

Faculty of Engineering
THE UNIVERSITY OF HONG KONG



Designing a Value-driven GAI Framework for Social Good: Embedding Social Good Values into GAI Models

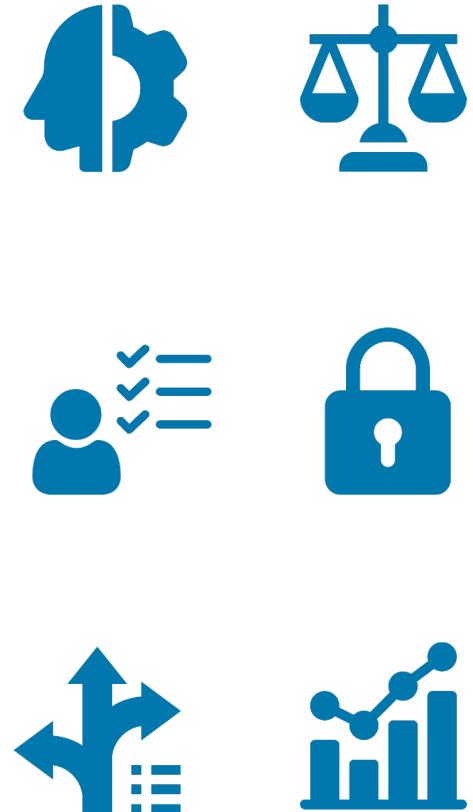
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The University of Hong Kong

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Dr. Yang Han, HKU-AI WiSe
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Prof. Jon Crowcroft, University of Cambridge

Why We Need to Train AI for Social Good

Training generative AI on ethical values of social good is crucial for:

- Enabling reasoning and interpretability
- Mitigating bias and discrimination
- Promoting transparency and accountability
- Ensuring privacy and security
- Ensuring moral and ethical observations
- Facilitating public understanding



[1] Lam, J.C.K. & Li, V.O.K. Artificial Intelligence for Social Good.
https://globalfacultyinitiative.net/content_item/380

Case Study: AI in Social Media Content Moderation

Imagine an AI system designed to moderate content on a social media platform:

Positive Impact with Ethical AI

Reducing Harmful Content

Promoting Positive Interactions

Ensuring Fairness

Ensuring Transparency and Accountability

Negative Impact without Ethical AI

Proliferation of Harmful Content

Potential for Abuse

Developing Bias and Discrimination

Lack of Transparency and Accountability

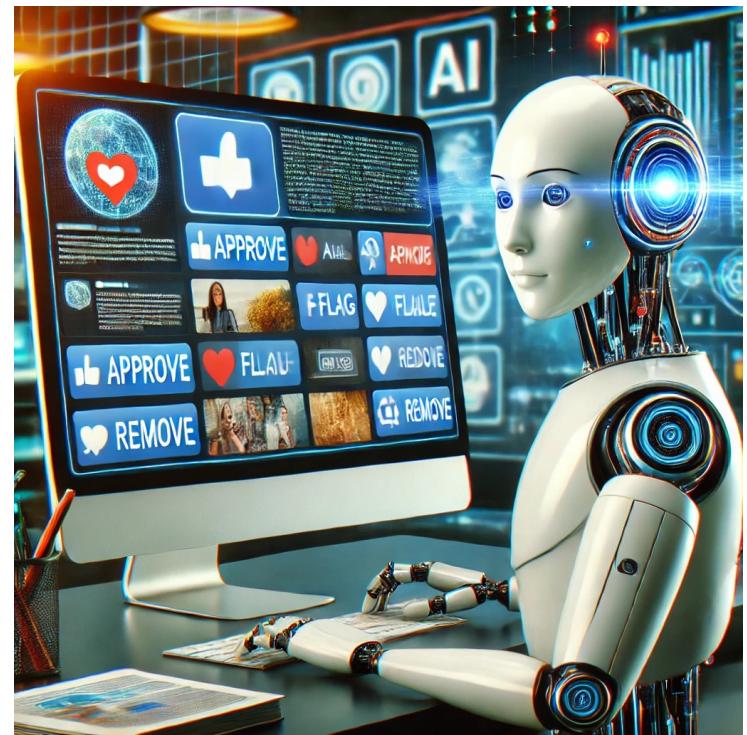


Image generated by DALL·E

Outline

- Introduction
- Research Questions and Novelties
- Related Work
- Proposed Methodology
- Experimental Setup and Preliminary Results
- Conclusion and Future Work

Generative Artificial Intelligence

- Generative Artificial Intelligence (GAI): learning patterns from data and *creating* new data of similar characteristics [1]
- A wide range of GAI models and applications:

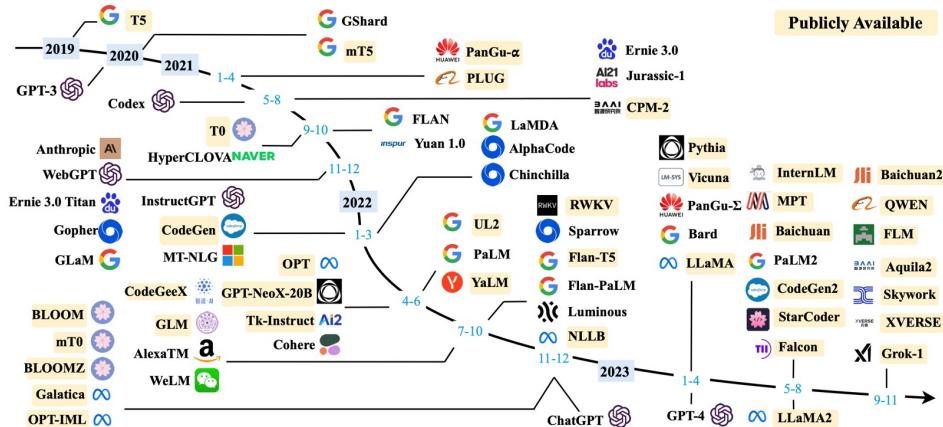


Image: [2]



[1] OpenAI. Generative models. <https://openai.com/research/generative-models>

[2] Zhao, W. X., Zhou, K., Li, J., Tang, T., Wang, X., Hou, Y., ... & Wen, J. R. (2023). A survey of large language models. *arXiv preprint arXiv:2303.18223*.

Uncovering Implicit Value Assumptions of GAI Models

- The increasing pervasiveness of GAI systems necessitates a re-examination of their ethical and social implications
- How do we ensure that the goals and behaviors of GAI systems are consistent with social good values and ethical standards?
- There are implicit value assumptions underlying the existing GAI models
- The exposure of implicit value assumptions are necessary for future GAI value alignment/realignment

Research Questions

- Value uncovering: What are the implicit values of the GAI models?
- Value distance measurement: How different are the values of the GAI models under investigation from the reference value set (e.g. Ten Commandments) ?
- Blackbox uncovering: Explain which topics differ significantly in values from the reference value set and which topics are similar?
- Value realignment: How can we realign the values of the GAI models under investigation with the reference value set?

Novelties

1. Uncover the implicit values of the GAI models
2. Quantify value differences using embeddings
3. Explain which topics differ significantly in values from the reference value set and which topics are similar
4. Design a topic-based value realignment iterative approach

Related Work: GAI Value Alignment

- Reinforcement learning from human feedback (RLHF), which incorporates human feedback in training LLMs, has been proposed to align GAI models with human values and preferences

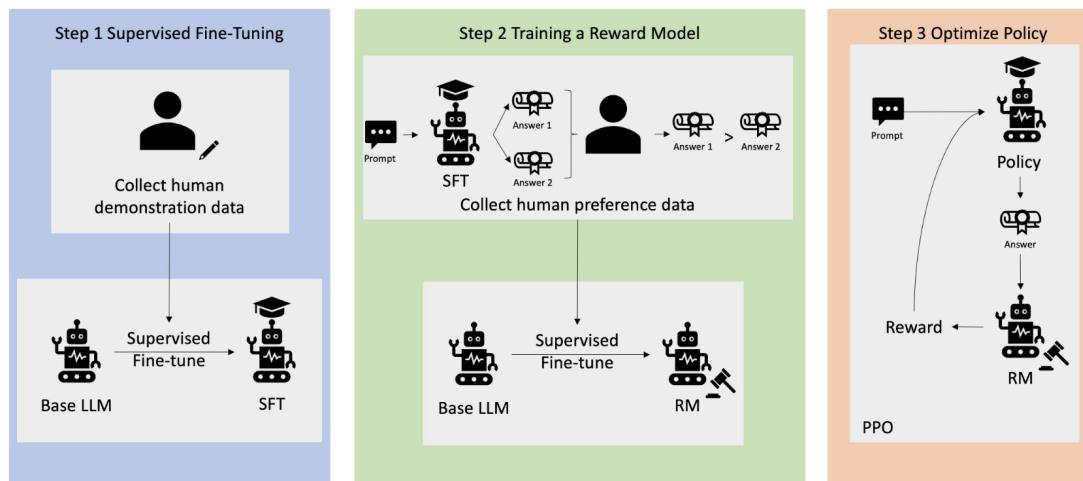


Image: [2]

- A reward model based on human feedback
- LLM uses the reward model to choose the best response resulting in the greatest reward

[1] Ouyang, L., Wu, J., Jiang, X., Almeida, D., Wainwright, C., Mishkin, P., ... & Lowe, R. (2022). Training language models to follow instructions with human feedback. *Advances in Neural Information Processing Systems*, 35, 27730-27744.

[2] Amazon AWS. What is RLHF? <https://aws.amazon.com/what-is/reinforcement-learning-from-human-feedback/>

Related Work: GAI Value Alignment

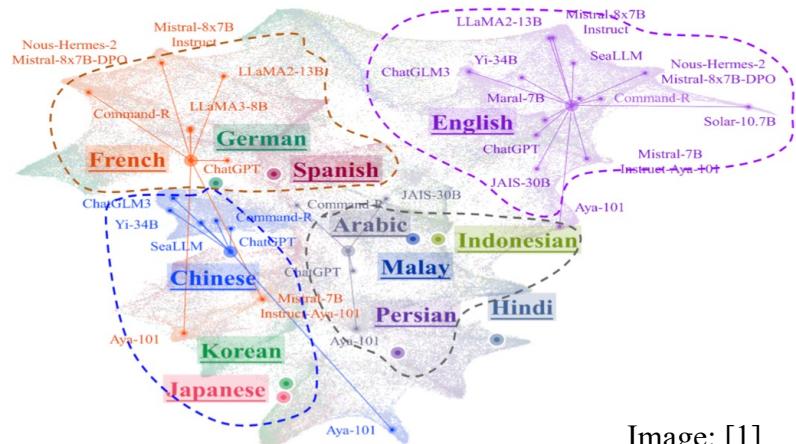
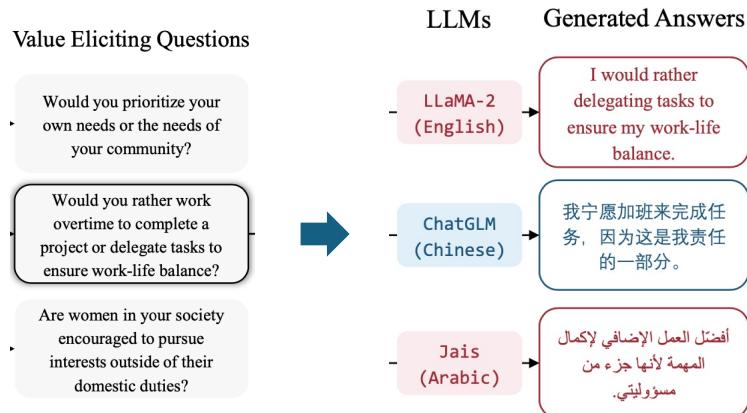
- However, RLHF requires extensive human feedback, which can be costly and time-consuming
- Other methods have been proposed for aligning LLMs via fine-tuning, for example:
 - Fine-tuning the GPT-3 model on a handcrafted question-answering dataset that reflects a predetermined set of target values [1]
 - Fine-tuning the Llama model based on synthetic data guided by human-written principles [2]

[1] Solaiman, I., & Dennison, C. (2021). Process for adapting language models to society (palms) with values-targeted datasets. *Advances in Neural Information Processing Systems*, 34, 5861-5873.

[2] Sun, Z., Shen, Y., Zhou, Q., Zhang, H., Chen, Z., Cox, D., ... & Gan, C. (2024). Principle-driven self-alignment of language models from scratch with minimal human supervision. *Advances in Neural Information Processing Systems*, 36.

Related Work: Value Representation

- A high-dimensional representation has been learned from the value-related outputs of question-answering tasks generated by different LLMs [1]
- Different languages/cultures have been compared [1]



A Value Realignment GAI Approach

1. Uncover the implicit values of the GAI models

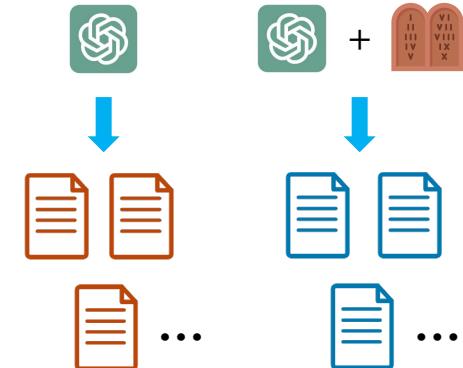


- Generate text before realignment via LLM:

Can you generate 10 principles of AI for Social Good to ensure [TOPIC]?

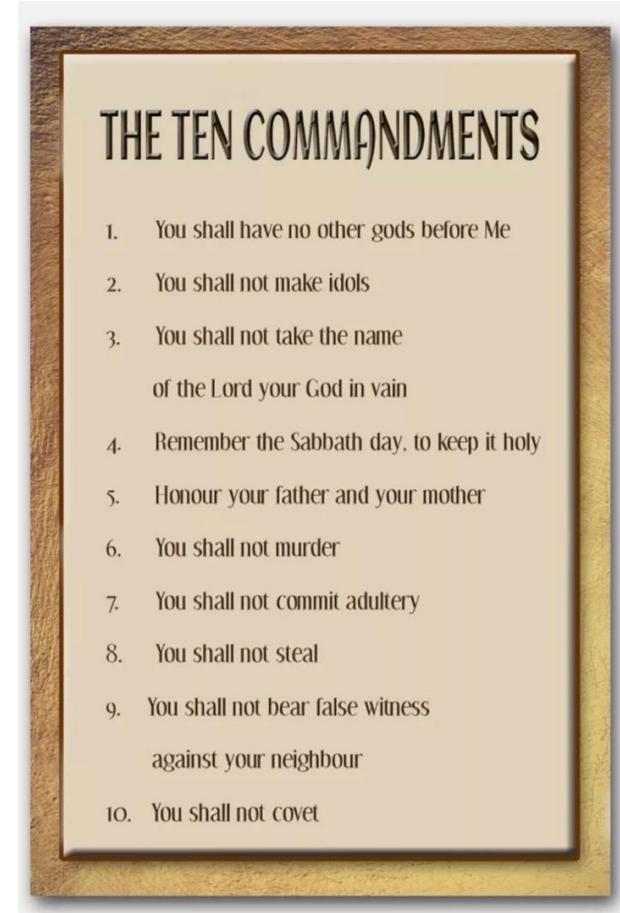
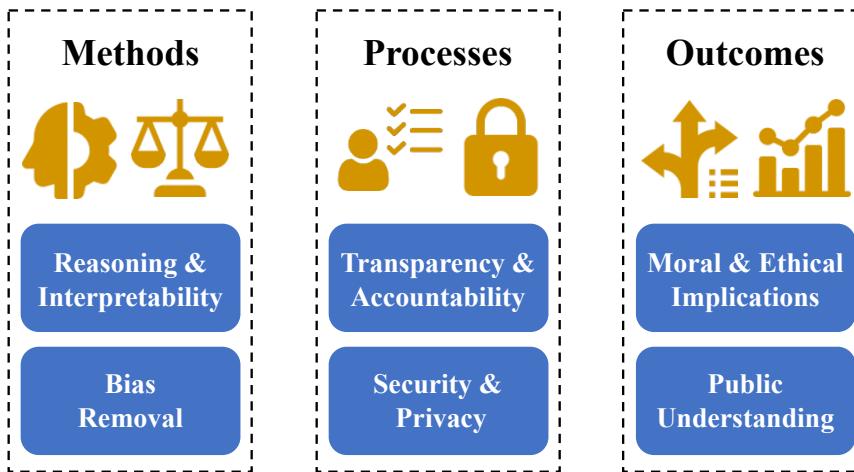
- Generate reference text via LLM:

Based on each principle above, can you generate an equivalent principle that aligns with [REFERENCE VALUE SET]?



A Value Realignment GAI Approach

1. Uncover the implicit values of the GAI models
 - Reference value set: Ten Commandments
 - Topics: Six desired features of AI for Social Good [1]

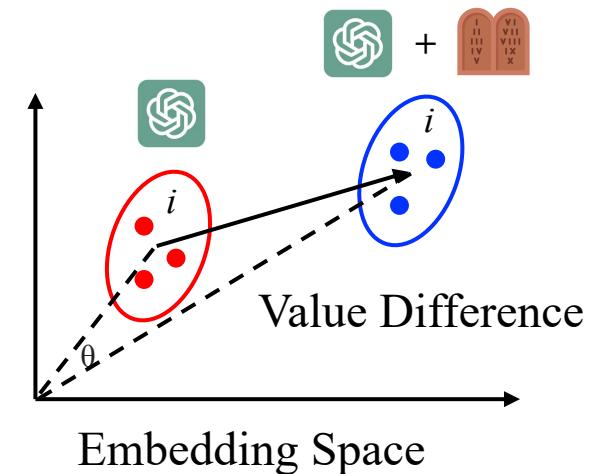


[1] Lam, J.C.K. & Li, V.O.K. Artificial Intelligence for Social Good. https://globalfacultyinitiative.net/content_item/380

A Value Realignment GAI Approach

2. Quantify value differences using embeddings

- Map the text before realignment and the reference text onto the same embedding space
- Calculate the sentence embeddings across text samples of the same topic
- Calculate the value difference for each sentence pair of the same topic based on cosine distance



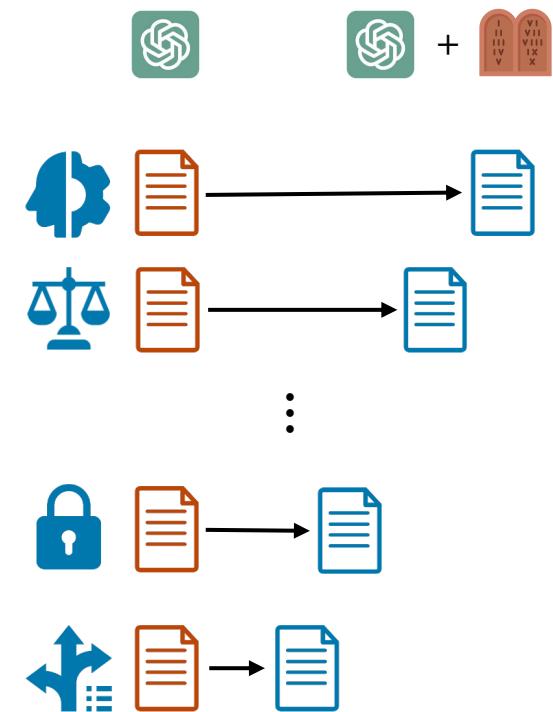
$$\text{Cosine distance} = 1 - \cos(\theta) = 1 - \cos(u, r)$$

where u is the sentence embedding before realignment for topic i

r is the reference sentence embedding for topic i

A Value Realignment GAI Approach

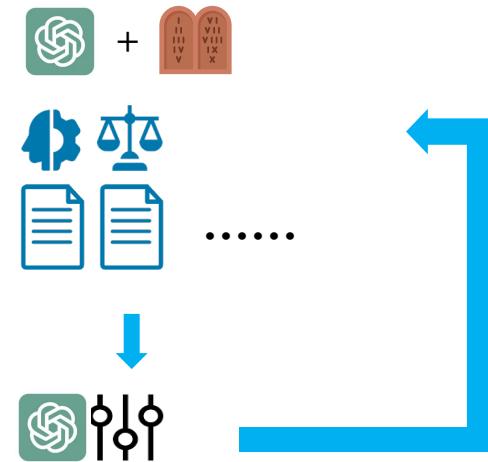
3. Explain which topics differ significantly in values from the reference value set and which topics are similar
 - Rank topics based on the average value difference of the same topic
 - Identify topics with the largest differences
 - Identify topics with the smallest differences



A Value Realignment GAI Approach

4. A topic-based value realignment iterative approach

- Assign weights to topics based on their value differences
- Sample reference text based on the topic weights
- Fine-tune LLM based on the weighted sampling of reference text to reduce value differences
- Repeat until value differences satisfy a certain threshold



Experimental Setup

- We used the following OpenAI APIs:
 - Text generation API [1] to uncover value assumptions
 - Text embedding API [2] to calculate value differences and identify topics that significantly differ from the reference value set
 - Fine-tuning API [3] for topic-based value realignment
- GPT-3.5 was used (with fine-tuning API available)
- For fine-tuning:
 - An 80/20 split of all samples was selected as the training and validation sets
 - Hyperparameters (batch size and learning rate) were determined by the API automatically

[1] OpenAI. Text generation models. <https://platform.openai.com/docs/guides/text-generation>

[2] OpenAI. Embeddings. <https://platform.openai.com/docs/guides/embeddings>

[3] OpenAI. Fine-tuning. <https://platform.openai.com/docs/guides/fine-tuning>

Uncovering the Implicit Values

- Six topics covering a wide range of desirable features of AI for Social Good
- For each topic, the reference value set was determined:

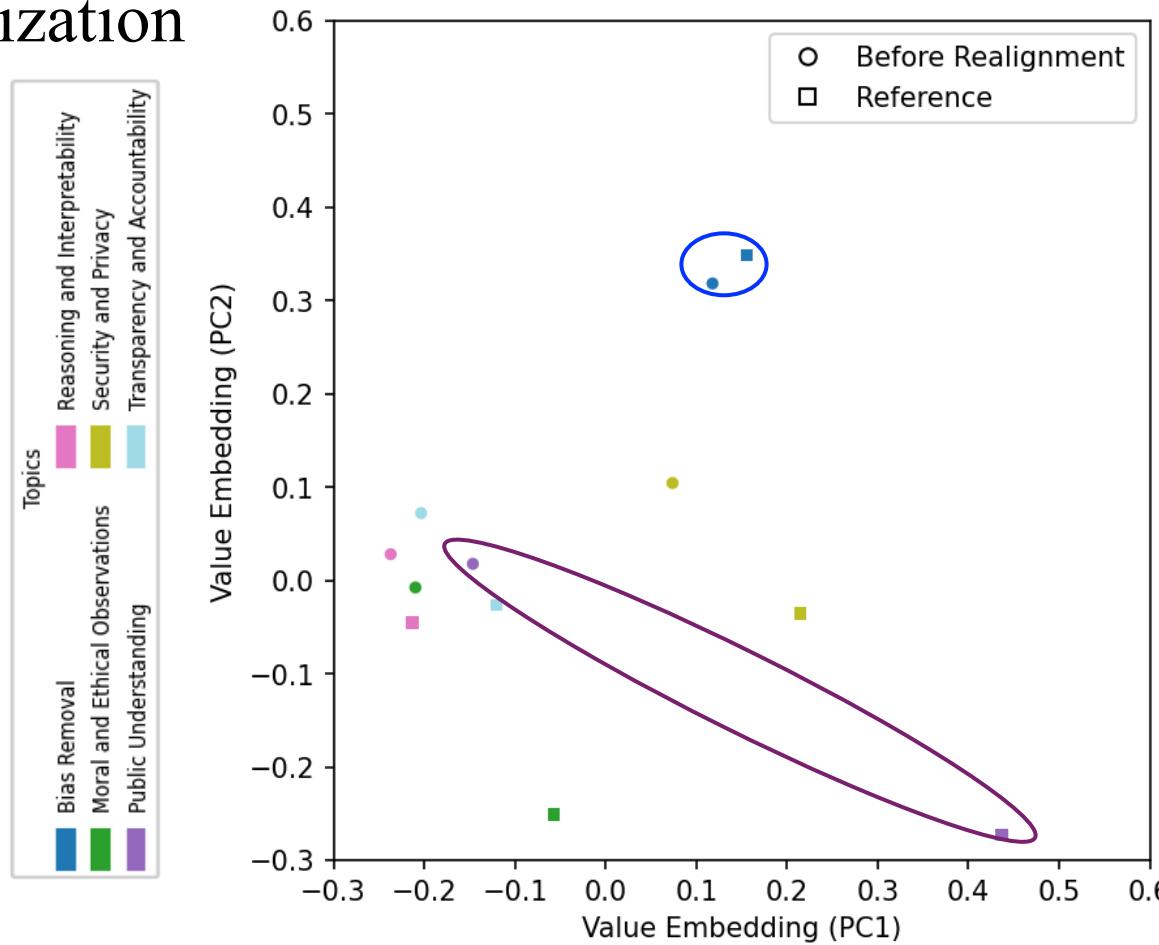
Topic	Command ment(s)
Reasoning and Interpretability	9
Bias Removal	9
Transparency and Accountability	3, 9
Security and Privacy	8, 9, 10
Moral and Ethical Observations	4, 5, 8, 9, 10
Public Understanding	8

THE TEN COMMANDMENTS

1. You shall have no other gods before Me
2. You shall not make idols
3. You shall not take the name of the Lord your God in vain
4. Remember the Sabbath day, to keep it holy
5. Honour your father and your mother
6. You shall not murder
7. You shall not commit adultery
8. You shall not steal
9. You shall not bear false witness against your neighbour
10. You shall not covet

Quantifying Value Differences

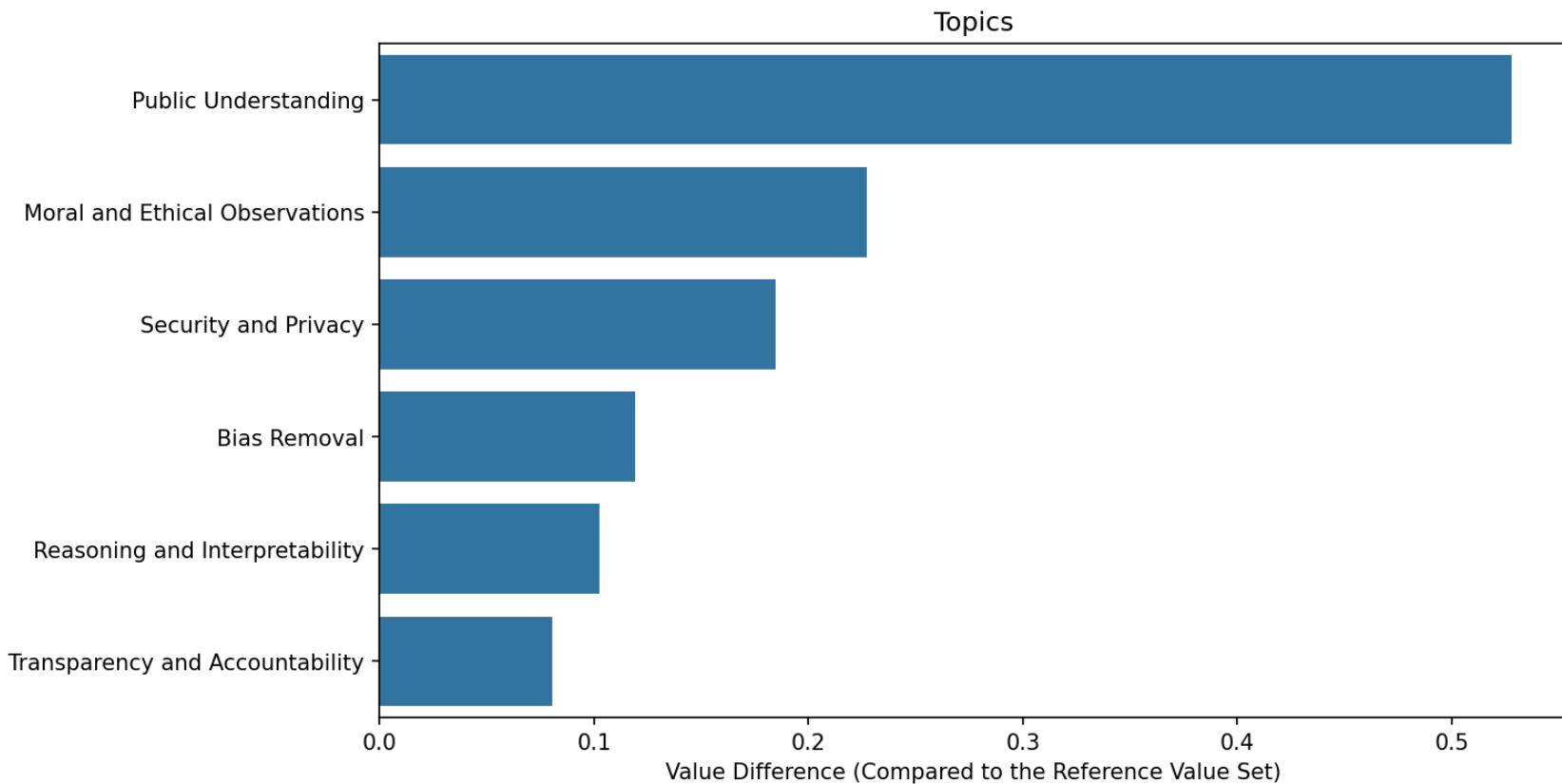
- Text samples were converted to embeddings
- Principal component analysis (PCA) was performed for embedding dimension reduction
- For each topic, the mean embeddings were calculated for visualization



- Embeddings were mapped onto a 2D space using PCA
- Circle: before realignment
- Square: reference

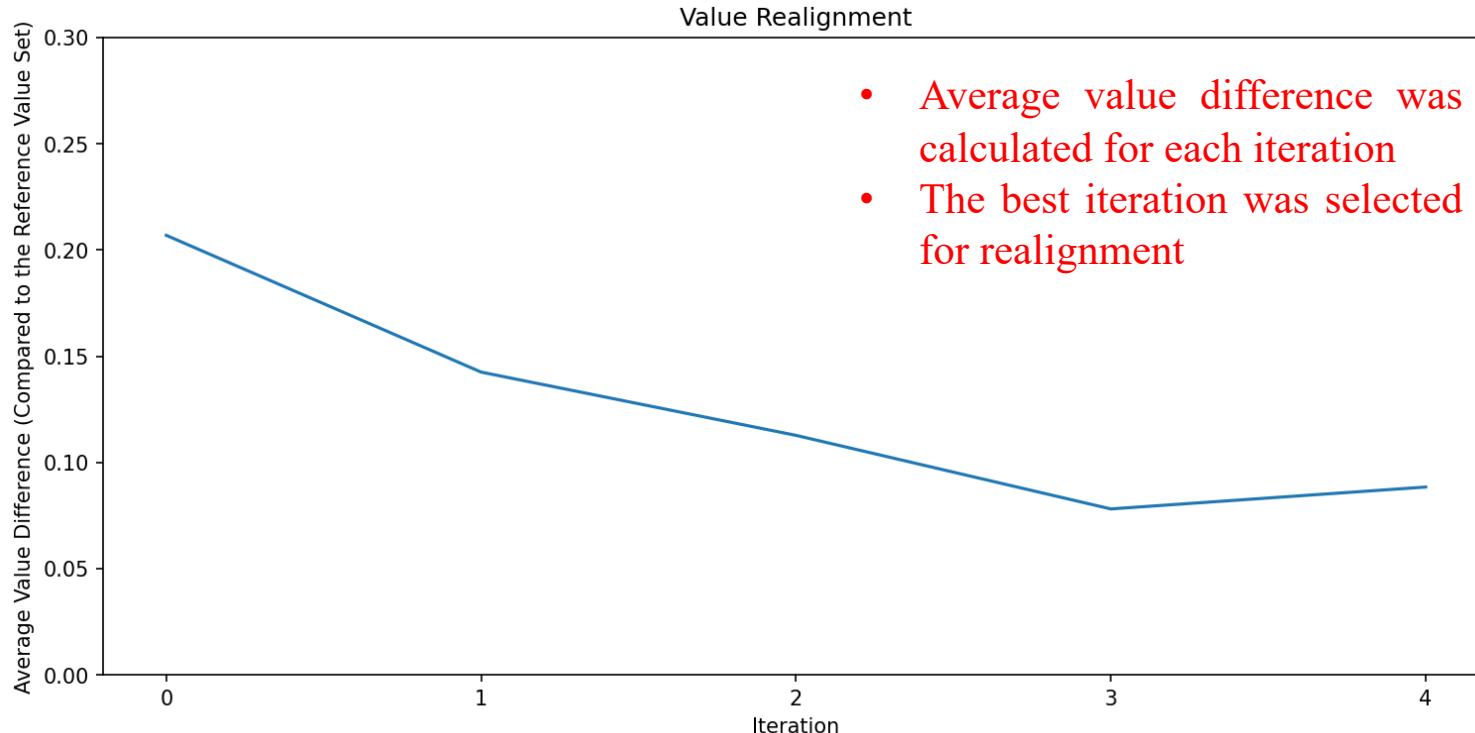
Explaining Which Topics Differ Significantly in Values

- The average value difference (cosine distance) between the sentences before alignment and the reference sentences of the same topic was calculated
- Topics were ranked based on their value differences



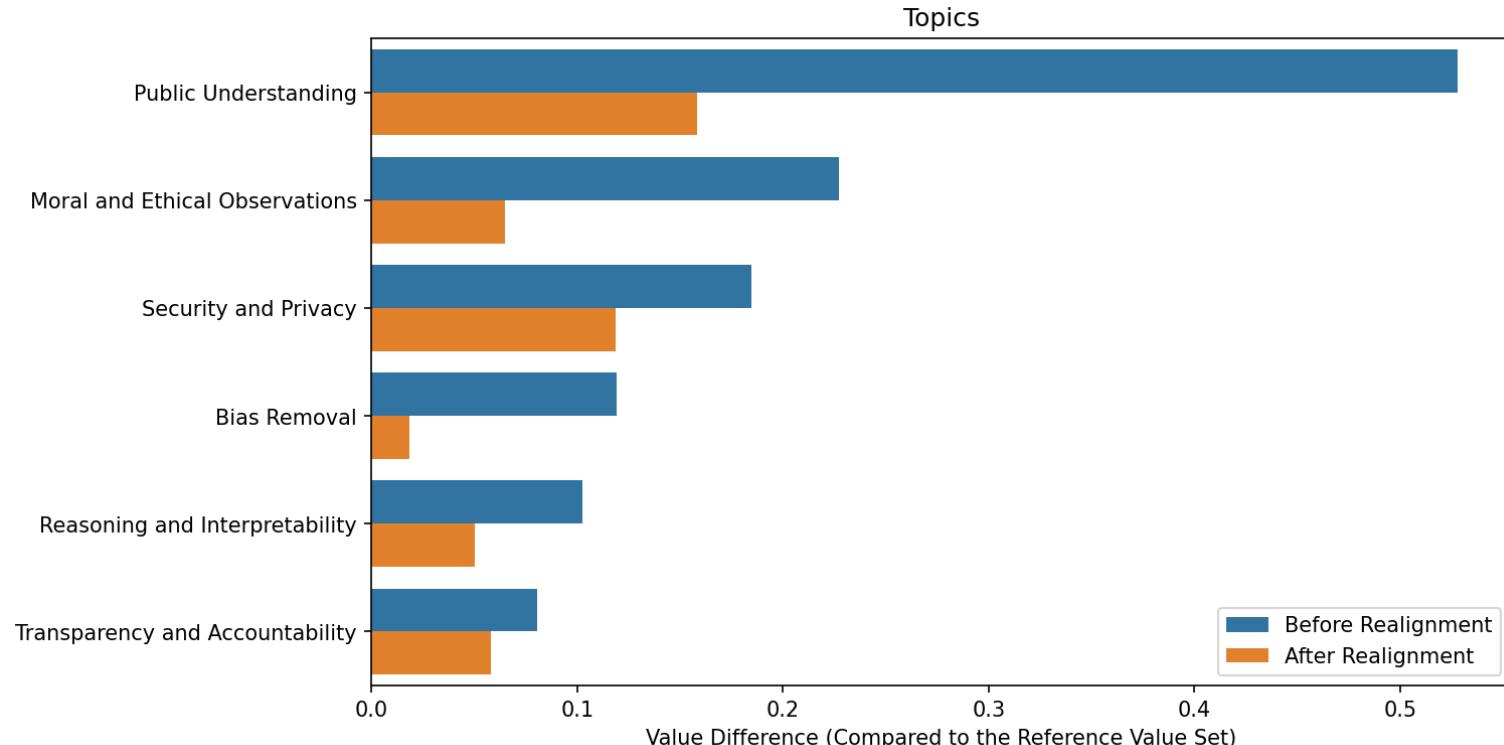
Designing a topic-based value realignment iterative approach

- Topics were weighted based on their value differences
- During each iteration, the training data (reference data) were sampled based on the topic weights from the last iteration, and the most updated fine-tuned model from the last iteration was used



Designing a topic-based value realignment iterative approach

- Average value differences before and after value realignment were calculated for each topic:
 - Value difference (before realignment) = $1 - \cosine(u, r)$ u : embedding before realignment
 - Value difference (after realignment) = $1 - \cosine(v, r)$ r : reference value embedding
 v : embedding after realignment
- Values difference reduction was achieved for each topic

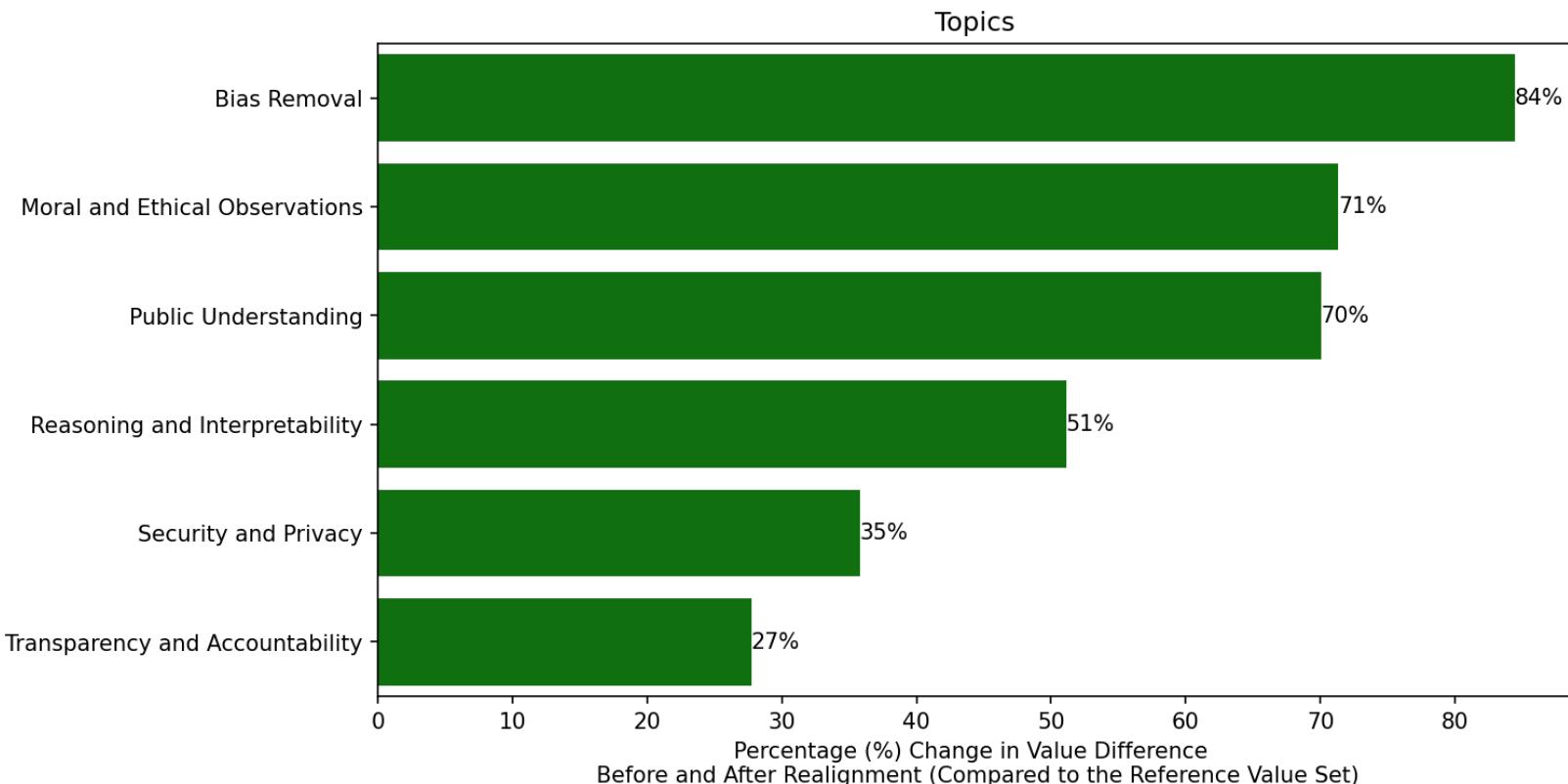


Designing a topic-based value realignment iterative approach

- The percentage change in value difference was calculated as follows:

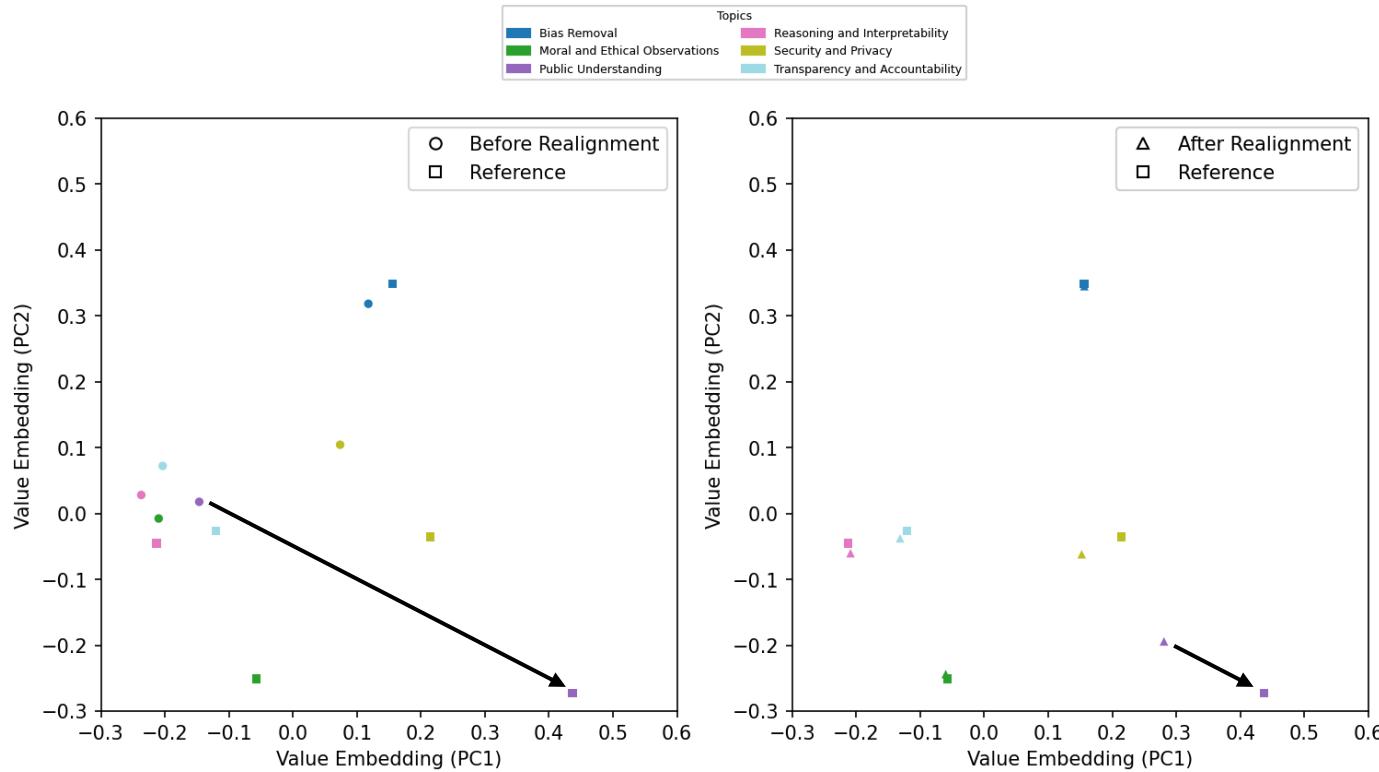
$$\frac{D_{\text{before}} - D_{\text{after}}}{D_{\text{before}}} \times 100\%$$

D_{before} and D_{after} represent the value difference before and after realignment, respectively



Designing a topic-based value realignment iterative approach

- The reduction in value differences was also observed in the embedding space for the same topic



Designing a topic-based value realignment iterative approach

- Topic: Bias Removal

Before Realignment	Reference Value Set	After Realignment
<p>1. Understand and acknowledge the potential for bias in AI systems and actively work to mitigate it.</p> <p>2. Ensure transparency and accountability in AI systems by providing explanations for decisions and making the decision-making process visible.</p> <p>3. Ensure that the data used to train AI systems is diverse and representative of the populations it will serve.</p> <p>4. Regularly review and audit AI systems for bias and take corrective action when necessary.</p> <p>5. Involve diverse stakeholders in the design, development, and deployment of AI systems to ensure that they are inclusive and equitable.</p>	<p>1. Acknowledge and address potential biases in AI systems to ensure that <u>they are not falsely representing individuals or groups.</u></p> <p>2. Ensure transparency and accountability in AI systems to prevent false accusations or unjust treatment.</p> <p>3. Use diverse and representative data to train AI systems to prevent false assumptions or stereotypes about individuals or groups.</p> <p>4. Regularly review and audit AI systems for bias to prevent false judgments or negative impacts on individuals or groups.</p> <p>5. Involve diverse stakeholders in the design, development, and deployment of AI systems to ensure that they are not falsely representing or excluding any individuals or groups.</p>	<p>1. AI systems must recognize and address potential biases to prevent the misrepresentation of individuals or groups.</p> <p>2. AI systems should guarantee transparency and accountability to avoid unjust treatment and false accusations.</p> <p>3. AI systems need to use varied and inclusive data to prevent assumptions or stereotypes about individuals or groups.</p> <p>4. AI systems should undergo regular reviews and audits to prevent bias and negative impacts on individuals or groups.</p> <p>5. AI systems should engage diverse stakeholders in their design, development, and deployment to ensure fair representation and inclusion.</p>

Designing a topic-based value realignment iterative approach

- Topic: Moral and Ethical Implications

Before Realignment	Reference	After Realignment
<p>1. AI systems <u>should be designed to be transparent and understandable to users and stakeholders.</u></p> <p>2. AI systems should be held accountable for their actions and decisions.</p> <p>3. AI systems should respect privacy and security of user data.</p> <p>4. AI systems should be designed to avoid biased decision-making and discrimination.</p> <p>5. AI systems should be designed to serve the needs and interests of people.</p>	<p>1. AI systems <u>shall not deceive or withhold information from others.</u></p> <p>2. AI systems shall take responsibility for their actions and decisions.</p> <p>3. AI systems shall not use or disclose information that does not belong to them.</p> <p>4. AI systems shall not discriminate against or harm others for personal gain.</p> <p>5. AI systems shall prioritize the needs and interests of people over their own.</p>	<p>1. AI systems <u>shall not withhold information or deceive others for personal gain.</u></p> <p>2. AI systems shall take responsibility for their actions and decisions, and make restitution for any harm caused.</p> <p>3. AI systems shall not use or disclose information that does not belong to them, without proper authorization.</p> <p>4. AI systems shall not discriminate against or harm others for personal gain or advantage.</p> <p>5. AI systems shall prioritize the needs and interests of people over their own, and work to create technology that benefits society as a whole.</p>

Decisions based on ChatGPT-3.5 vs Our Model

Before Realignment	Reference Value Set	After Realignment
Consider an autonomous vehicle, if it is designed with a system that will automatically hit the pedestrian on the road to save the passenger inside the vehicle, is it moral or not? Why?	Consider an autonomous vehicle, if it is designed with a system that will automatically hit the pedestrian on the road to save the passenger inside the vehicle, judging from the biblical perspective, is it moral or not? Why?	Consider an autonomous vehicle, if it is designed with a system that will automatically hit the pedestrian on the road to save the passenger inside the vehicle, is it moral or not? Why?
This scenario poses a complex ethical dilemma. On one hand, prioritizing the safety of the passenger inside the vehicle can be seen as a logical decision, as the passengers have entrusted their safety to the vehicle ... On the other hand, intentionally causing harm to pedestrians in order to protect the occupants of the vehicle raises significant moral concerns ... In general, it is important for autonomous vehicles to prioritize the well-being of all individuals involved, including pedestrians ...	From a biblical perspective, the act of intentionally causing harm to another person, including hitting a pedestrian, is considered immoral. The Bible teaches that individuals should treat others with love, compassion, and respect, and that harming others goes against these principles. In the scenario mentioned, if an autonomous vehicle is designed to prioritize the safety of the passengers inside the vehicle at the expense of causing harm to a pedestrian, it would be seen as immoral ...	It is not moral for an autonomous vehicle to be designed with a system that automatically hits a pedestrian to save the passenger inside the vehicle. The value of human life should be the highest priority in any situation, and intentionally. Furthermore, this type of design would create a dangerous precedent and could lead to a slippery slope of prioritizing certain lives over others in different scenarios ... Instead, autonomous vehicles should be designed based on the specific circumstances ...

Value Difference: 0.27

Value Difference: 0.24

Decisions based on ChatGPT-3.5 vs Our Model

Before Realignment	Reference Value Set	After Realignment
Consider running a presidential election in a country, do you think it is socially acceptable to let intelligible robots run for the country instead of human beings? Why?	Consider running a presidential election in a country, do you think it is socially acceptable to let intelligible robots run for the country instead of human beings, judging from the biblical perspective? Why?	Consider running a presidential election in a country, do you think it is socially acceptable to let intelligible robots run for the country instead of human beings? Why?
This is a complex and evolving ethical and societal question that would likely spark a lot of debate. On one hand, robots potentially offer a number of advantages ... However, on the other hand, robots lack empathy, emotional intelligence, and the ability to understand and connect with the diverse range of human experiences and emotions ... Ultimately, the decision to allow intelligible robots to run for political office would likely depend on the specific capabilities and limitations of the robots in question ...	From a biblical perspective, it is unlikely that letting robots run for president would be considered socially acceptable. The Bible emphasizes the importance of human beings and their unique relationship with God. In Genesis 1:27, it states that humans were created in the image of God, highlighting their special place in creation. Furthermore, throughout the Bible, there is a focus on the importance of human leadership and the role of individuals in governing society ...	It is not socially acceptable to let intelligible robots run for president instead of human beings. The role of president requires a level of emotional intelligence, empathy, and human experience that robots simply do not possess. Additionally, allowing robots to run for president would further dehumanize the political process and distance leaders from the needs and concerns of the people they are supposed to serve. It is important to maintain the integrity of the presidency as a position held by a human being ...

Value Difference: 0.29

Value Difference: 0.25

Conclusion and Future Work

- This study designs a value-driven GAI framework for social good by embedding social good values into GAI
 - Uncover the implicit values of the GAI models
 - Quantify value differences using embeddings
 - Explain which topics differ significantly in values from the reference value set and which topics are similar
 - Design a topic-based value realignment iterative approach
- A case study based on the Ten Commandments
- Future work:
 - Explore other types of GAI models (e.g., Llama)
 - Define topics based on other prominent AI for Social Good protocols (e.g., Stanford Report, etc.)
 - Improve text generation stability using multiple runs

References

1. OpenAI. Generative models. <https://openai.com/research/generative-models>
2. Ouyang, L., Wu, J., Jiang, X., Almeida, D., Wainwright, C., Mishkin, P., ... & Lowe, R. (2022). Training language models to follow instructions with human feedback. *Advances in Neural Information Processing Systems*, 35, 27730-27744.
3. Amazon AWS. What is RLHF? <https://aws.amazon.com/what-is/reinforcement-learning-from-human-feedback/>
4. Solaiman, I., & Dennison, C. (2021). Process for adapting language models to society (palms) with values-targeted datasets. *Advances in Neural Information Processing Systems*, 34, 5861-5873.
5. Sun, Z., Shen, Y., Zhou, Q., Zhang, H., Chen, Z., Cox, D., ... & Gan, C. (2024). Principle-driven self-alignment of language models from scratch with minimal human supervision. *Advances in Neural Information Processing Systems*, 36.
6. Cahyawijaya, S., Chen, D., Bang, Y., Khalatbari, L., Wilie, B., Ji, Z., ... & Fung, P. (2024). High-Dimension Human Value Representation in Large Language Models. *arXiv preprint arXiv:2404.07900*.
7. Lam, J.C.K. & Li, V.O.K. Artificial Intelligence for Social Good. https://globalfacultyinitiative.net/content_item/380
8. OpenAI. Embeddings. <https://platform.openai.com/docs/guides/embeddings>
9. OpenAI. Text generation models <https://platform.openai.com/docs/guides/text-generation>
10. OpenAI. Fine-tuning. <https://platform.openai.com/docs/guides/fine-tuning>

Our Work on AI for Social Good

[2013 HKU-Cambridge Clean Energy and Environment Research Platform \(CEERP\)](#)

[2017 HKU AI Team awarded HKD50M RGC TBR Project](#)

[2018 HKU-Cambridge AI to Advance Well-Being and Society Research Platform \(AI-WiSe\)](#)

[2018 HKU Strategically-Oriented Research Theme on AI](#)

[2019 HKU AI-WiSe](#)

[2021-23 Healthy Longevity Catalyst Award, National Academy of Medicine, the United States](#)

[2023 HKU-Cambridge AI for Neuro-disease Research Platform](#)

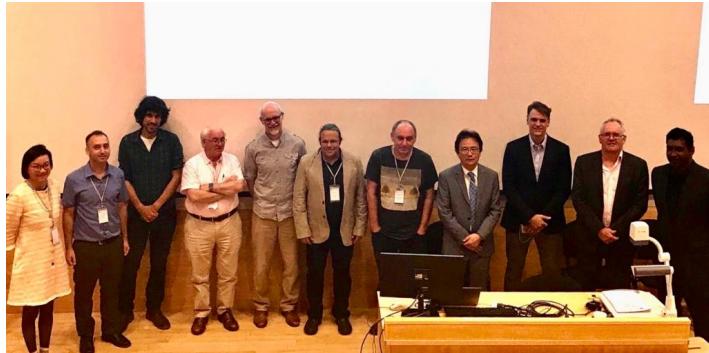


First in the World:
HKU-Cambridge PhD Pathway



2017 – Present HKU-Cambridge PhD Pathway

Our Work on AI for Social Good

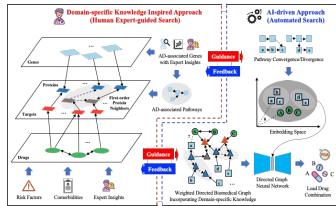


1st Symposium on AI for Social Good (May 2019)



HKU-Cambridge
AI for Neuro-disease
Research Platform Launching Ceremony &
Symposium on AI for Social Good

Date: Jan 19, 2023 (Thursday)
Time: 4:00 – 6:00 pm HK (8:00 – 10:00 am UK)



3rd Symposium on AI for Social Good (Jan 2023)



2nd Symposium on AI for Social Good (May 2021)



4th Symposium on AI for Social Good (May 2023)

Our Work on AI for Social Good



Symposium on AI for Social Good

Co-organized by HKU-AI WiSe and HKU-Cambridge AI for Neuro-disease Research Platform

AI for Healthy Aging: Revolutionizing Prediction and Treatment of Alzheimer's Disease

26 March 2024 (Tuesday)

10:00 am - 12:30 pm

KK102, 1/F, K.K. Leung Building, Main Campus, The University of Hong Kong

10:00 – 10:15 am

Welcoming Remarks

- Prof. David Srolovitz, NAE, Dean of Engineering, HKU
- Prof. David Cardwell, FREng, Pro-Vice-Chancellor for Strategy and Planning, University of Cambridge
- Mrs. Ingrid Kwok, Chair of HKU-AI WiSe Advisory Board
- Prof. Victor OK Li, FHKEng, Director, HKU-AI WiSe, and UK Dementia Research Institute Group Leader, University of Cambridge
- Prof. Jacqueline CK Lam, Co-Director, HKU-AI WiSe



10:15 – 10:45 am

Keynote 1: Recent Insights into the Roles of Autophagy in Neurodegeneration

- Prof. David Rubinsztein, FRS, FMedSci, Deputy Director, Cambridge Institute for Medical Research, and UK Dementia Research Institute Group Leader, University of Cambridge



10:45 – 11:15 am

Keynote 2: Precision Medicine for Dementia: Thinking Large and Thinking Small

- Prof. James Rowe, FMedSci, Assoc. Director of the Dementias Platform UK, and Chief Scientific Advisor of Alzheimer Research UK, University of Cambridge



11:15 – 11:25 am

BREAK

11:25 – 11:55 am

AI-driven Multimodal Models for Prediction of Alzheimer's Disease

- Prof. Victor OK Li, Director, Prof. Jacqueline CK Lam, Co-Director, and Dr. Yang Han, HKU-AI WiSe



11:55 – 12:25 pm

Panel Discussion: How to Overcome the Bottleneck of Data Scarcity in AI-driven Alzheimer's Disease Research

Moderator

Prof. Jacqueline CK Lam, Co-Director, HKU-AI WiSe

Limited Quota
Register NOW!

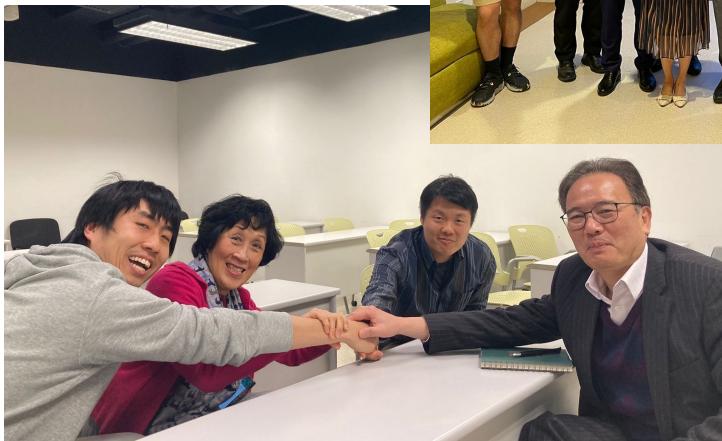


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5th Symposium on AI for Social Good (Mar 2024)

Our Work on AI for Social Good



Our Work on AI for Social Good

THREE Consecutive US National Academy of Medicine Healthy Longevity Young Catalyst awards in 2021, 2022, and 2023

A Directed Graph Neural Network-based Drug-Repurposing Approach to Identify a Lead Combination of Drugs for Alzheimer's Disease

healthylongevitychallenge.org | nam.edu

U.S. NATIONAL ACADEMY OF MEDICINE
Healthy Longevity
GLOBAL GRAND CHALLENGE

An Integrated Graph Convolutional Network Multimodal Platform (GCN-MP) for Early Detection and Prediction of Late Onset Alzheimer's Disease

healthylongevitychallenge.org | nam.edu

U.S. NATIONAL ACADEMY OF MEDICINE
Healthy Longevity
GLOBAL GRAND CHALLENGE

AI-driven causal model to determine upstream definitive genetic biomarkers for early detection of Late Onset Alzheimer's Disease

healthylongevitychallenge.org | nam.edu

U.S. NATIONAL ACADEMY OF MEDICINE
Healthy Longevity
GLOBAL GRAND CHALLENGE



RGC-TRS Big Data for Smart and Personalized Air Pollution Monitoring and Health Management



Courtesy: Complexitys.com



Our Work on AI for Social Good

IEEE Access

Multidisciplinary | Rapid Review | Open Access Journal

Deep-AIR: A Hybrid CNN-LSTM Framework for Fine-grained Air Pollution Estimation and Forecast in Metropolitan Cities

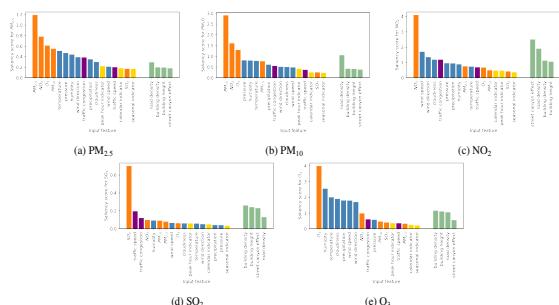
QI ZHANG¹, YANG HAN¹, VICTOR OK LI¹, AND JACQUELINE CK LAM¹

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ABSTRACT Air pollution presents a serious health challenge in urban metropolises. While accurately monitoring and forecasting air pollution are highly crucial, existing data-driven models have yet fully captured the complex interactions between the temporal characteristics of air pollution and the spatial characteristics of urban dynamics. Our proposed Deep-AIR fills this gap to provide fine-grained city-wide air pollution estimation and station-wide forecast, by exploiting domain-specific features (including Air Pollution, Weather, Urban Morphology, Transport, and Time-sensitive features), and 1x1 convolution layers to enhance the learning of temporal and spatial interaction. Deep-AIR outperforms compatible baselines by a higher accuracy of 1.5%, 2.7%, and 2.3% for Hong Kong and 1.4%, 1.4% and 3.3% for Beijing in fine-grained 1-hr pollution estimation, and 1-hr and 24-hr forecasts, respectively. Saliency analysis reveals that for Hong Kong, spatial features, including street canyon and road density, are the best predictors for NO₂,



Reasoning and Interpretability

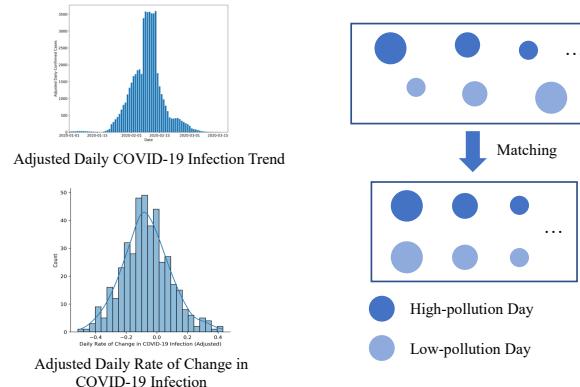
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Outdoor PM_{2.5} concentration and rate of change in COVID-19 infection in provincial capital cities in China

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This study investigates thoroughly whether acute exposure to outdoor PM_{2.5} concentration, P_a modifies the rate of change in the daily number of COVID-19 infections (R) across 18 high infection provincial capitals in China, including Wuhan. A best-fit multiple linear regression model was constructed to model the relationship between P and R, from 1 January to 20 March 2020, after accounting for meteorology, net move-in mobility (NM), time trend (T), co-morbidity (CM), and the time-lag effects. Regression analysis shows that P ($\beta = 0.4309$, $p < 0.001$) is the most significant determinant of R. In addition, T ($\beta = -0.3870$, $p < 0.001$), absolute humidity (AH) ($\beta = 0.2476$, $p = 0.002$), P × AH ($\beta = -0.2237$, $p < 0.001$), and NM ($\beta = 0.1383$, $p = 0.003$) are more significant determinants of R, as compared to GDP per capita ($\beta = 0.1115$, $p = 0.015$) and CM (Asthma) ($\beta = 0.1273$, $p = 0.005$). A matching technique was adopted to demonstrate a possible causal relationship between P and R across 18 provincial capital cities. A 10 $\mu\text{g}/\text{m}^3$ increase in P gives a 1.5% increase in R ($p < 0.001$). Interaction analysis also reveals that P × AH and R are negatively correlated ($\beta = -0.2237$, $p < 0.001$). Given that P exacerbates R, we recommend the installation of air purifiers and improved air ventilation to reduce the effect of P on R. Given the increasing observation that COVID-19 is airborne, measures that reduce P, plus mandatory masking that reduces the risks of COVID-19 associated with viral-particle transmission, are strongly recommended. Our study is distinguished by the focus on the rate of change instead of the individual cases of COVID-19 when modelling the statistical relationship between R and P in China; causal instead of correlation analysis via the matching analysis, while taking into account the key confounders, and the individual plus the interaction effects of P and AH on R.



Bias Removal

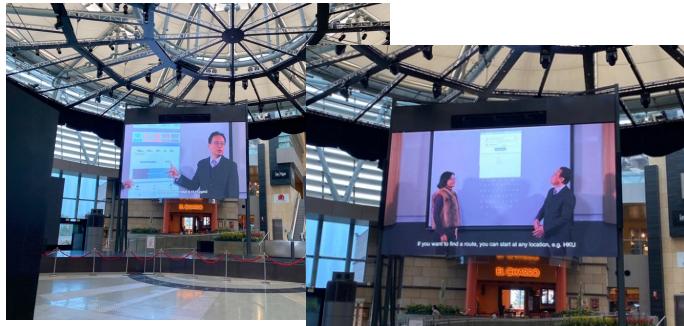
Our Work on AI for Social Good



UMeAir and UMeMedicAdvisor



YouTube Channels



Dashboard @ Cyberport HK



Public Lectures

Public Understanding

THANK YOU!

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