will be decided by "Liquidity requirement" and "Total risk preference". Basically, higher "Liquidity requirement" will cause less proportion on "Properties" and less "Total risk preference" will lead to less proportion on "Stocks". Rules in figure 7 for output are based on above logic.

So how to determine instrument proportions? Each output has one value for each instrument (range is in table 5). Let's say, for example, "Stocks" = 2.3, "Properties" = 5.6, "Bank-savings" = 1.6. Then the proportion for "Stocks" is $\frac{2.3}{2.3+5.6+1.6} = 24.2\%$, the proportion for "Properties" is $\frac{5.6}{2.3+5.6+1.6} = 58.9\%$ and the proportion for "Bank-savings" is $\frac{1.6}{2.3+5.6+1.6} = 16.9\%$.

	Risk	Return	Liquidity
Stocks	High	High	Medium
Properties	Medium	Medium	Low
Bank-savings	Low	Low	High

Table 4. Attributes of each financial instrument

Outputs	Low	Medium	High
Stocks	< 4	3~7	6~10
Properties	< 4	3~7	6~10
Bank-savings	< 4	3~7	6~10

Table 5. Output Fuzzy Partition

(Liquidity Requirement)	Stock/Property/Bank savings		
High	L/L/H	M/L/H	M/L/H
Medium	L/L/H	M/M/M	H/M/M
Low	L/M/H	M/H/M	H/M/L
	Low	Medium	High (Total risk preference)

Figure 7. Rule table for Output

Fuzzy System Design

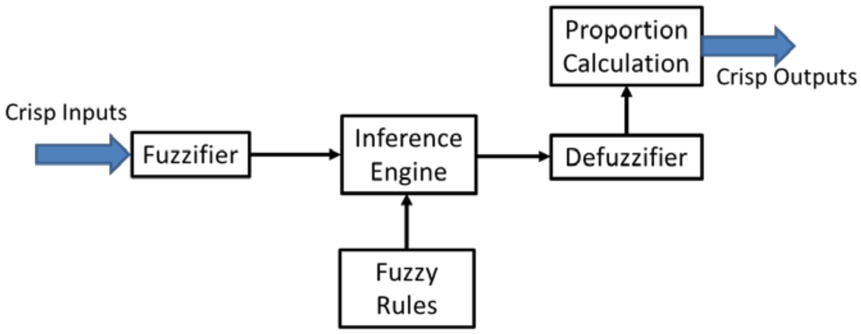

Figure 8. Fuzzy System

The Fuzzy System was designed in Python using Scikit-Fuzzy package which is a collection of fuzzy logic algorithms. In this system, the “Fuzzifier” and “Fuzzy Rules” are as introduced before and the “Defuzzifier” uses the Center of Area (COA) approach.

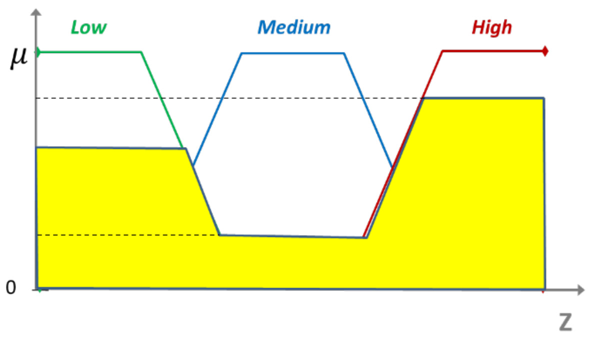

Figure 9. COA Defuzzifier

Test Case I

	customer profile
Case 1	Young single professional who lives a simple life
Case 2	Young single professional who lives a high quality life
Case 3	Young single professional who lives a simple life wants to take big risk

Table 6. First 3 Cases

	Monthly income	Total assets	Age	Willingness to take risk	Dependence expense	Ratio of Living expenses/Total assets	Big-item expenses
Case 1	10000	1000000	25	0.5	5	3	1
Case 2	10000	1000000	25	0.5	5	20	1
Case 3	10000	1000000	25	0.9	5	3	1

Table 7. Inputs of First 3 Cases

The first 3 cases are designed to have very high similarity in order to illustrate our system’s performance.

1. The first case is a 25 year old professional who has high monthly income ($10,000) and high total assets ($1,000,000). He lives a simple life because his living expense only take 3% of his total assets. He expects there will be big-item expense in 1 year and dependents’ expense in 5 years. Overall, he has high risk-taking ability and average liquidity

requirement. However, his willingness to take risk is only 0.5, which limits his investment in high-risk financial instruments. The recommendation of our system is that his investment should be equally distributed among “Stocks”, “Property” and “Savings”.

2. The second case keeps all inputs the same with the first one except he is now having a luxury life (20% ratio of living expenses/total assets). Compared to the first case, liquidity requirement is increased, and the result exactly reflects the change as some assets should be transferred from “Property” to “Savings”.

3. The third case increases “willingness to take risk” up to 0.9 from case 1. The output exposes him to more risk by shifting some assets from “Property” and “Savings” to “Stocks”.

Outputs of our system make sense by comparing the 3 very similar cases. To further test the rationality of our system, more generic cases will be presented next.

	Stocks	Property	Savings
Case 1	33.33%	33.33%	33.33%
Case 2	33.33%	11.75%	54.92%
Case 3	45.17%	27.42%	27.42%

Table 8. Output of First 3 Cases