Participatory Modeling for Societal Complexity in Healthcare

Background and motivation

By Heider Jeffer

Explore our project and **Visit our lab**

Research Proposal: Participatory Modeling for Societal Complexity in Healthcare

Hello and welcome! We're excited to share our work on participatory modeling for societal complexity in healthcare. Explore and engage with our resources below:

- **Discover Our Project**: Learn about our approach and research on GitHub
- Try It Out: Experiment with our simulation through this interactive Google Colab notebook.
- **Explore the Code**: Dive into the details of our simulation by reviewing the source code.

We'd love for you to explore, experiment, and share your thoughts with us!

Presentation Structure

Part 1: My Background and how it relates to this KTH's PhD position?

Part 2: What motivates me to pursue this position specifically?

Part 3: How would My technical skill contribute to the research goals of this project?

Part 4: Project where I used participatory modeling or similar techniques "KTH PhD project, Developed using Python by Heider Jeffer to answer **(Research Questions)"?**

Part 5: What do I hope to learn from working within the InSilicoHealth Doctoral Network and at KTH?

Part 6: I have Questions

Part 7: Appendix: Numerical Example, Simulation Steps

Part 1: My Background and how it relates to this KTH’s PhD position?

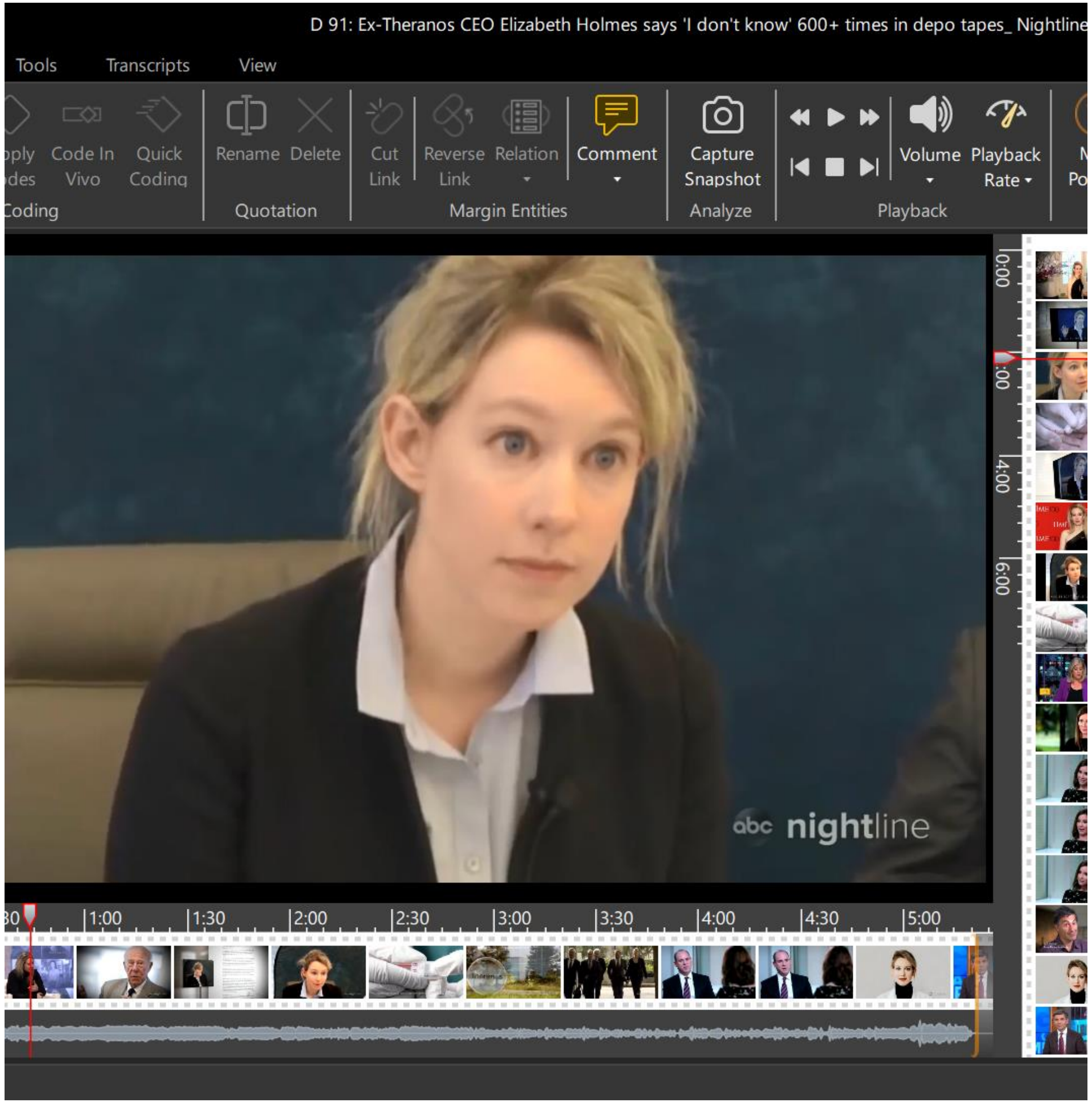
1. Interdisciplinary academic background
2. Master’s thesis

1. Interdisciplinary academic background

- Having completed degrees in Physics and Operations Research, followed by advanced studies in Computer Science and Artificial Intelligence.
- My experience at USI, ETH Zürich and the Free University of Bozen-Bolzano (UNIBZ) involved hands-on projects and laboratory focused on participatory Modulation Simulation Optimization, Human Machine Interaction, software reliability and testing, Stochastic process and system dynamics—areas I believe are highly relevant to this position.

2. Master’s thesis

- I explored the failure factors of the “Elizabeth Anne Holmes the American biotechnology entrepreneur the founder of Theranos as an exemplar case study for my research, specifically addressing the regulatory and legal challenges that contributed to its downfall. Using gray literature”.
- I developed a model for both qualitative and quantitative data collection and analysis. This approach allowed me to identify key factors related to the healthcare sector’s challenges. Through this work, I further developed my technical expertise in Python, data analysis, and complex model building—skills I am eager to apply in the PhD role at KTH.


D 91: Ex-Theranos CEO Elizabeth Holmes says 'I don't know' 600+ times in depo tapes_ Nightline
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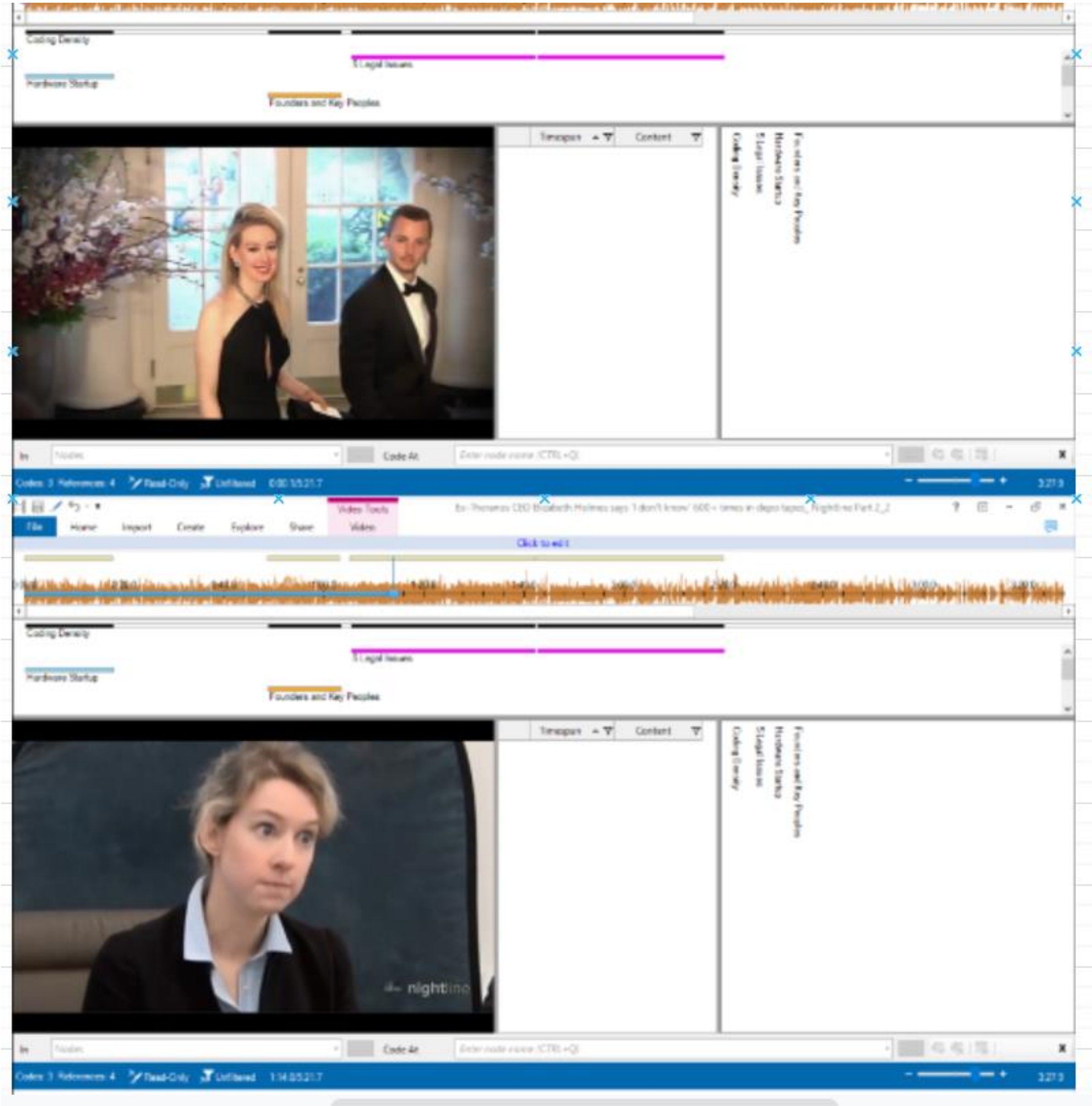

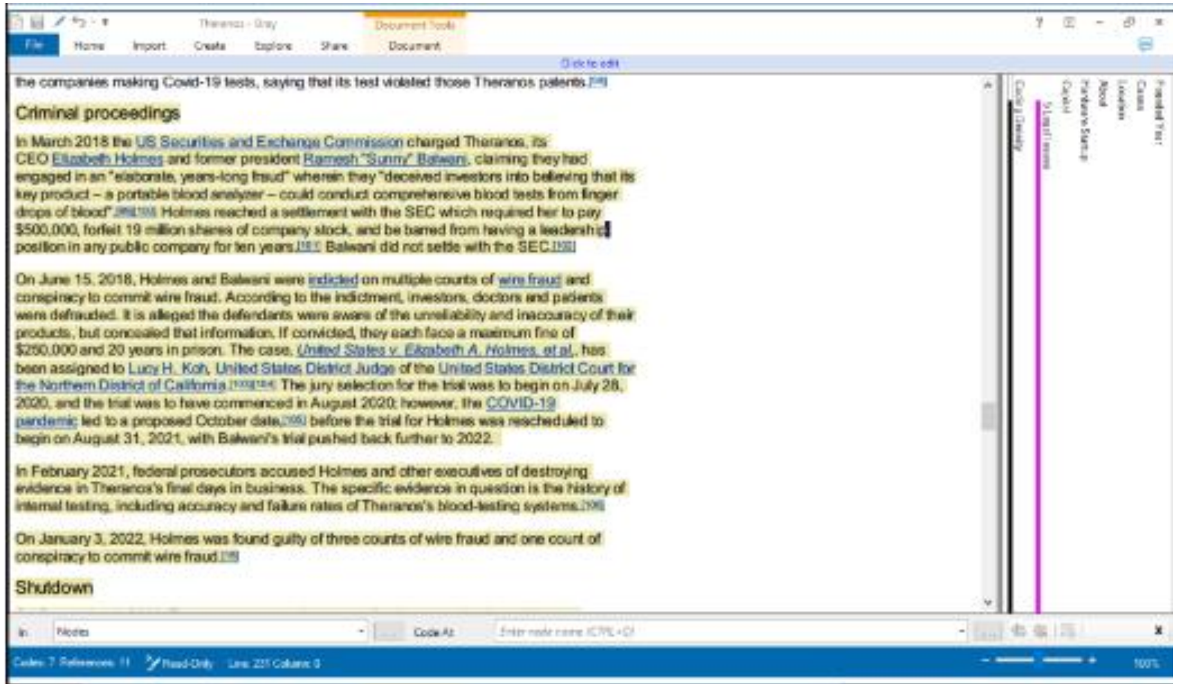
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the companies making Covid-19 tests, saying that its test violated those Theranos patents.
Criminal proceedings
In March 2018 the US Securities and Exchange Commission charged Theranos, its CEO Elizabeth Holmes and former president Ramesh "Sunny" Balwani, claiming they had engaged in an "elaborate, years-long fraud" wherein they "deceived investors into believing that its key product – a portable blood analyzer – could conduct comprehensive blood tests from finger drops of blood". Holmes reached a settlement with the SEC which required her to pay $500,000, forfeit 19 million shares of company stock, and be barred from having a leadership position in any public company for ten years. Balwani did not settle with the SEC.
On June 15, 2018, Holmes and Balwani were indicted on multiple counts of wire fraud and conspiracy to commit wire fraud. According to the indictment, investors, doctors and patients were defrauded. It is alleged the defendants were aware of the unreliability and inaccuracy of their products, but concealed that information. If convicted, they each face a maximum fine of $250,000 and 20 years in prison. The case, United States v. Elizabeth A. Holmes, et al., has been assigned to Lucy H. Koh, United States District Judge of the United States District Court for the Northern District of California. The jury selection for the trial was to begin on July 28, 2020, and the trial was to have commenced in August 2020; however, the COVID-19 pandemic led to a proposed October date, before the trial for Holmes was rescheduled to begin on August 31, 2021, with Balwani's trial pushed back further to 2022.
In February 2021, federal prosecutors accused Holmes and other executives of destroying evidence in Theranos's final days in business. The specific evidence in question is the history of internal testing, including accuracy and failure rates of Theranos's blood-testing systems.
On January 3, 2022, Holmes was found guilty of three counts of wire fraud and one count of conspiracy to commit wire fraud.
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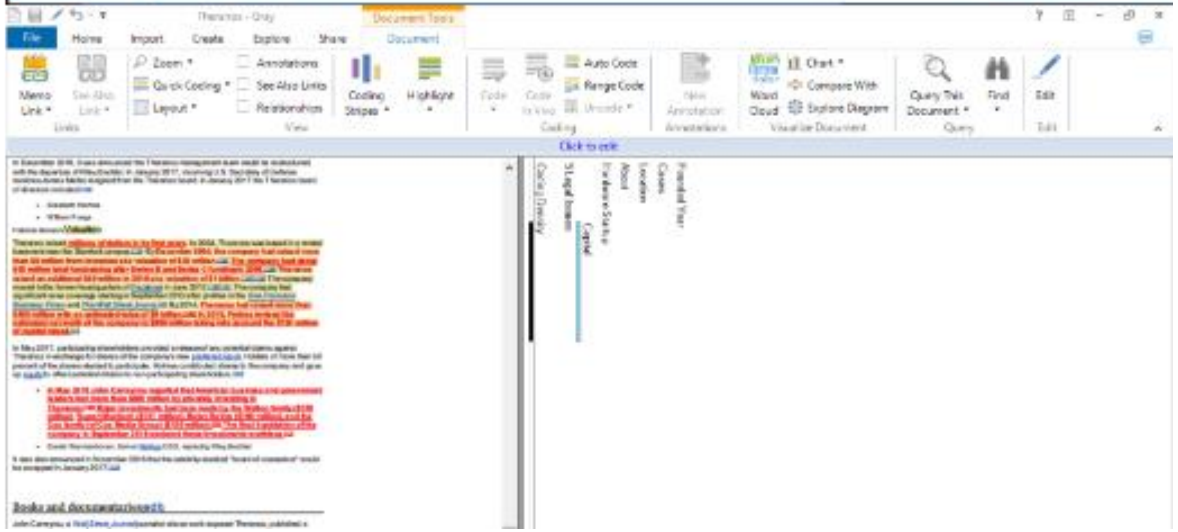
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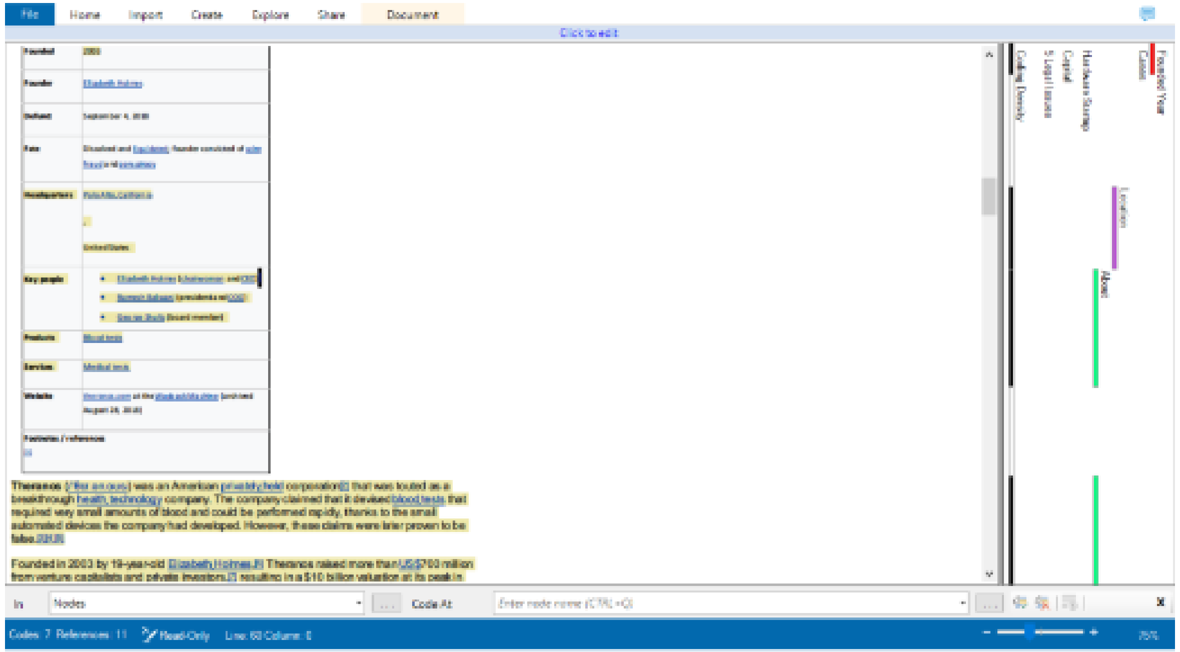
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Founded in 2003 by 19-year-old Elizabeth Holmes, Theranos raised more than US$700 million from venture capitalists and private investors, resulting in a $10 billion valuation at its peak in
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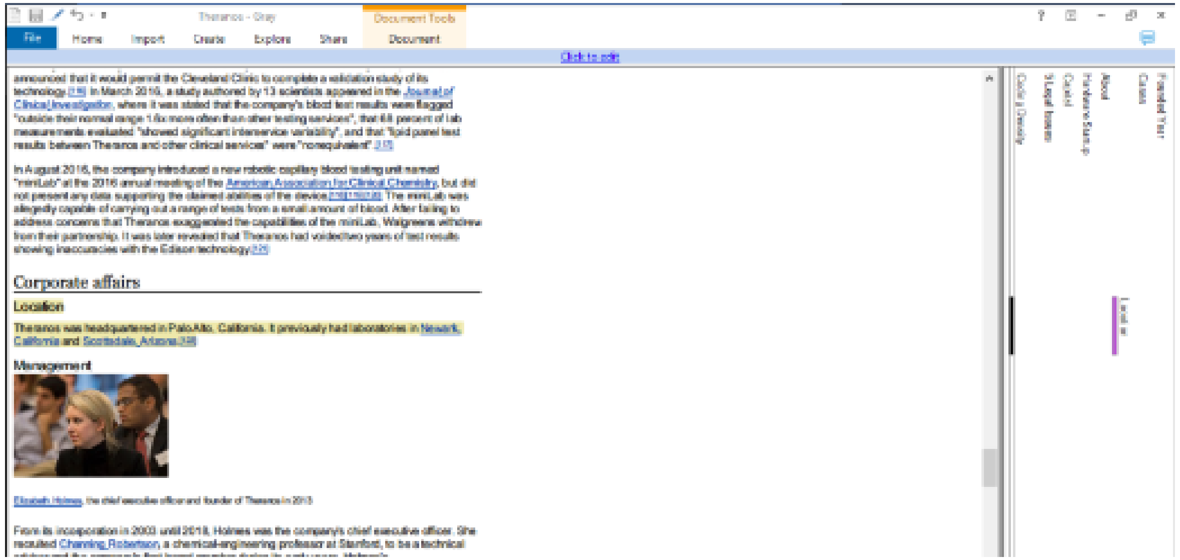
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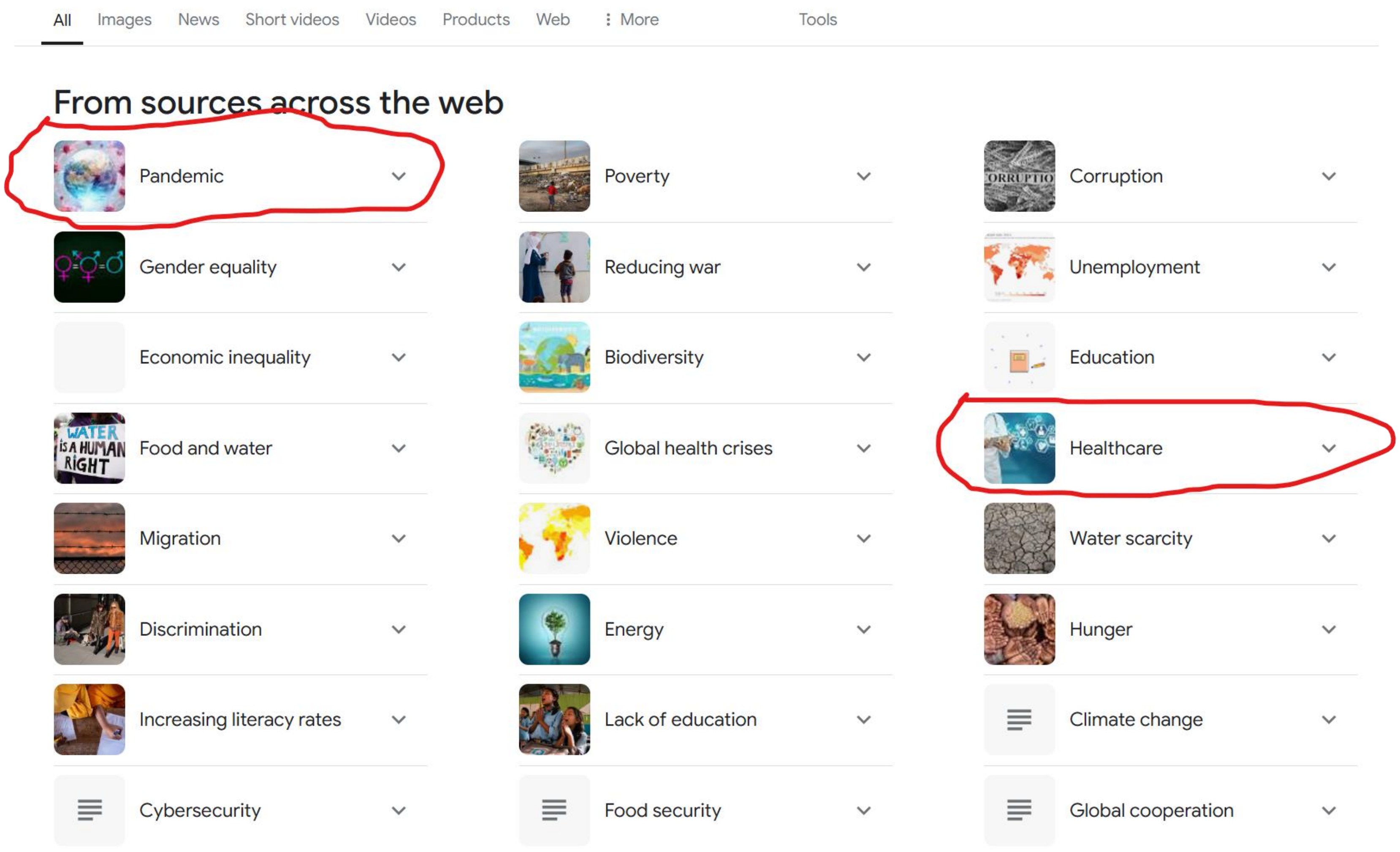
Location
Theranos was headquartered in Palo Alto, California. It previously had laboratories in Newark, California and Scottsdale, Arizona.
Management
Elizabeth Holmes, the chief executive officer and founder of Theranos in 2013

Part 2: What motivates me to pursue this position specifically?

1. The escalating challenges in global healthcare
2. Driving Impact
3. Passion for Real-World Impact

1. The escalating challenges in global healthcare



1. The escalating challenges in global healthcare

- Global healthcare challenges—pandemics like COVID-19, antimicrobial resistance, unequal healthcare access, and rising health issues—are urgent and demand innovative solutions.
- The escalating challenges in global healthcare are hot topics that require immediate action, and we must start as soon as humanly possible.
- I am motivated to address these crises through KTH’s platform, leveraging its leadership in research, technology, and collaboration to drive impactful solutions.
- KTH’s expertise uniquely positions it to lead efforts in healthcare accessibility, health systems innovation, and health support in local, European and international level.
- Aligning my skills with KTH’s mission, I aim to help tackle these pressing issues and build resilience against future global health challenges.

2. Driving Impact

- Advancing In Silico Models to Transform Decision-Making in Healthcare
- What excites me most about this position is the chance to work on the societal complexities surrounding in silico models in healthcare.
- I see enormous potential in developing models that help stakeholders—such as healthcare providers and administrators—make informed decisions that benefit patients.

3. Passion for Real-World Impact

- Leveraging Expertise in Design and Optimization to Contribute to KTH's Vision.
- My past projects on designing, modulation, simulation and optimization has fueled my interest in impactful, real-world applications, which aligns well with KTH’s vision.
- I believe my motivation, combined with a practical approach, would enable me to contribute significantly to this PhD project and make a meaningful impact.

Part 3: How would My technical skill contribute to the research goals of this project?

1. Technical skills
2. Experience

1. Technical skills

- My technical skills span a variety of areas relevant to this project.
- I am proficient in Python, Java, and other languages for modeling and simulation, which aligns well with the participatory modeling and complexity analyses required in this PhD project.

2. Experience

Experience with statistical methods and data visualization will support the rigorous analysis needed to validate and communicate findings effectively.

Part 4: Project where I used participatory modeling or similar techniques

In this KTH PhD project. The Python code I developed for the KTH Project simulates stakeholder interactions and contributions within a participatory modeling framework, providing answers to the (**Research Questions**) explored in this project:

- **Primary Research Question:**

  How can participatory modeling approaches be designed to simulate and address stakeholder interactions, agency complexities, and decision-making processes in the adoption of in silico models for healthcare systems?

- **Secondary Research Questions:**

  How can simulation techniques be used to capture and analyze the interplay of diverse stakeholders in the healthcare ecosystem?

  - *The code models the interactions and contributions of different stakeholders, providing a quantitative and qualitative analysis of their roles in decision-making processes.*

Part 5: What do I hope to learn from working within the InSilicoHealth Doctoral Network and at KTH?

1. Exploring KTH’s Approach
2. Real-World Healthcare Insights
3. Gaining a Holistic Understanding of Healthcare Challenges

1. Exploring KTH's Approach

To learn about KTH's approach to integrating participatory modeling within healthcare systems and to understand the nuances of translating model outputs into practical strategies that can be implemented in hospitals

2. Real-World Healthcare Insights

The secondments in Amsterdam and Karolinska University Hospital are also particularly exciting to me, as they offer a chance to experience firsthand how models are applied in real-world healthcare settings.

3. Gaining a Holistic Understanding of Healthcare Challenges

Allowing me to develop solutions that support evidence-based policy and management decisions in healthcare

Part 6: Questions

- Could you share more about the specific goals the research group hopes to achieve with this project?
- How does KTH facilitate collaboration between doctoral candidates within the InSilicoHealth network?
- What qualities or skills have you found most beneficial for success in this doctoral program?
- Could you explain more about the participatory model approaches used in this project?

Part 7: Appendix

A: Healthcare Participatory Model Simulation

B: Statistical Distribution and Visualization

1. Random Fluctuations and Why They Are Used

2. Uptake Rate and Why It Is Used

3. Feedback Loop and Why It Is Used

4. Visualizing Trends and Why It Is Important

5. Why Combine These Elements?

6. Numerical Example, Simulation Steps

The engagement level is simulated for different groups

- **Patients**: How involved patients are in a healthcare system, project, or study.
- **Doctors**: The degree of participation or involvement of doctors in a healthcare setting or initiative.
- **Nurses**: The level of engagement of nursing staff in activities, events, or initiatives.
- **Administrators**: The level of involvement of administrative personnel in decision-making, planning, or day-to-day operations.

A: Healthcare Participatory Model Simulation

- I have developed a Python-based code that simulates a simplified healthcare participatory model. This model collects, processes, and visualizes opinions from various healthcare stakeholders (patients, doctors, administrators).
- The simulation demonstrates key processes such as data collection, stakeholder engagement, and system dynamics analysis—skills highly relevant to the Doctoral project.
- The modular design of this code not only reflects my expertise in Python and data processing, but also demonstrates a deep understanding of participatory modeling, system dynamics, and stakeholder interactions within healthcare settings.
- This code is adaptable, allowing for future refinement and expansion.

B: Statistical Distribution and Visualization

- I used Python to design a statistical distribution plot that visualizes simulated engagement levels of different healthcare stakeholders over a 12-month period.
- The histogram, with Kernel Density Estimate (KDE) lines, provides insights into the distribution and frequency of engagement within stakeholder groups (e.g., patients, doctors, nurses, administrators).
- This visualization helps identify patterns—such as variations in engagement stability across different groups—and highlights areas where targeted strategies could improve participation.

1. Random Fluctuations and Why They Are Used

- **Reason**: Engagement levels in real-world systems (e.g., healthcare participation) are inherently unpredictable and influenced by numerous factors such as personal behavior, external policies, or environmental changes.
- **Purpose in the Simulation**:
  - They introduce variability, making the model more realistic by simulating both increases and decreases in engagement levels over time.
  - Random fluctuations also allow the model to reflect potential short-term disruptions (e.g., staff shortages, new initiatives).
- **Example**: If "Patients" engagement starts at 0.6 and fluctuates randomly within $[-0.02,+0.02]$[-0.02, +0.02]$[-0.02,+0.02]$, the variability mimics real-world behaviors such as patients being more engaged during health campaigns and less engaged during holidays.

2. Uptake Rate and Why It Is Used

- **Reason**: The uptake rate summarizes the system's overall engagement by averaging the contributions of all stakeholder groups (patients, doctors, nurses, administrators).
- **Purpose in the Simulation**:
  - It provides a high-level metric to evaluate the program's success.
  - By tracking uptake over time, it identifies patterns and trends that can inform decision-making (e.g., whether engagement is improving or declining).
  - Aggregating individual engagement levels into a single uptake rate is useful for comparing across time or scenarios.
- **Example**: If engagement for doctors is high but low for administrators, the uptake rate highlights this gap. Monitoring it monthly ensures timely adjustments.

3. Feedback Loop and Why It Is Used

- **Reason**: Engagement in one period influences future participation, as people’s behavior often follows momentum (positive or negative). For instance:
  - A stakeholder's higher engagement in one month could lead to better results or satisfaction, encouraging continued involvement.
  - Conversely, disengagement could compound due to frustration, leading to further drops.
- **Purpose in the Simulation**:
  - The feedback loop captures these cascading effects, helping simulate long-term dynamics.
  - It reflects realistic cause-and-effect relationships, showing how policies or external shocks affect sustained participation.
- **Example**: If "Doctors" engagement decreases slightly in Month 2, the new lower level sets the baseline for Month 3, leading to a compounding effect unless counteracted by positive fluctuations.

4. Visualizing Trends and Why It Is Important

- **Reason**: Trends over time help stakeholders understand the overall direction of the system and pinpoint areas for intervention.
- **Purpose in the Simulation**:
  - Identifying whether engagement levels are increasing, stable, or declining over time helps evaluate program success.
  - Visualization simplifies complex data, making it accessible for decision-makers.
- **Example**: A plot showing consistent drops in administrator engagement could prompt targeted measures (e.g., new training or incentives).

5. Why Combine These Elements?

- **Holistic Analysis**: The combination of random fluctuations, uptake rate, and feedback loop provides a realistic, dynamic view of how engagement evolves over time.
- **Practical Decision-Making**: Decision-makers can:
  - Evaluate overall system health (via uptake rate).
  - Understand variability and uncertainty (via random fluctuations).
  - Plan interventions (based on trend analysis and feedback loops).
- In summary, these features ensure that the simulation closely mirrors real-world complexities, allowing for actionable insights and effective planning in dynamic systems like healthcare.

Summary of Key Formulas

1. **Engagement Level Update**:

$$\text{New Engagement}_t = \max(0, \min(1, \text{Previous Engagement}_{t-1} + \Delta))$$

where $\Delta \sim U(-0.05, +0.05)$.

2. **Uptake Rate**:

$$\text{Uptake Rate} = \frac{\sum \text{Engagement Levels}}{N}$$

where N is the number of stakeholders (4 in this case).

3. **Updated Engagement for Feedback Loop**:

$$\text{Updated Engagement}_t = \text{Previous Engagement}_t + \Delta_{\text{fluctuation}}$$

where $\Delta_{\text{fluctuation}} \sim U(-0.02, +0.02)$.

1. Engagement Simulation Formula

$$\text{New Engagement}_t = \max(0, \min(1, \text{Previous Engagement}_{t-1} + \Delta))$$

Where:

- New Engagement_t is the engagement level at the current month t,
- $\text{Previous Engagement}_{t-1}$ is the engagement level of the previous month,
- Δ is a random change drawn from a uniform distribution within the range $[-\text{fluctuation}, \text{fluctuation}]$, i.e., $\Delta \sim U(-0.05, 0.05)$,
- The $\max(0, \min(1, \cdot))$ operation ensures the engagement level stays between 0 and 1, as engagement cannot be negative or exceed 1.

This process is repeated for each stakeholder over the 12 months.

2. Model Uptake Rate Formula

$$\text{Uptake Rate} = \frac{\sum \text{Engagement Levels}}{N}$$

Where:

- $\sum \text{Engagement Levels}$ is the total engagement from all stakeholders (sum of engagement levels for all groups).
- N is the number of stakeholders (in this case, 4: Patients, Doctors, Nurses, Administrators).

This formula calculates the average engagement level across all stakeholders, which is used as the **uptake rate**.

3. Uptake Rate Feedback Loop

- **Updated Engagement Levels**: For each stakeholder, a random fluctuation between $[-0.02, +0.02]$ is applied to their current engagement level. The fluctuation is calculated using:

$$\text{Updated Engagement}_t = \text{Previous Engagement}_t + \Delta_{\text{fluctuation}}$$

where $\Delta_{\text{fluctuation}} \sim U(-0.02, +0.02)$.

- The updated engagement levels are then used to calculate the **new uptake rate** using the formula mentioned earlier.

Numerical Example
Simulation Steps

Numerical example

This numerical example illustrates how:

- Engagement levels fluctuate based on random changes each month.
- The uptake rate is calculated as the average of the engagement levels.
- A feedback loop exists, where each month's engagement influences the next, and this pattern can be visualized to see the overall trend.

Simulation Steps

- Step 1: Define Initial Engagement Levels
- Step 2: Simulate Engagement Fluctuations for 12 Months
- Step 3: Calculate Uptake Rate for Month 2
- Step 4: Simulate for Month 3
- Step 5: Calculate Uptake Rate for Month 3
- Step 6: Repeat for Remaining Months

Step 1: Define Initial Engagement Levels

- We begin with the following **initial engagement levels** for each stakeholder:
- **Patients**: 0.6 (60% engaged)
- **Doctors**: 0.8 (80% engaged)
- **Nurses**: 0.75 (75% engaged)
- **Administrators**: 0.5 (50% engaged)

Step 2: Simulate Engagement Fluctuations for 12 Months

we apply random fluctuations (within the range [−0.05,+0.05][-0.05, +0.05][−0.05,+0.05]) each month to the initial engagement levels.

- **Month 1:**
- **Initial Engagement** (for all stakeholders):
  - **Patients**: 0.6
  - **Doctors**: 0.8
  - **Nurses**: 0.75
  - **Administrators**: 0.5

Month 2 (First Fluctuation)

Assume the random fluctuations for each stakeholder are as follows:

- **Patients**: $\Delta = +0.03$
- **Doctors**: $\Delta = -0.02$
- **Nurses**: $\Delta = +0.01$
- **Administrators**: $\Delta = +0.04$

Now, apply the formula for **New Engagement**:

$$\text{New Engagement}_t = \max(0, \min(1, \text{Previous Engagement}_{t-1} + \Delta))$$

- **Patients**:

  $$0.6 + 0.03 = 0.63$$

  No need for clipping, so the new engagement for Patients is **0.63**.

- **Doctors**:

  $$0.8 - 0.02 = 0.78$$

  No need for clipping, so the new engagement for Doctors is **0.78**.

- **Nurses**:

  $$0.75 + 0.01 = 0.76$$

  No need for clipping, so the new engagement for Nurses is **0.76**.

- **Administrators**:

  $$0.5 + 0.04 = 0.54$$

  No need for clipping, so the new engagement for Administrators is **0.54**.

Month 2 Engagement Levels

- **Patients**: 0.63
- **Doctors**: 0.78
- **Nurses**: 0.76
- **Administrators**: 0.54

Step 3: Calculate Uptake Rate for Month 2

The **uptake rate** is the average engagement across all stakeholders:

$$\text{Uptake Rate} = \frac{\sum \text{Engagement Levels}}{N}$$

For Month 2:

$$\text{Uptake Rate} = \frac{0.63 + 0.78 + 0.76 + 0.54}{4} = \frac{2.71}{4} = 0.68$$

So, the uptake rate for **Month 2** is **0.68**.

Step 4: Simulate for Month 3

Assume the fluctuations for each stakeholder are:

- Patients: $\Delta = -0.02$
- Doctors: $\Delta = +0.01$
- Nurses: $\Delta = -0.03$
- Administrators: $\Delta = -0.01$

Apply the formula for **New Engagement**:

- **Patients**:

  $$0.63 - 0.02 = 0.61$$

  No need for clipping, so the new engagement for Patients is **0.61**.

- **Doctors**:

  $$0.78 + 0.01 = 0.79$$

  No need for clipping, so the new engagement for Doctors is **0.79**.

- **Nurses**:

  $$0.76 - 0.03 = 0.73$$

  No need for clipping, so the new engagement for Nurses is **0.73**.

- **Administrators**:

  $$0.54 - 0.01 = 0.53$$

  No need for clipping, so the new engagement for Administrators is **0.53**.

Month 3 Engagement Levels

- **Patients**: 0.61
- **Doctors**: 0.79
- **Nurses**: 0.73
- **Administrators**: 0.53

Step 5: Calculate Uptake Rate for Month 3

Again, calculate the uptake rate:

$$\text{Uptake Rate} = \frac{0.61 + 0.79 + 0.73 + 0.53}{4} = \frac{2.66}{4} = 0.665$$

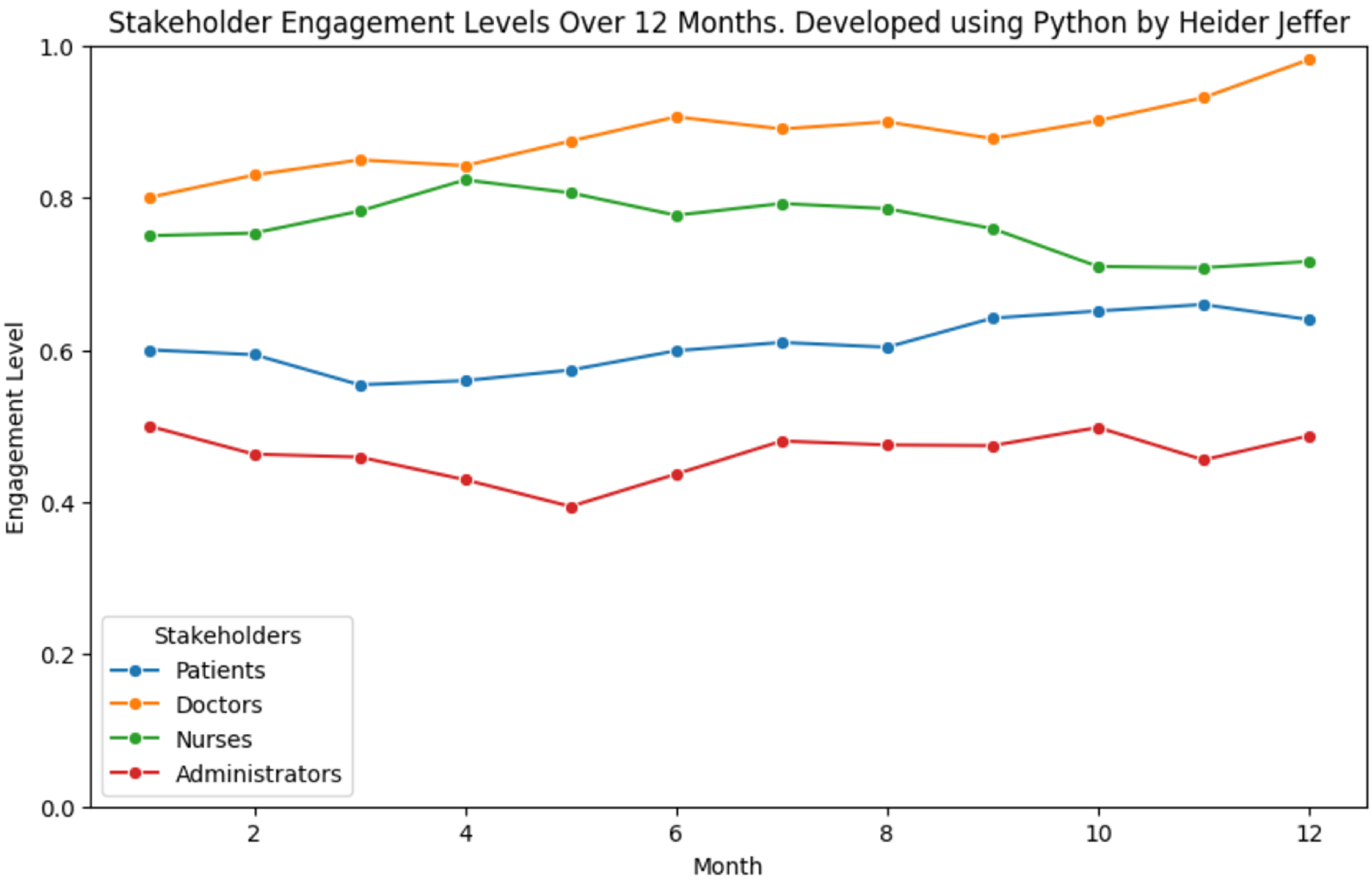
So, the uptake rate for **Month 3** is **0.665**.

Summary of the First 3 Months

Month	Patients	Doctors	Nurses	Administrators	Uptake Rate
1	0.6	0.8	0.75	0.5	-
2	0.63	0.78	0.76	0.54	0.68
3	0.61	0.79	0.73	0.53	0.665

Step 6: Repeat for Remaining Months

- The same process is repeated for the remaining months (Month 4 to Month 12), where new fluctuations are applied each month to simulate the evolution of engagement levels and the corresponding uptake rate.
- The final uptakes are plotted over time to visualize the model's performance.


Stakeholder Engagement Levels Over 12 Months. Developed using Python by Heider Jeffer
Engagement Level
Month
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Stakeholders
Patients
Doctors
Nurses
Administrators

Healthcare Participatory Moc

Code

Notebook

Python 3 (ipykernel)

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Average Engagement Levels by Stakeholder:
Stakeholder
Administrators    0.462681
Doctors           0.881931
Nurses            0.763536
Patients          0.607069
Name: Engagement, dtype: float64
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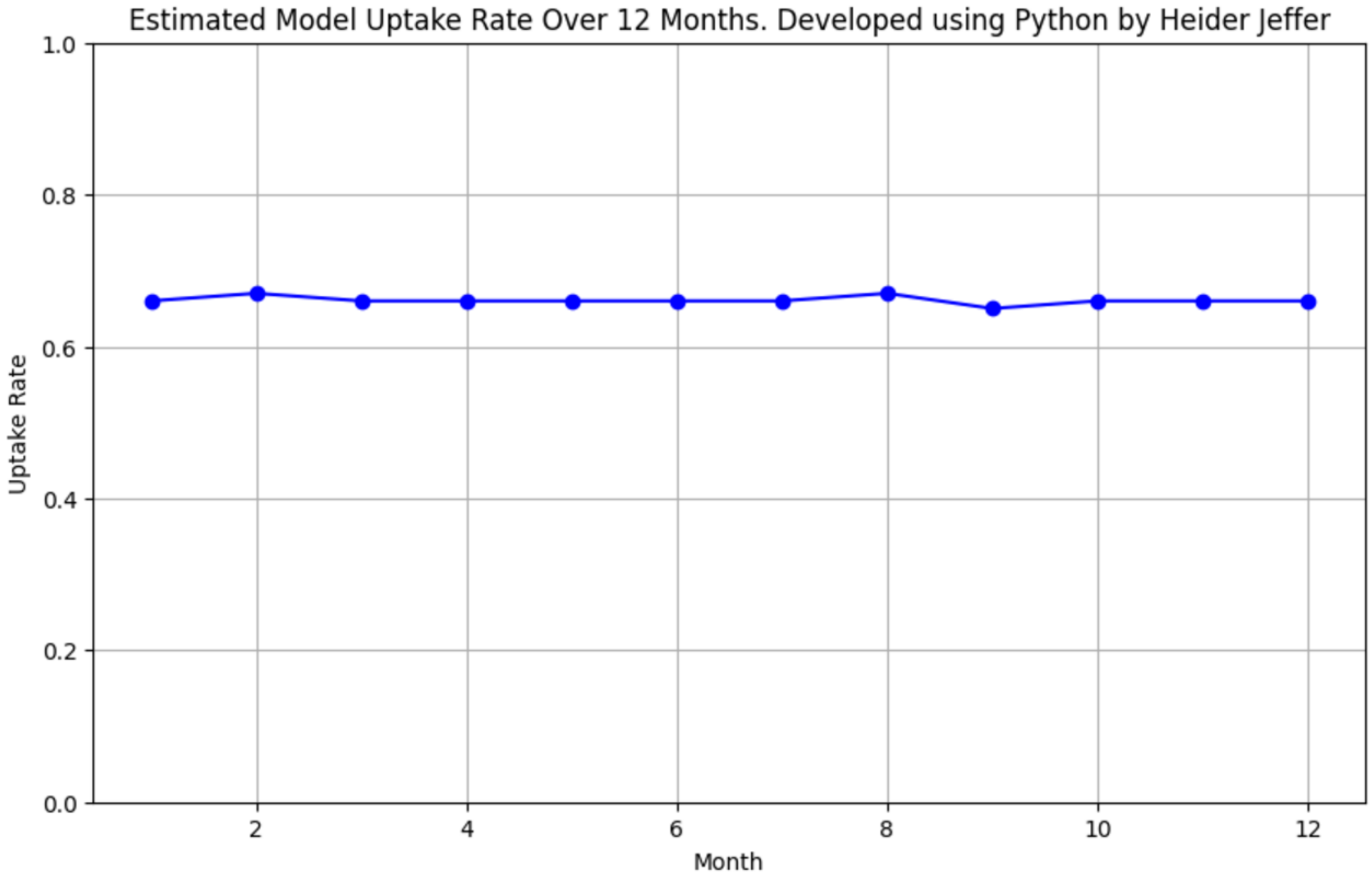

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