

UCLA

Samueli
School of Engineering

Interactive Systems



SURP 2021

UCLA SAMUELI SUMMER UNDERGRADUATE RESEARCH PROGRAM



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DEAN'S MESSAGE



Ronald and Valerie Sugar Dean

The Summer Undergraduate Research Program (SURP) provides an intensive summer research experience in a wide range of engineering and physical science fields. Undergraduate students from all walks of life participate in research with UCLA Samueli School of Engineering faculty to gain real-world lab experience.

Due to the COVID-19 pandemic that is still affecting us this summer, SURP has had to transition the program into a remote learning environment for many of its scholars. Despite this challenge, SURP's many scaffolding resources and social events have still been able to occur and students were able to:

- Conduct research in a cutting-edge field at a world-renowned research institution.
- Meet and network with a community of peers who have similar goals and interests.
- Create a professional scientific poster and publish a research abstract.
- Learn to communicate research outcomes and present a detailed Summary of Project.
- Gain a competitive advantage for engineering graduate schools.
- Learn how you can impact your community as an engineer.

This year, a record 66 undergraduate students were selected to join the 2021 SURP cohort, spread out across 31 faculty in 6 engineering departments. We are happy to announce 64% of these are women, 20% are underrepresented minorities, and many are first generation and low income students. SURP is involved with ongoing efforts in fostering a more diverse, equitable and inclusive community at UCLA Samueli Engineering.

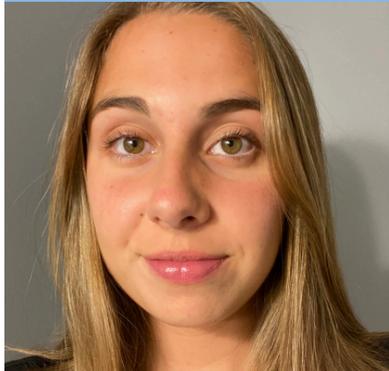
Creating new knowledge is a very difficult yet important task, and these high-performing students have done an outstanding job working through the rigors of academic research. These students should be very proud of all that they have accomplished in a short time this summer. I encourage you to explore our publication and learn about all the cutting-edge knowledge that is being created here.

Sincerely,

A handwritten signature in black ink, appearing to read "Jayathi Murthy".

Dr. Jayathi Murthy
Ronald and Valerie Sugar Dean

Sarah Kimak



Computer/Cognitive Science
Freshman, University of Delaware

Analyzing the Effectiveness of Social Robots in Children's Speech Assessments

FACULTY ADVISOR
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DEPARTMENT
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ABSTRACT

Speech recognition devices have vastly transformed people's way of life, as everyone knows of "hey google" and "Alexa," but there are greater possibilities with such systems including improving the early education of children. Many children are behind in their reading and speech acquisition skills, a direct result of lack of exposure to vocabulary and oral skills. While other companies have created intelligent tutoring systems, they do not possess the ability to pick up on the acquisition of children. In order to determine the success of a young child interacting with a social robot, a series of tasks were completed and recorded with an instructor, child and the robot JIBO. These sessions were analyzed to quantify patterns in interactions such as boredom, excitement, and frustration. The data concluded that boredom and prompts from the instructor occurred most often, showing that young children struggle the most with staying focused during the long tasks. The more interjections from the instructor, the longer the sessions lasted since they kept the children on track, but it was found only 18.7% of the recordings were a child speaking. It's suggested the tasks be shortened so that there can be more success in the students completing all of the tasks to be recorded and analyzed for future sessions. Social robots can be used in classrooms, clinician offices and even at home to develop learning at a young age that is most beneficial for the future.

Analyzing the Effectiveness of Social Robots in Children's Speech Assessments



Sarah Kimak - Speech Processing & Auditory Perception Lab
Department of Electrical and Computer Engineering
Professor Abeer Alwan & DLS Alexander Johnson
University of California, Los Angeles

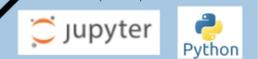
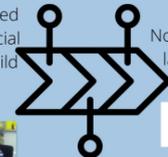


Introduction & Background

- Tech giants lack major focus on the articulation of children when creating and developing speech recognition devices
- Intelligent tutoring systems only have success with kids over 10 years old, after their crucial developmental education years [1]
- The goal of this project is to analyze how children interact with a social robot in order to determine what improvements need to be made so they can successfully conduct a session of tasks
- Robots can conduct individual and specialized lessons that benefit the child's reading, speech and language acquisition skills, which many kids are falling behind in today

Materials & Methods

1. Sessions conducted and recorded by social robot JIBO with a child aged 4-7 and an instructor [1]
2. Transcripts analyzed for patterns of boredom, excitement, needing assistance from the instructor, etc.
3. Anaconda Jupyter Notebook and Python coding language used to quantify and compare patterns



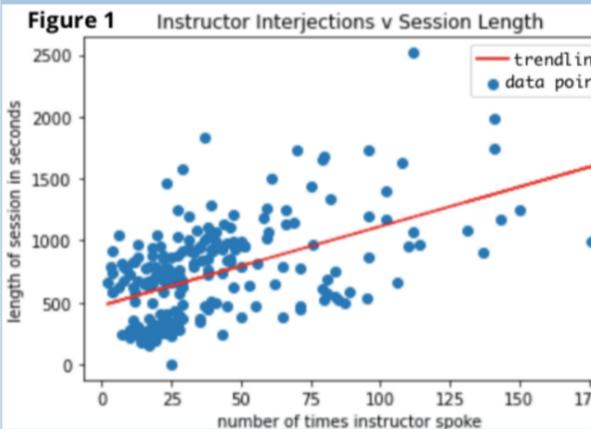
Results & Discussion

Quantifying Patterns (by hand):

- Incompletion of tasks and interjections from the instructor were the most frequent patterns that occurred.
- Analyzing by hand reveals specifics that are hard to identify with code since all sessions are unique to the student and instructor.
- The instructor interjected to move the session along when JIBO couldn't, by helping the student to get back on track or understand the assignment, and in order to get the student to give more details in the explanation task (where they had to answer personal questions about themselves and their life).

Quantifying Patterns (with code):

- A function was used to go through transcripts and total the occurrences of exact phrases showing instructor interjections:
- [I]:** 8730 the instructor was speaking in the format of the transcripts, but there is no way of knowing if they are helping the child or just making casual conversation
- anything else:** 654 - a popular secondary prompt in the explanation tasks when the instructor desired more details
- what is this:** 1920 - used as a prompt, but was also how JIBO asked children to identify images, letters and numbers



- Using the NumPy library, the Figure 1 graph was created to display how more prompts by the instructor increased session length, as indicated by both the by hand and with code analyses.
- Use of prompts such as "anything else?" and "what is this?" helped students to refocus on the task and continue answering questions.

- In using code to calculate the average percentage of student's speaking throughout all of the transcripts it was found that **only about 18.7%** of the recordings were actually the students.
- This finding demonstrates how often JIBO or the instructor were conducting the task or prompting the student.

Conclusions

- Analyzing the transcripts both by hand and with code was insightful in seeing how students interacted with JIBO, situations where JIBO could not successfully move the session along, as well as the trend of prompts by instructors increasing the length of the session.
- Students mostly struggled with the explanation tasks because they required them to form complex sentences whereas in other tasks they simply had to identify images, letters and numbers.
- A suggestion for future experiments is to adjust the length so that the students remain engaged and can actually complete the tasks. It is important for them to finish the sessions successfully in order to collect data more specific to the articulation of children, after their interaction with JIBO the social robot is improved.

Acknowledgements

- I am grateful for NSF for sponsoring my position in the 2021 SURP, which has been an amazing opportunity for me to expand my knowledge, interests, and possibilities for the future.
- A special thank you to Dr. Alwan and prior researchers for giving me an incredible project to work on and learn from this summer and my DLS Alexander Johnson for teaching and guiding me in my research and new topics of interest in the field.

References

- [1] Gary Yeung, Alison L. Bailey, Amber Alshari, Marlen Q. Pérez, Alejandra Martín, Samuel Spaulding, Hae Won Park, Abeer Alwan and Cynthia Breazeal. "Towards the Development of Personalized Learning Companion Robots for Early Speech and Language Assessment", AERA, 2019, DOI: 10.3021/431402
- [2] Gary Yeung, Alison L. Bailey, Amber Alshari, Morgan Tinkler, Marlen Q. Pérez, Alejandra Martín, Anahit A. Pogossian, Samuel Spaulding, Hae Won Park, Manushage Muzo, Abeer Alwan and Cynthia Breazeal, "A robotic interface for the administration of language, literacy, and speech pathology assessments for children", SLATE, 2019, pp. 41-42
- [3] "JIBO Robot - He can't wait to meet you." Boston, MA, 2017. [Online]. Available: <https://www.jibo.com>

Grace Kwak



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Printable Robotic Boat Swarms with Actuation and Sensing Capabilities

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ABSTRACT

The design and development of robotic devices remains limited to those with considerable time, funds, and technical expertise. Our goal is to increase the accessibility of robotics so that the average person can design and create their own robotic boats. I set out to provide a variety of boat hull morphologies with three new actuation capabilities: a propeller, paddlewheel, and rudder. After designing the 2D layout of these origami-inspired boats, I implemented them in the Robot Compiler (RoCo) framework for generating foldable robotic designs, thus allowing a user to add any actuation capability to any boat hull by setting parameters in code. I then used a paper cutter to cut out inexpensive thin plastic sheets into foldable boats with actuators driven by continuous rotation servos and DC motors. I found that the propeller produces fast linear motion, the paddlewheel enables motion that is linear and rotational, and the rudder adds more precise steering capabilities. In order to test my boats' autonomous capabilities such as following a colored object, I integrated my boats with OpenMV cameras and inertial measurement units (IMUs), which provided basic feedback-controlled movement. I found that given this relatively small set of tools and materials, it's possible to generate a wide variety of robotic boats. This work establishes a foundation for the community at large to rapidly, easily, and inexpensively create novel types of robotic boats.

Printable Robotic Boat Swarms with Actuation and Sensing Capabilities

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 Laboratory for Embedded Machines and Ubiquitous Robots
 UCLA Electrical and Computer Engineering Department



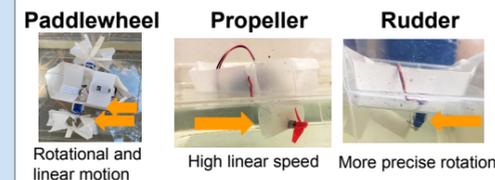
Introduction

We build upon a framework for foldable robotic designs in order to allow users to build printable robotic boats with driven propellers, paddle-wheels, and rudders.

Materials

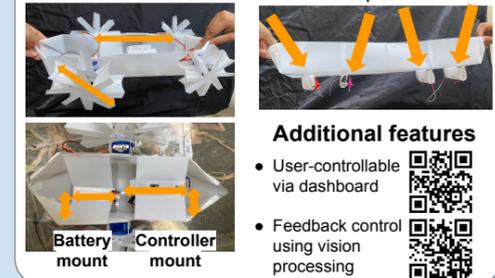


Results

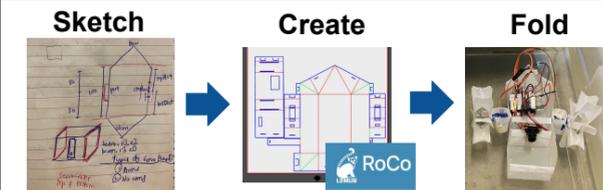


Parameterized
Adjustable dimensions and actuator positioning

Modularized
Designs can be cut and pasted

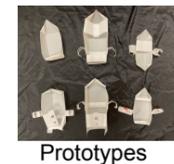


Design Process



Rapid, simple, low-cost

- Origami-like straight folds
- Tab-and-slot connections
- Single-sheet fabrication



Conclusion

Modularity + Parameterization → New Designs

Future work

- Amphibian vehicles
- Boat sails and masts



Acknowledgements

- William Herrera, SURP
- Ankur Mehta, UCLA LEMUR
- UCLA ECE Fast Track
- National Science Foundation

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Freshman, UCLA

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William Clark



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Expanding Human-Computer Interaction via Object Recognition Implemented into a Hand Signal Actuated Robotic Arm (SARA)

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ABSTRACT

Human-computer interaction (HCI) has advanced the efficacy of a multitude of sectors such as communication and consumerism. However, there exists a gap where most HCI research is conducted to improve quality in industrial aspects rather than personal aspects. Our research extends HCI to improve quality of life by designing and implementing a hand signal response AI into a six degree of freedom (6DoF) robotic arm. We call this our hand signal actuated robotic arm, SARA. An implementation of forward kinematics (FK) and inverse kinematics (IK) in python allows the robotic arm to actuate in response to complex hand signals, made possible via our hand recognition software. This software presents a real-time object-tracking process that recognizes hand signals by finger landmark mapping. A rule classifier distinguishes different variations of raised fingers. To confirm mechanical actuation and limitations, we developed a simulator in MATLAB using a virtual robotic arm that parallels SARA. Our research ultimately produced a design that, when implemented, gives SARA the capability to react to diverse hand signals independently. Qualitative demos conducted with a variety of hand signals validated our research design and implementation. A set of thirty-two hand signals was displayed to SARA that resulted in successful actuation in accordance with the simulator. The application of this design aims to assist individuals with physical limitations, making HCI more personal. The success of implementing a hand signal response AI makes the interaction with a robotic arm intuitive, ultimately expanding the scope of HCI to enhance the human experience.

Expanding Human-Computer Interaction via Object Recognition Implemented into a Hand Signal Actuated Robotic Arm (SARA)

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Introduction

Human-computer interaction (HCI) has advanced the efficacy of a multitude of sectors such as communication and consumerism. However, there exists a gap where most HCI research is conducted to improve quality in industrial aspects rather than personal aspects. Previous research has shown that it is possible to enhance HCI by integrating robotic arms into the human body.[1]

The focal point of our research involves a robotic arm, which is a mechanical appendage consisting of 6 anthropomorphic joints.

Methods

Step 1: Coding in Python

- Utilizing the library MediaPipe, we implemented a hand tracking and signal recognition software
- Using FK and IK concepts, we created software that outputs the six joint angles with an input of a position
- Referencing the motor documentation, we created code to actuate SARA to our preferences

Step 2: Simulator

To confirm mechanical actuation and limitations, we developed a simulator in MATLAB using a virtual robotic arm that parallels SARA. This was written with the help of Peter Corke's Robotic Toolbox.

Step 3: Experimental

In-lab qualitative demos conducted with a variety of hand signals enhanced our research design and implementation. Actuation was observed, recorded, and analyzed. The code was optimized based on the previous results.

Results

Below are specific results obtained from our research. The first of each set of images is the hand signal displayed to SARA. The middle image contains the simulated positions and joint angles obtained through our simulator. The last image is what SARA has actuated to after processing the hand signal shown to it.

Similar to the results shown above, an additional twenty-nine hand signals were displayed to SARA that resulted in successful actuation in accordance with our simulator.

Objective

Our research extends HCI to improve quality of life by designing and implementing a hand signal response AI into a six degree of freedom (6DoF) robotic arm. We call this our hand signal actuated robotic arm, SARA. Using SARA, we aim to bridge the gap between humans and computers.

Principles/Concepts

Forward Kinematics (FK)

is the mathematical process that allows us to find the position and orientation of the end effector on the X, Y, and Z axes from the joint angles.

Figure 1 shows the relationship between joint angles ($\theta_1, \theta_2, \theta_3$) and the position of the end effector through FK.[2]

Inverse Kinematics (IK)

is the mathematical process that allows us to find the joint angles from the X, Y, and Z coordinates of the end effector.

Figure 2 shows the relationship between the position of the end effector and the joint angles ($\theta_1, \theta_2, \theta_3$) through IK.[2]

Mathematical Methods

DH Parameters

A DH parameter table was used to find the end-effector position, via FK. The DH parameters consist of four factors: 1. link length, 2. link twist, 3. link offset, 4. joint angle. These factors can be inserted in the following table:

Joints	Theta	Link Twist (alpha)	Link length(l)	Link Offset (d)
0 - 1	0°	90°	2"	$0''$
1 - 2	0°	0°	6.75"	$0''$
2 - 3	0°	0°	8"	$0''$
3 - 4	90°	0°	$0''$	$0''$
4 - 5	90°	0°	$0''$	$0''$
5 - 6	90°	0°	$0''$	$0''$

Rotation Matrix

Rotation matrices were derived from the DH Table above. The following formula shows the relationship between the different matrices:

$$R_6^3 = R_3^{0-1} R_6^0$$

The formula corresponding to the rotation for joints 3-6 is:

$$R_6^3 = \begin{bmatrix} -s\theta_3 c\theta_2 c\theta_1 - c\theta_3 s\theta_2 & s\theta_3 c\theta_2 c\theta_1 - c\theta_3 c\theta_2 & -s\theta_3 s\theta_2 & c\theta_2 c\theta_1 c\theta_3 - s\theta_2 s\theta_1 & -c\theta_2 c\theta_1 c\theta_3 - s\theta_2 s\theta_1 & c\theta_1 c\theta_3 & -s\theta_2 c\theta_3 & c\theta_3 & s\theta_2 s\theta_3 + c\theta_3 & c\theta_3 & s\theta_3 \end{bmatrix}$$

The formula to find all theta angles is:

$$\theta_1 = \tan^{-1}(y/x)$$

$$\theta_2 = \tan^{-1}(s_3/c_3)$$

$$\theta_3 = \tan^{-1}(\frac{(c_3 a_3 + a_2)(z - s_2 4a_4) - s_3 a_3 (x c_1 + y s_1 - c_2 4a_4)}{(c_3 a_3 + a_2)(x c_1 + y - c_2 4a_4) + s_3 a_3 (z - s_2 4a_4)})$$

$$\theta_4 = 234 - 2 - 3$$

$$\theta_5 = \tan^{-1}(\frac{c_2 34 (c_1 a_3 + s_1 a_2) + s_2 34 a_2}{s_1 a_3 - c_1 a_2})$$

$$\theta_6 = \tan^{-1}(\frac{-s_2 34 (c_1 a_3 + s_1 a_2) + (c_2 34 a_2)}{-s_2 34 (c_1 a_3 + s_1 a_2) + (c_2 34 a_2)})$$

* s = sin, c = cos, x, y, z = end position; # = θ_n , a = link length; O = link twist; n = origin

Conclusion

In this research, we successfully implemented a hand signal recognition AI, an accurate simulator, and actuation with FK and IK. Our research ultimately produced a design that, when implemented, gives SARA the capability to react to diverse hand signals independently.

Impact

This design aims to assist individuals with physical limitations, making HCI more personal. This ultimately reduces the communication gap between computers and humans.

Future Work

Continued research of signal recognition could explore the possibility for machines to read and react to human emotions. Future studies may involve the expansion of the SARA prototype to include an applicable end effector, such as a gripper or other tools.

References

[1] Sasaki, Tomoya, et al. "MetaArms: Body Remapping Using Feet-Controlled Artificial Arms." The 31st Annual ACM Symposium on User Interface Software and Technology Adjunct Proceedings, 11 Oct. 2018, pp. 65-74, doi:10.1145/3286037.3271628.

[2] "Forward and Inverse Kinematics Part 1." YouTube, August 3, 2011, <https://www.youtube.com/watch?v=Vjsu8T4NpXk>

Acknowledgements

We would like to thank Professor Chen for providing us the opportunity to do research through the UCLA Summer Undergraduate Research Program (SURP). We also would like to thank Nick Li for offering us guidance and knowledge throughout our time with him. Lastly, we would like to express gratitude towards Will Herrera and the SURP staff for their hard work in organizing this program.

Materials

- Python IDE Pycharm
- Python Library MediaPipe
- R+ Manager
- a six degree of freedom (6DoF) robotic arm
- six Dynamixel XM540 motors
- 11.1 V Battery
- Peter Corke's Robotics Toolbox MATLAB

Jaehoon Song



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Freshman, Irvine Valley College

Origami Webapp User Interface & Integration of New Designs

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Electrical and Computer Engineering

ABSTRACT

The Origami Design App is a web application that can view, compile, and change the parameters of robots along interfaces. UCLA's LEMUR originally designed this webapp as a means to make robot compiling easier for those that lack the engineering or the programming background. I integrated some of the functionalities such as being able to view necessary component files when inputting a subcomponent into a html form by using a PATH method. This is significant because a user could potentially compile a robot easier or faster than using the standard RoCo application. I also edited some of the existing user interface such as editing the style of transitioning buttons with css files to provide the user with optimal visual experience. For the future, I plan to conduct a user study to observe that the changes I have implemented have benefited the Origami Design App and prove that the changes within the user interface were successful. I also plan to implement the functionality to combine components along interfaces which will most likely reduce the time that a user needs to spend in order to design a robot.

Origami Webapp User Interface & Integration of New Designs



Introduction

The Origami Design App is a web application that can view, compile, and change the parameters of robots along interfaces.

Web Interface Interaction

Results & Discussion

URL: 192.168.86.82:5000/Paperbot#

Loading models using POST method:

- Enables loading models much easier
- Can automatically call models within the library
- Load in new designs for better view

Tank Model:

- Loaded using POST method
- The '#' indicates that it has used POST

Component

Tank

- Takes user input and converts it into a component
- the need for compiling two additional python scripts eliminated

Objective

The goal is to improve the user interface of Origami Design App and to create an environment where a user without an engineering or programming background can easily and quickly compile robots.

RoCo

RoCo: Robot Compiler

Builder files

- Standard RoCo application is a set of python scripts
- component files that the webapp uses are generated here

RoCo Library

Rocolibrary: Library that contains pre-built/newly built component/models

- Webapp uses Rocolibrary to render designs

HTML

HTML and Jinja was used to inherit templates:

- Used delimiters to inherit the navigation bar
- Used html tags to create an easily navigable builder option which directs to the builder page

Jinja

By using **Jinja**, a templating engine, I was able to:

- Inherit templates
- Used python codes on html
- Used delimiters to fetch the user input

```
"{{ request.form["nm"] }}"
```

GET

GET method: fetches data from the server

- Used for rendering designs from thumbnails

Conclusion

- Easier robot compiling for those that lack the engineering or the programming background
- Plan to implement combining components along the interface
- New Interface Design

MODELS

name	name	name
name	name	name

User Interface

CSS Stylesheets:

- Used for general styling and layout
- Bigger and aligned transition buttons

Post

POST method: sends data to the server

- HTML input sends data to the server
- Loads the model that was sent

Acknowledgements

- Dr. Ankur Mehta, UCLA LEMUR
- William Herrera, Summer Undergraduate Research Program
- Grace Kwak, Bhavik Joshi, Jillian Pantig, Marisa Duran, Shahrul Kamil Hassan, and Sudarshan Seshadri
- NSF REU



Tyler Xu

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A Personalized Approach to Federated Learning

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ABSTRACT

Federated learning, a machine learning technique, has been gaining popularity as a method of protecting user data privacy for modern-day devices while still providing a great user experience by only sending model updates to the server instead of exchanging sensitive data. However, utilizing a singular global model is extremely restricting as the data is exceedingly diverse, which limits the global model from maximizing performance for each individual client. This heterogeneously distributed data across multiple clients is the primary motivation in utilizing personalized versions of federated learning. In this research, we implement algorithms that use personalized federated learning techniques such as clustering clients and utilizing temporary models for communication. Various hyperparameters - batch size, local communication rounds, number of clients - are adjusted to maximize the algorithm's accuracy levels. The algorithms are implemented using PyTorch (a machine learning library developed by Facebook's AI Research Lab) and both trained and tested using the CIFAR-10 image dataset. Using random heterogeneously distributed data, the algorithms converge to higher accuracy levels through these personalization techniques when compared to traditional federated learning utilizing a singular global model. Personalized federated learning is a key component within future machine learning applications - such as connecting autonomous vehicles - as it combines the effectiveness of traditional machine learning with crucial cloud security and data privacy protection.

SUMMER UNDERGRADUATE RESEARCH PROGRAM

A PERSONALIZED APPROACH TO FEDERATED LEARNING

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FAST TRACK TO SUCCESS
UCLA Electrical and Computer Engineering

Introduction

Problem
Federated learning struggles with non-IID (non-independent and identically distributed) diverse datasets due to its reliance upon a singular global model for multiple clients (devices). This traditional strategy is limited, as one global model cannot maximize the testing accuracy for different sets of data.

Approach
Implement personalized federated learning algorithms. Personalized techniques (client clustering and utilizing temporary models) will result in algorithms converging to higher accuracy levels.

Results and Discussion

Setting batch size to 50, local epochs to 20, and number of clients to 6, the hyperparameters of regularization (reg) and learning rate levels are adjusted to achieve the optimized accuracy for the personalized (pFedMe) federated learning algorithm.

FedAvg Individual Client Model (IID)	FedAvg Global Model (non-IID)	pFedMe Personal Model (non-IID)
73%	49%	79%

Personalized Federated Learning Results
0.01 Learning Rate, 20 Regularization

Learning rate of 0.01 and regularization of 20 converges to the highest testing accuracy rate of 79% for the personalized algorithm. A lower regularization is too slow to converge, while a high regularization will diverge.

	Reg 30	Reg 20	Reg 15	Reg 10	Reg 5
Learning Rate 0.01	76%	79%	78%	77%	74%
Learning Rate 0.05	71%	75%	74%	72%	70%

Materials and Methods

References

McMahan, H. Brendan, et al. "Communication-Efficient Learning of Deep Networks from Decentralized Data." ArXiv.org, 28 Feb. 2017, arxiv.org/abs/1602.05629.

Dinh, Canh T., et al. "Personalized Federated Learning with Moreau Envelopes." ArXiv.org, 3 Mar. 2021, arxiv.org/abs/2006.08848.

Conclusions

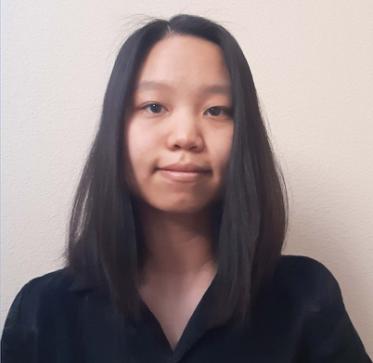
Personalized federated learning algorithms allow for models to outperform traditional federated learning algorithms when using non-IID data. Future implementation of other personalized algorithms such as FedFomo will further showcase the advantages of personalization techniques.

These techniques are key components within future machine learning applications (autonomous vehicles, traffic predictions, etc.) as they increase the performance of machine learning models on heterogenous datasets while eliminating data security risks within the cloud.

Acknowledgements

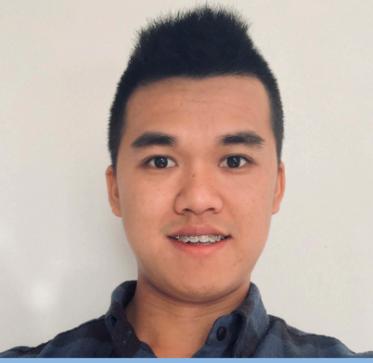
I would like to thank Kaan Özkara and Suhas Diggavi for their guidance and resources throughout this project. I would also like to thank NSF (REU) for their funding and the UCLA Summer Undergraduate Research Program (SURP) for this research opportunity.

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Reinforcement Learning in an Imperfect Information Game

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DEPARTMENT

Electrical and Computer Engineering

ABSTRACT

Reinforcement learning (RL) has been a growing subset of machine learning with increasing success and promise - but it has just begun to be used in complex, multiplayer environments and games. An agent learns in a complex environment through trial and error, beginning from fully random trials and finishing with sophisticated actions. We apply RL to the imperfect information game known as Liar's Dice, which presents a challenging mix of two-player dynamics and partial information to explore. The game forces players to call bluffs and doubt opponents while reading others' potential actions. Implementing reinforcement learning to imperfect information games allows us to find successful strategies and models in dynamic Markov Decision Process (MDP) environments that require sequential decision making. Utilizing both Python and MATLAB, we employed the popular Q-learning method of RL to train agents that begin with random actions or to use a combination of fixed strategies against others. An agent employing Q-learning improved its win rate from 50% to only 65% within 1,000,000 episodes against a simple agent. On the other hand, an agent that made decisions based on various fixed strategies available increased its win rate from 11% to 77.7% with 100,000 episodes. Those varying speeds demonstrate the difficulty of learning and the variability of Q-learning in a game with partial information. In future work, we may compare counterfactual regret minimization and more state-of-the-art RL algorithms, which would expand our understanding of various methods of a partially observed, dynamic environment such as Liar's Dice. By studying this game, we hope to one day broaden our results to the education space, a similar Markov process where individuals also make decisions sequentially. Using intervention tools such as quizzes and lectures, the interactions between students and instructors may be refined to improve student learning outcomes.



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Reinforcement Learning in an Imperfect Information Game

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Introduction

- As an imperfect information game, players in Liar's Dice are not omniscient.
- To find optimal strategies and models in dynamic Markov Decision Process (MDP) environments that require sequential decision making, we coded and tested out various agents to find key aspects.
- We applied reinforcement learning (RL), particularly Q-learning, to assist us with producing results regarding the most effective methods.

Key Terms

- Q-learning is an off-policy RL algorithm, and it learns from outside the policy taking random actions.
- SARSA is State-Action-Reward-State-Action on-policy RL algorithm and it updates the policy based on taken actions.

Game Rules

Within the scope of our work, Liar's Dice is a two-player game, where each player rolls 5 dice and has visual access solely to their own hand.

The first player begins bidding and announces any face value (max of 6) and the number of dice (max of 10). The other player has two choices: they may make a higher bid with a larger face or quantity, or they may call "Liar," whereupon all dice are revealed to examine the bid. The winner is determined by the validity of the latest bid.

Objectives

We aim to employ reinforcement learning methods, particularly Q-learning and SARSA algorithms, to attempt to outperform fixed strategies and, ultimately, beat a human player.

Methods

Project Diagram

```

graph TD
    A[Program a LD Game in Python Language] --> B[Naive]
    A --> C[Aggressive]
    A --> D[Honest]
    A --> E[Trust]
    A --> F[Probabilistic]
    A --> G[Training RL Methods]
    G --> H[Q-Learning Algorithm]
    G --> I[SARSA Algorithm]
    G --> J[Characteristics of Strategies]
    
```

- Set up a sequential environment where an agent's current actions influences its future moves across different episodes.
- Generate a series of game strategies as a baseline.
- Establish two reinforcement learning algorithm methods, tabular and meta-RL, to learn to play against other bots.

Tools

Baseline Bots (Fixed Strategies Agents)

- Naive: Makes a valid random bid.
- Honest: Calls the smallest honest bet in its hand.
- Aggressive: Calls the highest honest bet in its hand.
- Trusting: Makes a bid based on the opponent's call or calls the lowest bid in its hand.
- Probabilistic: Calculates the probability of calls and makes a move based on the results.

A Reinforcement Learning Bot

```

graph TD
    Start --> Init[Initialize random Q-values to the Q-Table]
    Init --> Begin[Begin the episode]
    Begin --> Choose[Choose an Action a in a State s using ε-greedy policy]
    Choose --> Perform[Perform that Action]
    Perform --> Measure[Measure Reward]
    Measure --> Move[Move to the new State s']
    Move --> Update[Update the Q value of the previous state by the learning function]
    Update --> Terminal{Is a terminal state?}
    Terminal -- No --> Choose
    Terminal -- Yes --> End
    
```

The Q-learning equation:

$$Q(s, a) = Q(s, a) + \alpha[R + \gamma \max_{a'} Q(s', a') - Q(s, a)] \quad (1)$$

The SARSA-learning equation:

$$Q(s, a) = Q(s, a) + \alpha[R + \gamma Q(s', a') - Q(s, a)] \quad (2)$$

Results and Analysis

Part 1: Examined Fixed Bots' Performance

	NaiveAg	HonestAg	ProbAg	MixedAg
Human	90%	80%	60%	55%

Figure 1: By playing 25 games, we may evaluate the strengths and weaknesses of each bot. A human can beat the naive and honest agents easily after 3 to 4 games. Since we programmed the various agents with a particular functionality, we are able to quickly distinguish the strategy that the bot employs. The mixed agent, an advanced version of trust, honest, aggressive, and probabilistic agent combined, is more effective against humans.

Part 2: RL Bots' Performance

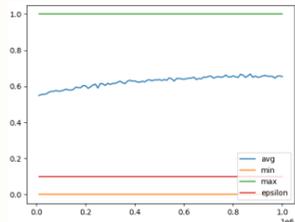


Figure 2: Q-learning agent begins with random actions and learns effective strategies against the naive agent over 1 million episodes of the game with constant epsilon $\epsilon = 0.1$. As this algorithm is a direct tabular Q-learning approach with more than 2 million Q-values, its learning curve is flat with a low slope value.

Conclusion

The agent employing Q-learning generates a better performance by learning to choose an optimal action compared to other fixed strategies. However, this study indicates that the true Q-learning model is slow and requires innumerable training episodes - at least 2 million - to learn effectively. In future work, we plan to explore counterfactual regret minimization and the ReBEL Facebook algorithm to reverse the downsides of our model and ultimately apply reinforcement learning to other dynamic environments that require sequential decision making, such as education.

References

- Brown, N., Bakhtin, A. (Dec 03, 2020). ReBEL: A general game-playing AI bot that excels at poker and more. <https://ai.facebook.com/blog/rebel-a-general-game-playing-ai-bot-that-excels-at-poker-and-more/>
- Sutton, Richard, Barto, Andrew G. Reinforcement Learning An Introduction, The MIT Press.
- http://www.en.wikipedia.org/wiki/Liar_Dice

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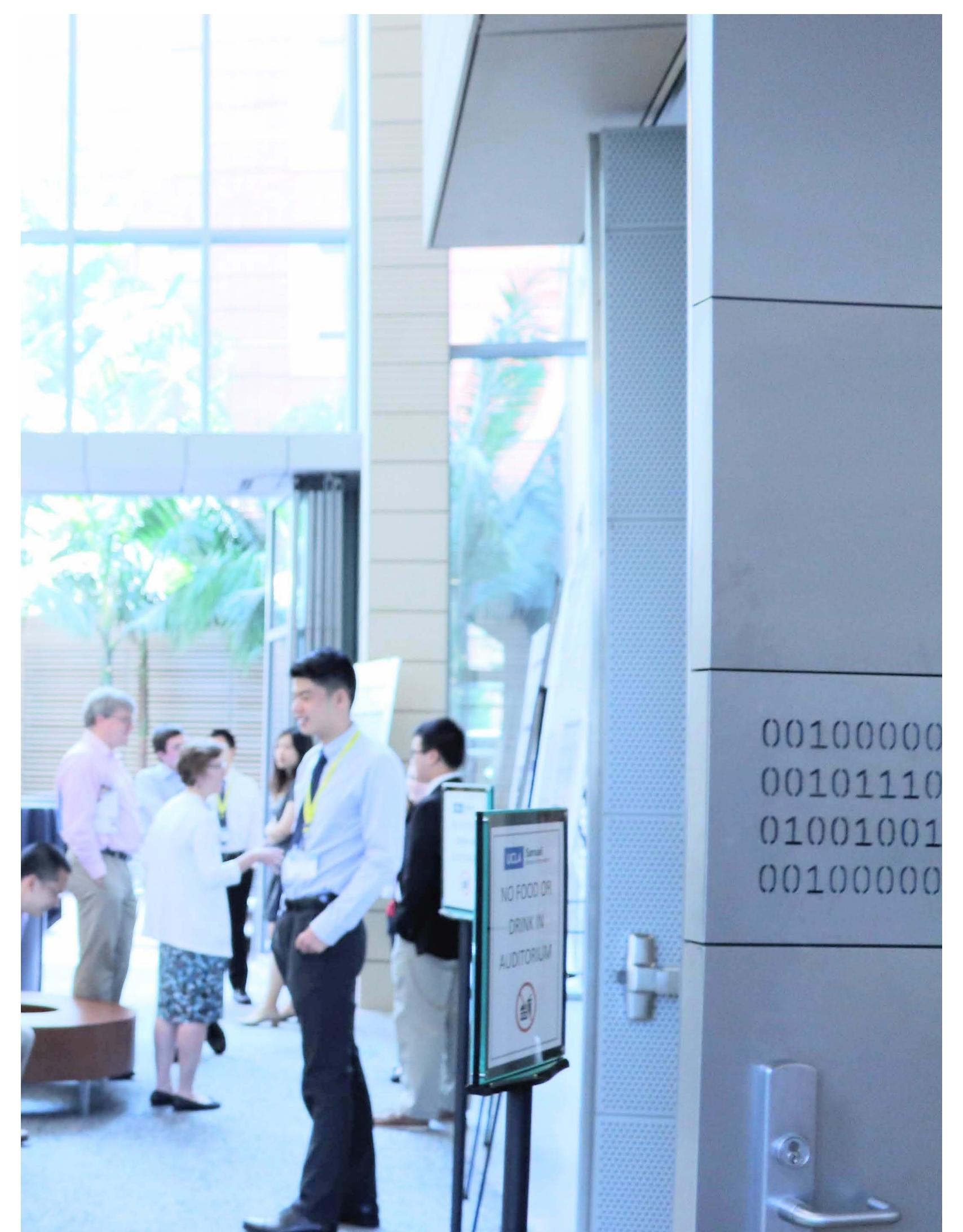
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