**Investment Portfolio Optimization with Robo-Advisor**

**MIE1622 Computational Finance and Risk Management**

**Group Course Project**

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# Introduction

With the advancement of Artificial Intelligence, an increasing number of industries have looked into this field in order to boost intelligence and efficiency in business processes. Robo-advisors are commonly employed in the first line of financial services to interact and communicate with clients, solve problems, and make automated, algorithm-driven investment advice under the supervision of humans.

In this project, our team developed a Robo-advisor chatbot using the IBM Cloud platform Watson Assistant to operate as an investment counselor with potential clients. During the conversation, we aim to let our clients express their preferences and willingness, and the Robo-advisor Chatbot will make an investment suggestion, such as a recommended portfolio strategy.

Stocks in the healthcare, agricultural, finance, and technology areas were chosen because professional investors pay close attention to these industries. A total of six investment strategies are chosen to perform at the backstage of the chatbot: "buy and hold" strategy, "equally weighted" portfolio strategy, "minimum variance" portfolio strategy, "maximum Sharpe ratio" portfolio strategy, "equal risk contribution" portfolio strategy, and "robust mean-variance optimization" portfolio strategy. Once the client has identified their preferred industry and risk tolerance level, each strategy will be tested to find the one that best meets the client's needs and provides the maximum return using our Python predefined functions. Donut plots will also be used to visualize the optimal weight of each stock in the portfolio.

This report presents an overview of the project, beginning with data preparation and progressing through the definition and design of the investment strategy, Robo-advisor with Watson assistant, and portfolio optimization functions. In the concluding part, we'll discuss how to link our Chatbot to Python code and how to use it in real-world scenarios.

**Data Preparation**

Yahoo Finance is the source for data collection and the python file “Yahoo\_Data.py” is designed for data extraction and cleaning. For this project, data ranges from March 31, 2017 to March 31, 2022 and only daily ‘Close’ prices are used to calculate the return as well as its expectation and covariance. Note that we set 2.5% as the averaged risk-free rate over the past 5 years.

As mentioned above, stocks related to Technology, Finance, Healthcare and Agriculture areas are chosen based on our research. There are 60 stocks in total being selected across these four industries for portfolio optimization. The table below shows stock tickers under each industry.

图片包含 游戏机, 窗户, 建筑

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# Investment Strategies Design

There are 6 computational investment strategies implemented in this project - “buy and hold” strategy, “equally weighted” portfolio strategy, “minimum variance” portfolio strategy, “maximum Sharpe ratio” portfolio strategy, “equal risk contribution” portfolio strategy, and “robust mean-variance optimization” portfolio strategy as explained below. The initial positions of each stock as in the initial units of each stock are assigned as 1s.

1. “Buy and hold” strategy:

In the “buy and hold” strategy, the initial positions, as in the initial units of each stock are held throughout the 5 years.

1. “Equally weighted” portfolio strategy:

In the “equally weighted” portfolio strategy, each stock is equally assigned to a weight of , n as in the number of stocks used in this portfolio. Then the units of each stock is calculated with the weight of each stock times the total portfolio value divided by the price of each stock.



1. “Minimum variance” portfolio strategy:

In the “minimum variance” portfolio strategy, the portfolio with the minimum variance on the efficient frontier is selected from solving with the CPLEX solver. The weights of each stock of this selected portfolio is then used to calculate the units of each stock, the same as the “equally weighted” portfolio strategy.



1. “Maximum Sharpe ratio” portfolio strategy:

In the “maximum Sharpe ratio” portfolio strategy, the portfolio that maximize the excess return for the additional volatility of holding a risky asset with a risk free rate of 0.025 by solving, with using CPLEX. The weights of each stock of this selected portfolio (excluding the risk free rate weight) is then used to calculate the units of each stock same as the “equally weighted” and “minimum variance” portfolio strategy.



1. “Equal risk contribution” portfolio strategy:

In the “equal risk contribution” portfolio strategy, the portfolio is computed with a risk that has equal contribution to the portfolio standard deviation with solving , subject to iwi=1 , w0  using IPOPT.  The weights of each stock are again used to calculate the units of each stock, same as the strategies before.

1. “Robust mean-variance optimization” portfolio strategy:

In the “robust mean-variance optimization” portfolio strategy, we select the target portfolio return estimation error of 1/n portfolio and select only the diagonal of the covariance matrix Q to reduce the overall uncertainty. Then computing the robust mean-variance portfolio by solving using CPLEX. The weights of each stock are still used to calculate the units of each stock, same as the strategies before.



The finalized units of each stock and cash remaining of the selected portfolio for each strategy will be stored for calculating the portfolio value by units of each stock times the price of stock with remaining cash added. The finalized weights of each portfolio will also be stored.

# Robo-Advisor Design with Watson Assistant

To form an optimal portfolio that best aligns with our client’s interest, we first collect general information of our clients using the Robo-advisor chatbot we developed. The IBM Watson Assistant Lite is used for our chatbot design. We activated the function dialog in the Assistant Setting. Then, we developed multiple dialog nodes asking different questions on the platform. For instance, we started with a dialog node called “welcome” which allows our chatbot to reply to clients with our greeting text “Hi, nice to meet you! I am your personal investment bot. I am here to offer investment suggestions for your needs. Let's make some money together!” if the assistant recognizes general greetings from our clients. Through the chatting process, investment-related questions from multiple perspectives will be asked.

After general greetings, our chatbot asks the clients about their purpose of investment. A client with an investment fund for education or retirement purposes potentially prefers a portfolio with less risk. In contrast, a client investing money for future purchases may prefer a portfolio with higher return and thus higher risk. Our chatbot also asks about clients’ investment knowledge level. If the client is new to investing, instead of directly asking “what’s your risk tolerance level”, the chatbot provides the client with a situation: “assuming you’re facing a 30% loss of your current investment in real life, what would you do in this situation?”. The client may choose “I would withdraw all of my money” or “I would withdraw some of my money”. In either case, our chatbot defines the client as the risk averter, and would treat them as the same as those experienced investors who choose risk level 1(Less Risk) in the question “what’s your risk tolerance level?”. For the clients who choose “I'd stay invested, but wouldn't add more”, the chatbot gathers them in the risk level 2(Medium Risk) group. For the clients who choose “I would keep adding to my investment”, we think they are more like a risk lover type and the chatbot would put them into the risk level 3(More Risk) group.

Additionally, we offer some freedom on the portfolio asset selection to our clients. Near the end of the conversation, our chatbot asks clients whether they have a preferred industry to invest in. The client can choose “No” for this question or “Yes” which will lead the client to the next question. Then, the client can choose the industry that they are most interested in from the range of Agriculture, Technology, Healthcare, and Finance & Insurance. If the clients choose “No” for this question, our chatbot defines them as having no preference on asset selection and then generates their final optimal portfolio with all 60 stocks being selected across the four industries. The last question our chatbot would ask is the investment amount our client wants to start with. The client can choose from 1k, 5k, 10k, 50k, or 100k.

To make sure our chatbot can recognize all possible clients’ responses and make the conversation process flow smoothly, we created intents for each question we ask in the Watson Assistant dialog. For example, as Figure 1 shows, in the intent “#Q5\_experienced\_investor\_risk\_level”, we include possible responses such as “high”, “high risk”, “level 3”,  “medium”, “medium risk”, “level 2”, “less”, “low”, “less risk”, “level 1”. The different expressions of responses with the same meaning would help our chatbot react to a wider range of clients’ needs.

图形用户界面, 文本, 应用程序, 电子邮件

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Figure 1: Intents Design Example

The conversation process designed by our team allows the chatbot to construct a client's customized optimal portfolio by connecting to our Python algorithm and adjusting the inputs in our Python functions. There are three main input values of our Python function that are defined by the survey results. The first one is the amount that the client wants to invest which will be treated as the initial cash amount of the portfolio. The second one is the industry information. If the client has a preference, we would only choose the stocks in the most preferred industry. If the client does not have any preference, the algorithm will choose the stocks from the stock list covering all of these four industries. The third one is the client’s risk level which will influence the choice of the final investment strategy.

# Optimization Functions Design

To deal with customers' preferences gathered from conversations with Robo-advisor and make a recommendation in investment strategy for them, three functions are pre-designed in Python, which processes backstage with human supervision, and performs the following functions, respectively:

1. Optimize the portfolio value for six strategies based on the industry client want to invest in and the client's invested amount.
2. Choose the strategy that fits the client's risk tolerance level and with a higher return level.
3. Visualize the optimal weight of the portfolio for the strategy selected in the previous step

First, choose stocks in the corresponding industry from March 2017 to March 2022, based on the customer's desired industry and the amount of money to be invested. Then, using the stock data and the customer's money, execute all investment strategies. Save the optimized portfolio value figures for the following steps.

In the second place, the six investment strategies are assigned to three levels.

* Risk level 1:  Buy and Hold, Minimum Variance Portfolio
* Risk level 2: Equally Weighted Portfolio, Equal Risk Contributions Portfolio, Robust Optimization Portfolio
* Risk Level 3: Maximum Sharpe Ratio Portfolio

We allocated clients to the appropriate risk level category depending on their expressed risk tolerance. Compare the portfolio values of the group's strategies, pick the one with the highest return, and present the results to the client.

The optimal weights of each stock in the portfolio are visually shown with a donut plot in the last stage, according to the recommended investment strategy. If the asset has a non-zero percentage, the graphic displays the asset's name. If our clients are willing to accept our recommendation, our Robo-advisor will highly suggest they invest in this ratio.

# Interaction and Connection

​​Interact the IBM Watson Assistant with the Python file by the API key, the service URL and the assistant ID.

Collect clients’ information (e.g. investment favor) during their conversation with Watson assistant. Particularly, identify the clients’ risk level and industry preference based on their corresponding answers. Clients can also customize their investing size by clarifying the cash amount they would invest. As long as the conversation ends, 3 parameters (e.g. risk level, industry preference, initial cash amount) will be applied to generate the final investing suggestion and a plot will be displayed to visualize the weights allocation within the given portfolio. Below is a practical example.

Icon

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hi

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Description automatically generatedHi, nice to meet you! I am your personal investment bot. I am here to offer the investment suggestions by your needs. Let's make some money together!

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Ok

Icon

Description automatically generatedNow, let's begin! What's the main reason you are investing? Choose from the following options: Retirement, Education, Future Purchases, or I do not know.

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in 4-5 years

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What is your income level this year? Choose from: 0-40k, 40k-80k, 80k-120k, 120k-200k, More than 200k. (CAN)

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more than 200k

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Description automatically generatedHow much do you know about investing? Choose from: I'm new to investing, I understand the basics, I've got a good understanding, I'm an investing expert

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i'm new to investing

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Welcome to the investment world! Now let's imagine if you lost 30% of your investment over the next year, what would you do? Choose from: I would withdraw all of my money; I would withdraw some of my money; I'd stay invested, but wouldn't add more; I would keep adding to my investment.

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i would withdraw all of my money

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Do you have a preferred industry? Choose: Yes, I do or No, I don't (Type your answer in full sentence)

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yes, i do

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Which of the following industries are you most interested in? Choose from: Agriculture, Technology, Healthcare, Finance and Insurance

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Agriculture

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We are almost there, the last question! Choose the investment amount that fits your needs the most: 1k, 5k, 10k, 50k, 100k

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50k

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Description automatically generatedWell done! Your information has been received and being processed. Thank you for your cooperation. Your optimal portfolio is ready!

Stocks are chosen from Agriculture industry

The strategy: Buy and Hold, the portfolio value is: 51874.1200

The strategy: Minimum Variance Portfolio, the portfolio value is: 51616.1279

The strategy with the highest return is: Buy and Hold

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Figure 2: Portfolio Allocation

# Discussion and Conclusion

After connecting the Robo-advisor to the Python file, we can interact with customers in Python and choose an investment strategy with optimized portfolio value based on the industry the client wants to invest in and the client's invested amount, get a strategy that fits the client's risk tolerance level and provides a better return and illustrate the optimal portfolio weight for the strategy implemented in the previous step through visualization. Ultimately, the client will get the overview of the best portfolio chosen based on their preference as their reference to invest.