CAP6671 Intelligent Systems

Lecture 18:
Exam Review
Modeling Humans
Conclusion

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Announcements

- Class cancelled on Mon
- Grades released for the RLAgent assignments and Presentations
- Final projects
  - 1 week extension possible but I recommend that you finish by this weekend.
- Final exam to be given as an open book timed Webcourses quiz
  - 3 hours in duration
  - To be taken some time between Apr 26-29
  - Make sure that you have a good internet connection since I don't allow exam retakes.

Exam Material

- No material on ROS
- No material from the student presentations.
- Everything else (assignments, papers, and lecture notes) is fair game
- Most of the focus will be on the lecture notes but since this is open book I will ask a few detailed questions about the papers!

Exam Format

- To be made available as a webcourses quiz.
- Can be taken between Apr 26-29
- Open book but no collaboration with other people!
  - No ChatGPT usage
- Short answer (3-4 sentences) about a specific point in the paper
- You will have to understand how the algorithms and systems work; you will be expected be specific
- Minimal math required

Example Question

- How does a plan differ from a policy? (supplement your answer with definitions and examples)

Multiagent Systems

- **RETSINA** multiagent system
  - General organization
  - Overview of internals of system
- Definitions of coordination types
- Research questions
- Case studies of using MASs for aircraft maintenance and military planning

Planning

- Dockworker domain
- STRIPS notation
- Must know **Graphplan**
- Do not need to understand internals of UCPOP
- Must understand general ideas behind HTN planning
- Understand limitations of **classical planning** and issues such as the **Sussman anomaly**
- Monte Carlo search
- Bandit algorithms
- **Upper Confidence bounds for Trees** (UCT)

Trading Agent Competition

- Must understand basic rules of TAC Classic competition
- Must understand ideas behind combinatorial valuation and **bidding**
- Must understand general operation of ATTac and Roxybot
- **Markov Decision Process**
- General ideas behind **Sample Average Approximation** (Roxybot)
- Not responsible remembering details of competition results

Robocup

- General research questions
- Problems addressed by specific leagues
- Details of the CMU-United team (TPOT-RL, potential field mechanisms, locker-room coordination)
- **UT Austin Villa**: dynamic role assignment and positioning system
- Selectively Reactive Coordination architecture
- Urban Rescue league and HRI issues
- No need to remember the specific results from competitions

Starcraft

- Description of the competition
- What makes RTS games interesting for AI
- Bot internals
- Unit micro strategy experiments

Reinforcement Learning

- Exploration vs. exploitation for policy search
- **Q-learning**
- Value iteration
- Model-free vs. model-based RL
- **Transfer learning**
  - Case study for Robocup
- Multi-agent learning (TPOT-RL)

Deep Learning Review

- Perceptron and perceptron learning rule
- **Neural network** and backpropagation
- Convolutional NN and max pool
  - Do not need to know recurrent RNNs and LSTMs
- **DQN** (basic)
- Policy gradient and actor critic

Robotics: Path Planning

- Fundamental concepts of map representation and terms
- **A*** and real-time A*
- Wavefront planner
- Workspace vs. configuration space
- Sampling planners (RRT, PRM)
- Graph-based planning and extraction (e.g., Voronoi/visibility graphs)
- No questions on ROS

Robotics: Localization

- Must understand general research issues behind mapping, localization and coverage
- Must understand Bayesian updating
- Must understand the process of belief update on maps
- Must understand operation of **Monte Carlo localization**
- Must understand general SLAM problem and these approaches
  - FASTSLAM
  - Kalman filter

Multi-robot Coordination

- Auction-based approach
- CoCOA: Mixed-integer linear programming
- General problem: Multi-agent Path Finding

Modeling Humans

- Motivation for social simulation research
- Background on SocialSim competition
- Operation of cross-platform simulations

Human Behavior Prediction

- We can use AI to model and predict human behavior.
- Why is this useful?

Human Behavior Prediction

- We can use AI to model and predict human behavior.
- Why is this useful?
  - Address HCI usability questions
  - Debug social-computational systems
    - MMOGs, social media platforms, crowdsourcing
  - Guide public policy decisions

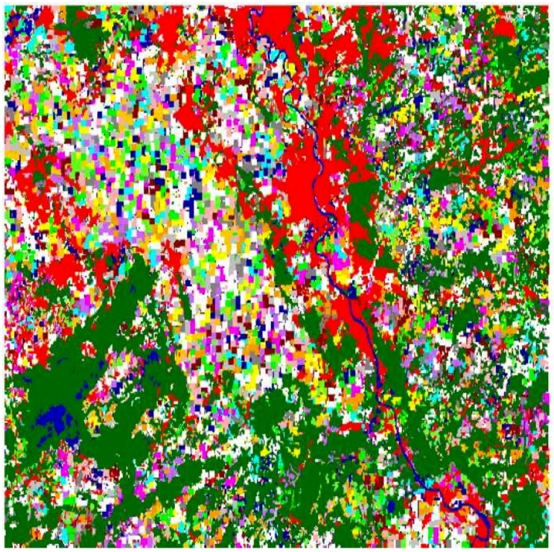
Techniques for Human Modeling

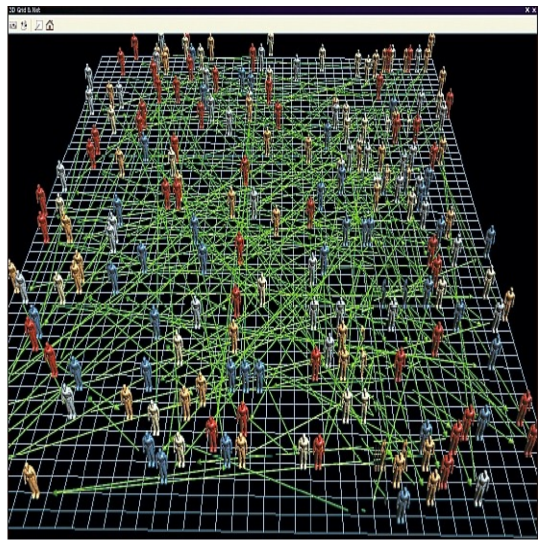
- Machine learning:
  - Time series prediction
  - Collective classification
    - Leverage network information
- Agent-based modeling:
  - Complex adaptive systems
    - Complexity arises from connections!
  - Cognitive agent architectures
    - Monolithic models that emulate human processing
- Fusion of two techniques

Reading

- Muric et al, Massive Cross-Platform Simulations of Online Social Networks, AAMAS 2020
  - This paper describes research that was done under the DARPA SocialSim program which also funds my research.

Future of Social Simulation?





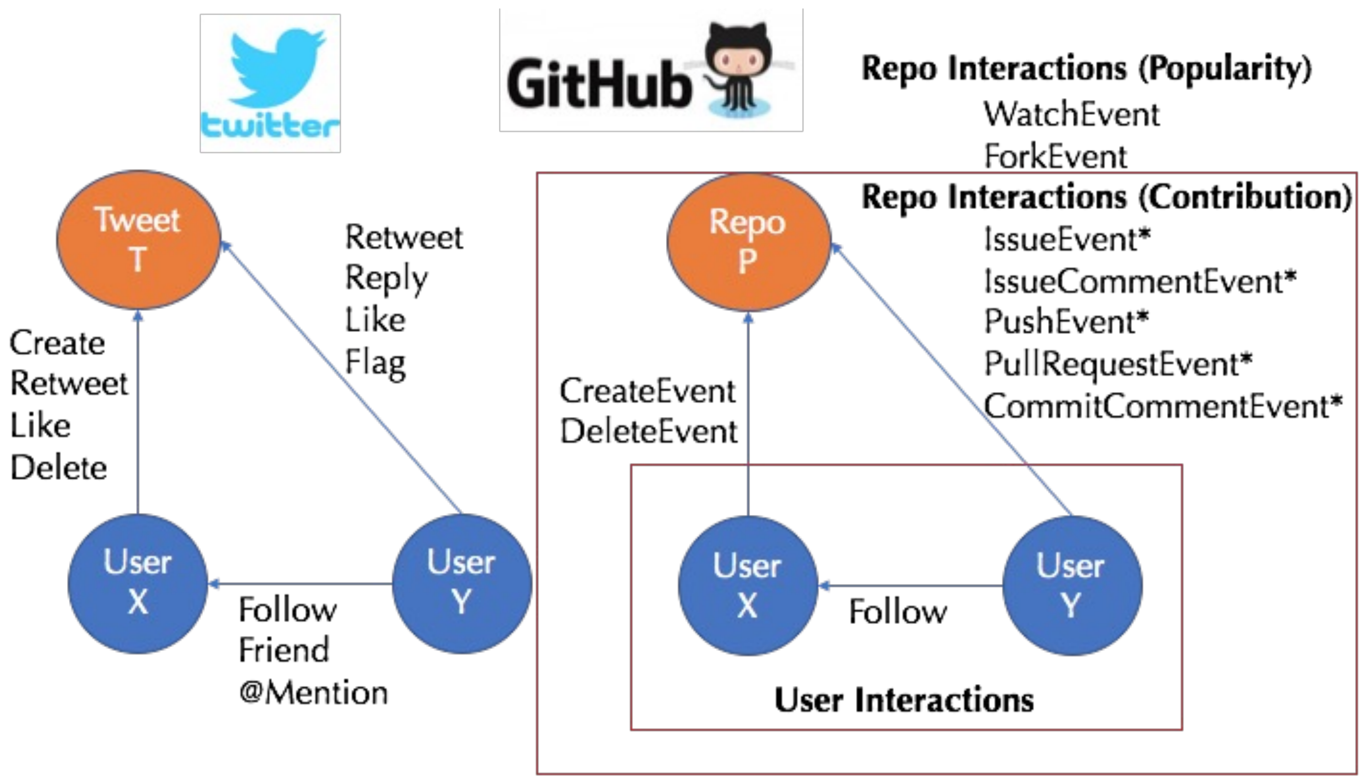
PAST NOW FUTURE

How do we achieve the vision of versatile, large-scale, high fidelity, social simulation?

- ***Bootstrap simulations with social media data***
- ***Rigorously test and measure simulation accuracy***

SocialSim Challenge

- 7 teams competing:
  - UIUC, USC, Rutgers, VTech, USF, and 2 different UCF teams
- Predict GitHub event time series 2 months into the future after viewing 26 months



Evaluation

Old Repos

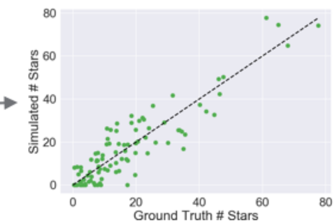
New Repos

Simulation

Ground Truth

Repo	Simulation	Ground Truth
repo1	20	15
repo3	10	-
repo4	34	36
repo5	-	31
repo_a	27	-
repo6	-	17
repo_b	23	-

Repo	Sim Count	Truth Count
repo1	20	15
repo4	34	36



Simulation

Repo	Count
repo1	20
repo3	10
repo4	34
repo_a	27
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Ground Truth

Repo	Count
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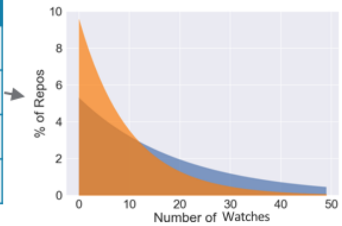

Simulation

Repo	Count
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Ground Truth

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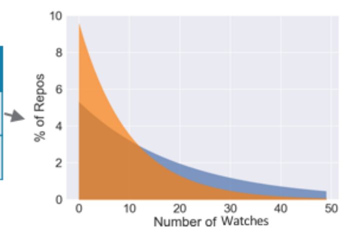
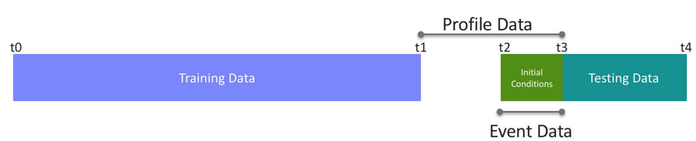
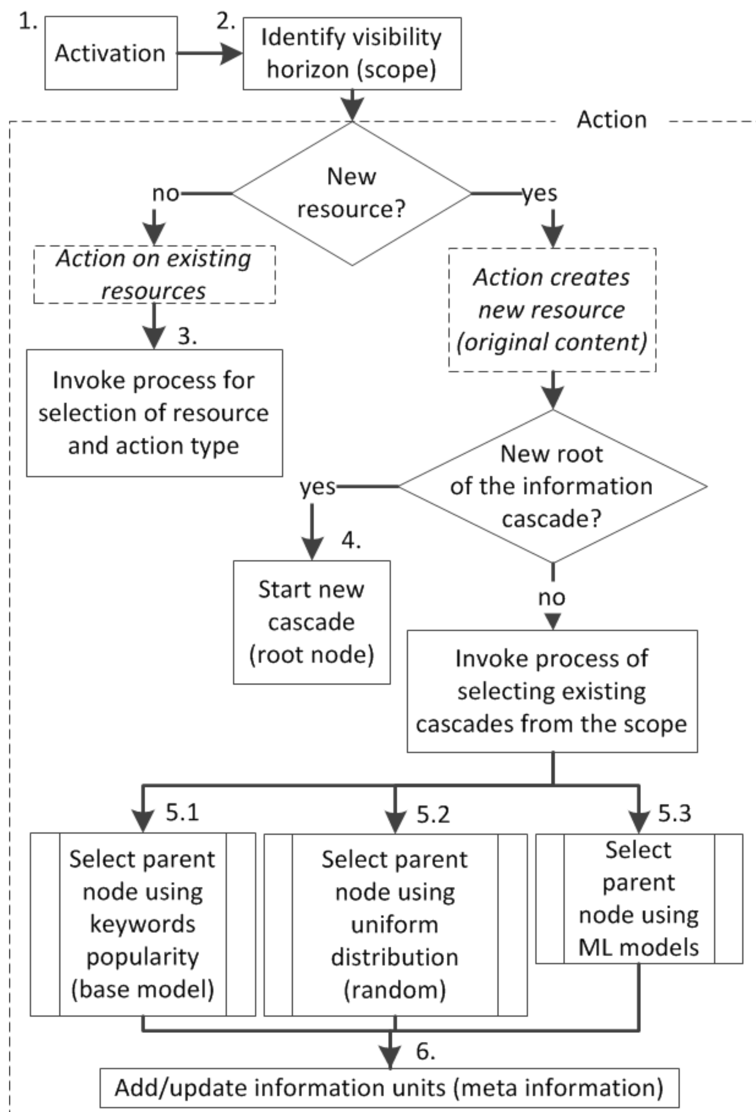




Our Team's Approach

- Creating a large set of agent-based models coded in Netlogo and Repast HPC
- Each model attempts to capture a different social theory
  - Diffusion of Information
  - Complex Adaptive Systems
  - Reputation Knowledge Economy
  - **Data-driven User Archetypes**
- Model parameters are learned and combined using evolutionary model discovery

DASH Agent (USC)



My Work: Cluster-based Archetypes

- Hypothesis: users will have different usage styles (“archetypes”) which will manifest as differences in average distributions of user monthly events.
- Use machine learning to uncover these patterns
- Clustering user activity histograms
- Clustering repo activity histograms
- Sequence analysis
  - LSTM
  - Sequence pattern mining
- Encode in an agent-based model
- Result: better performing model with a reduction in parameters that EMD needs to optimize

Datasets

- Calculated **average monthly** activity of users per event type

Features

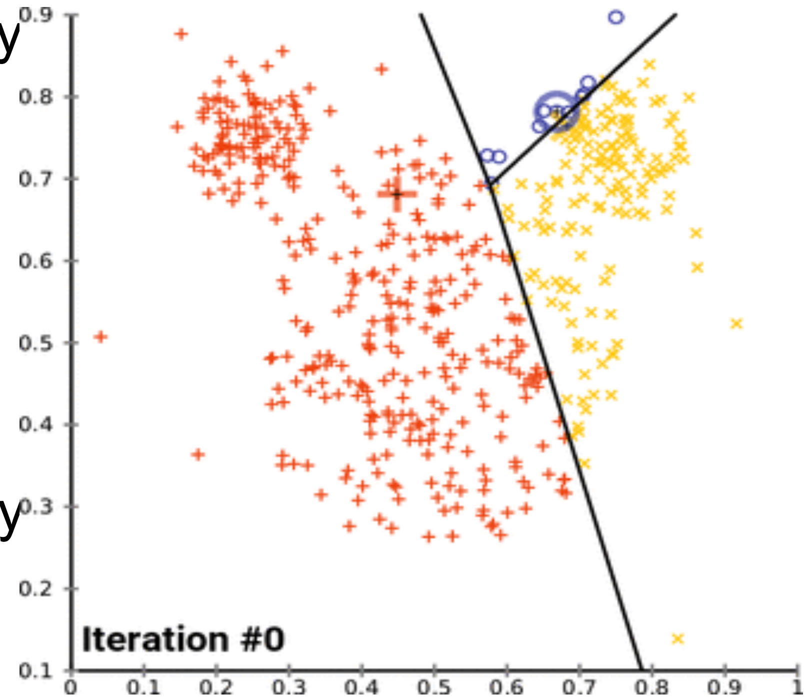
- Calculated **total** activity of users

- Users with at least one activity ~ **9 million**
- Users with more than **10** total activity ~ **4 million**

Clustered these users

- Known bots ~ **1000**

Dropped



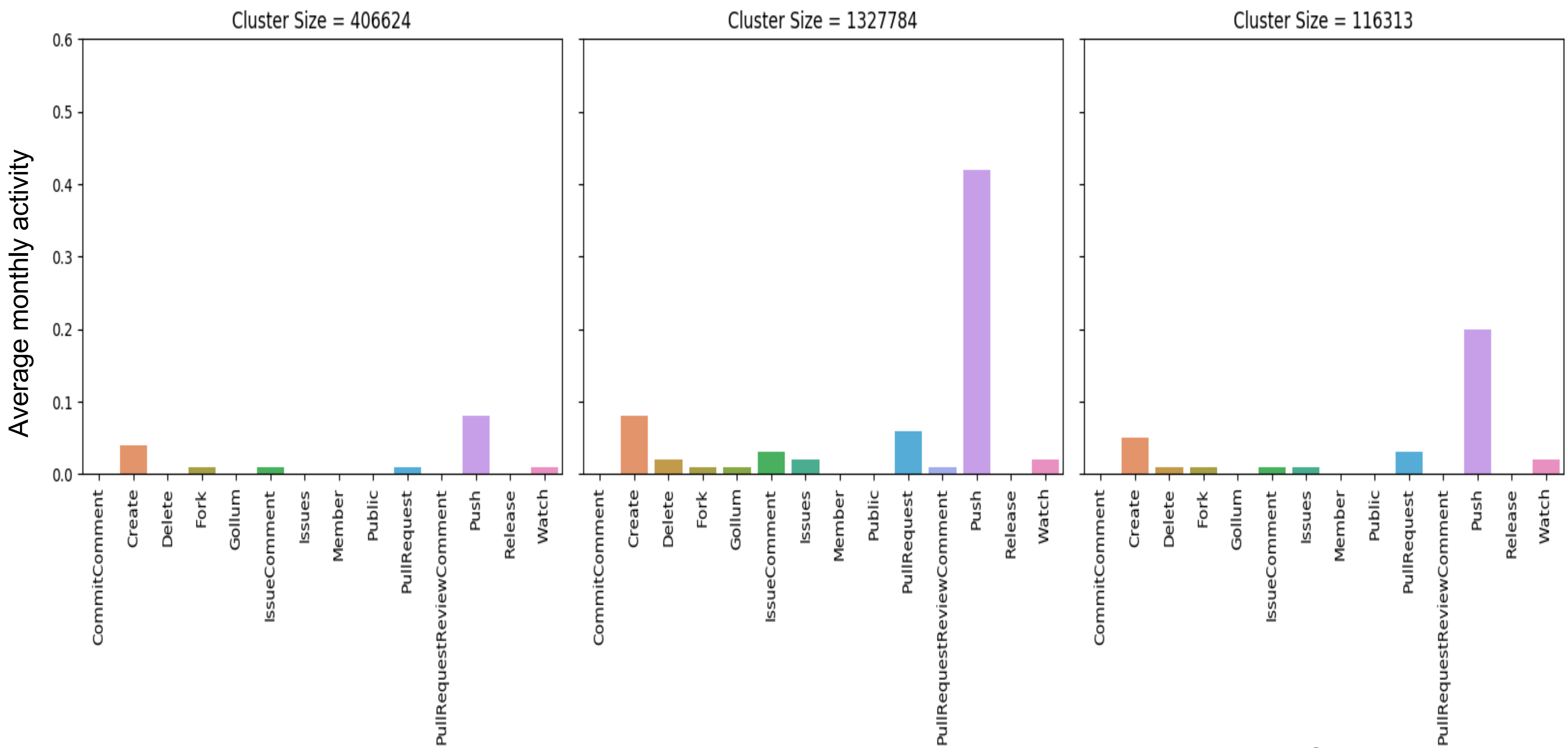
Normalized k-means clustering

Rate-based Partitions

Partition	Average Monthly Activity	# Users
1	(0,10]	1.9M
2	(10, 100]	1.8M
3	(100, 1K]	48K
4	(1K, 10K]	863
5	(10K, inf)	86

Cluster Centroids: 10 < Average Monthly Activity < 100

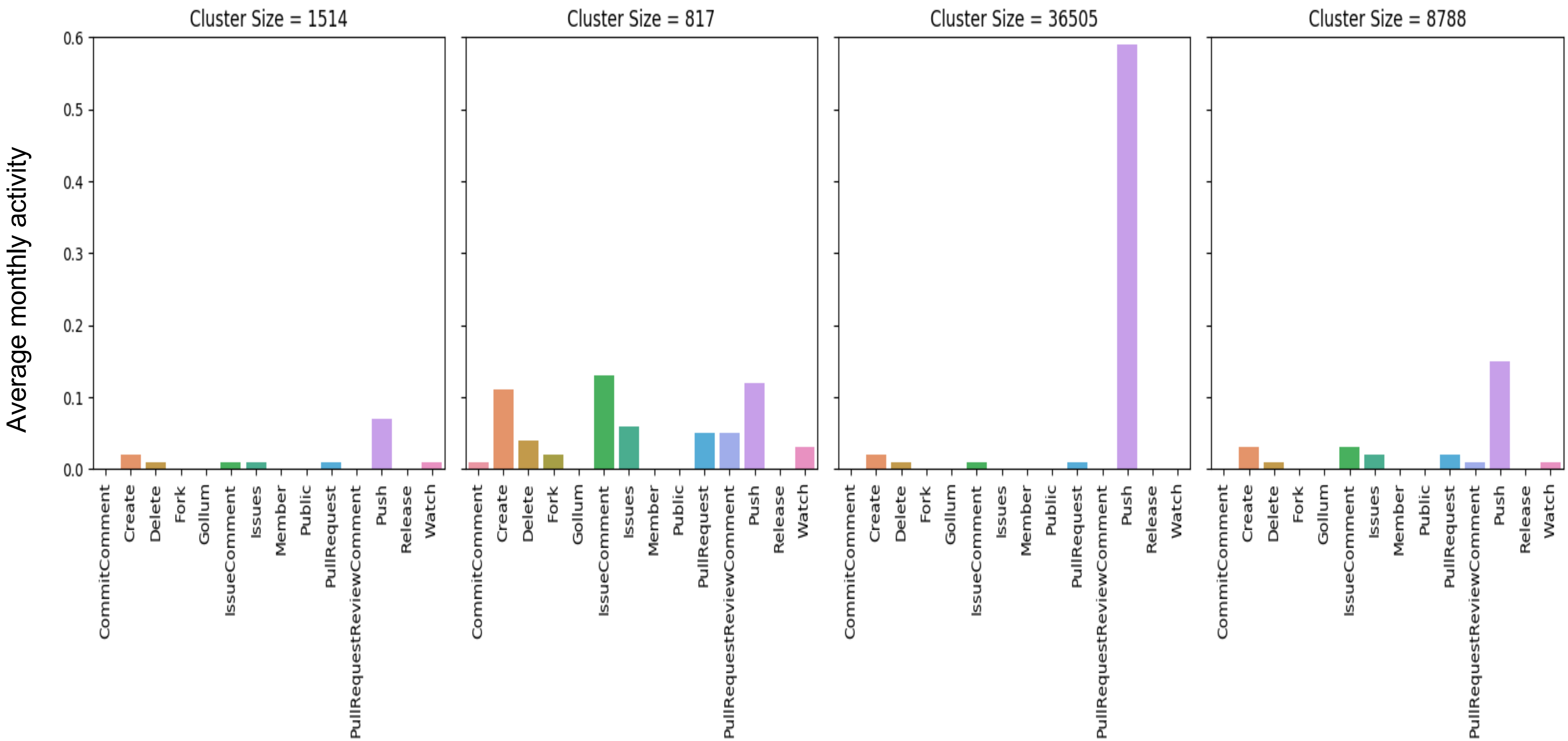
Example Usage Patterns



All users in this partition generate more Push events than other types of events but the relative proportions of the events differ.

Cluster Centroids: 100 < Average Monthly Activity < 1K

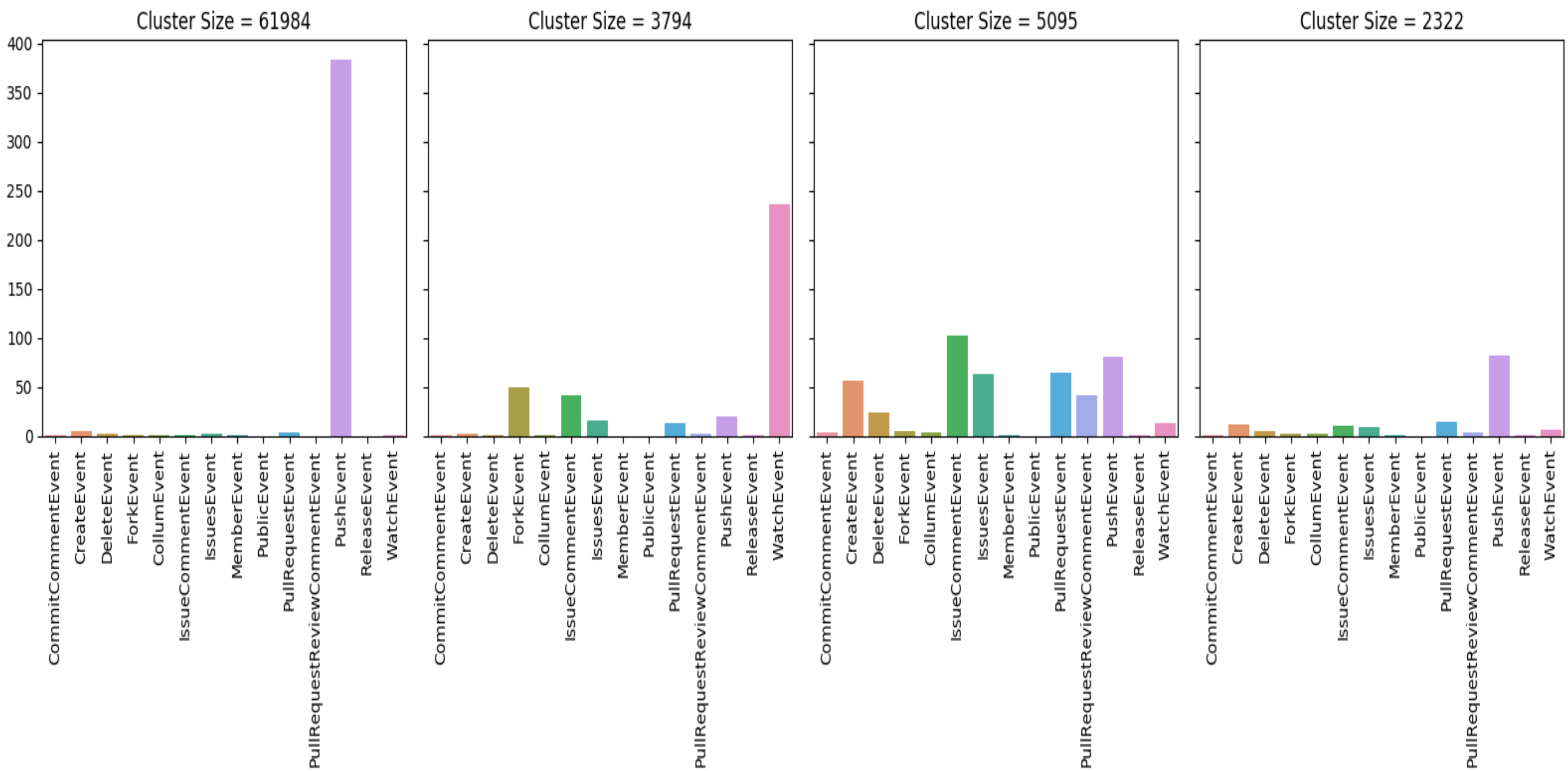
Example Usage Patterns



The largest group of users generates a lot of Push events; the smallest group has a more evenly balanced activity profile divided between Create, IssueComment, and Push

Clustering Repos

Partition (100, 1K]



There also interesting differences between repos with some receiving many Push and others with many WatchEvents.

Cluster Stability Analysis

- To find the number of clusters (k) that makes the most stable clusters
- In a stable clustering, we expect to observe similar clusters from month to month
- To measure month to month stability, we computed similarity between clusterings of consecutive months
- We computed Adjusted Rand Index (ARI) to measure similarity between clusterings
  - ARI is 1.0 when clusters are identical and close to 0.0 for random labeling.
- The stability score is the average similarity score of all consecutive months

Clusters Count	Stability Scores			
	0-10	10-100	100-1000	1000-10000
3	0.931	**0.996**	0.920	**0.685**
4	**0.949**	0.988	**0.928**	0.671
5	0.912	0.919	0.841	0.557
6	0.825	0.989	0.867	0.604
7	0.795	0.934	0.751	0.594
8	0.791	0.974	0.796	0.577
9	0.769	0.973	0.617	0.571

- The best scores
- The second best scores

Netlogo Agent Behavior

- User agents select a behavior to perform based on the event frequency defined by their archetype
- User agents maintain a list of familiar repositories
- If watching or forking:
  - Select a fixed number of repositories at random
  - From this subset, choose the repositories with the most number of watches and forks to watch/fork
  - Add repo to list of familiar repositories
- If contributing:
  - Select a repository from the familiar repositories list

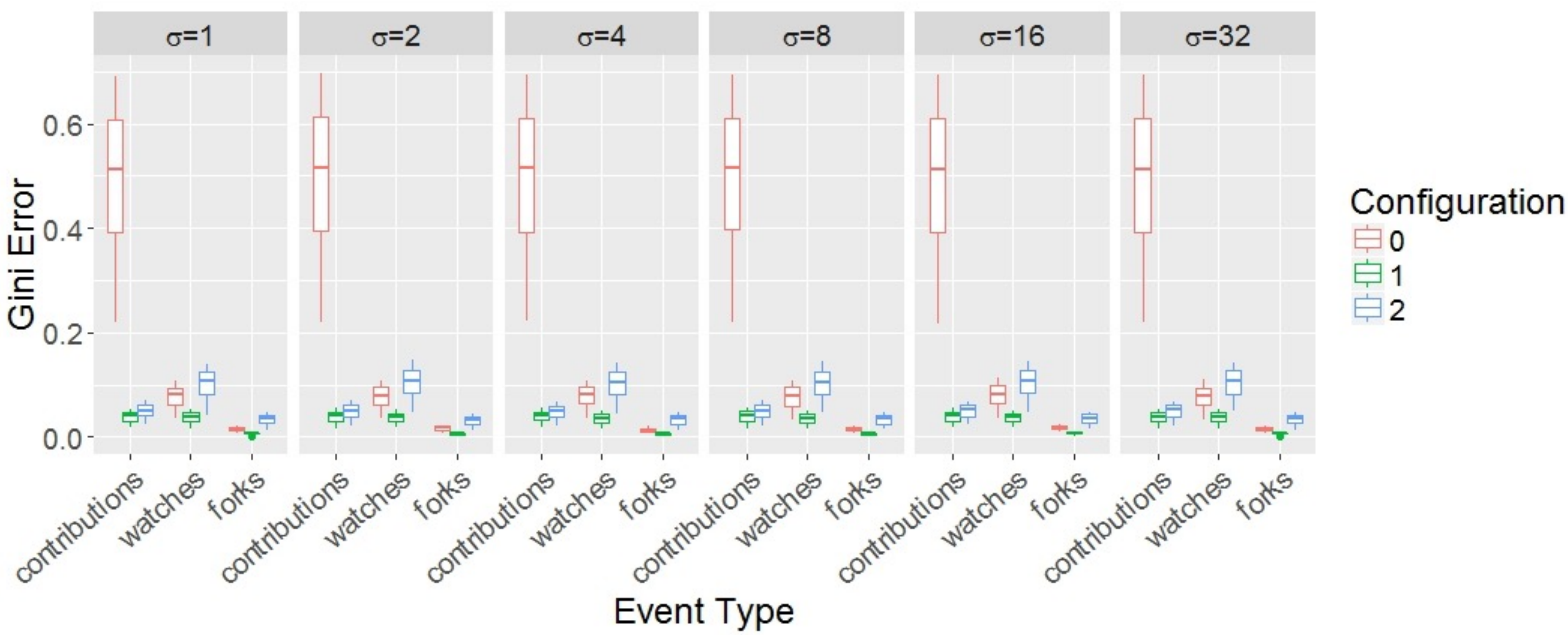
Experiments on ABM Archetypes

Rate Partitions

Cluster

Select k based on cluster stability

Translate centroids into relative event frequencies and population distribution



Improves Gini coefficient of event distribution over simple mean model

Course Summary

- We surveyed:
  - Software agents
  - Robots
  - Human-agent-robot interaction
- Discussed semi-applied case studies of systems:
  - What has been implemented?
  - What is still lacking?
- But what do these systems have in common?

Intelligence=Search

- Search is an integral part of AI!
- Some would argue that AI consists of only 2 fundamental concepts:
- Knowledge:
  - Representation and manipulation of factual and probabilistic knowledge
- Search:
  - Explore knowledge alternatives to find the best quality answer
- To be truly intelligent you must be able to find a good answer within a reasonable length of time!

Search Types

- Optimal
  - Best possible solution
  - Might not be achievable in a reasonable time
- Satisficing
  - Come up with the best quality decision within given resource constraints
  - Solution quality can be significantly worse than an optimal solution
  - Stop search and approximate the result

Search Approaches

- Search plus heuristics (A* and others)
- Dynamic programming (solve and cache subproblems)
  - Reinforcement learning (value iteration)
  - Bayesian MAP (maximum a posteriori)
- Parallel search
  - Graphplan
- Stochastic search techniques
  - UCT, RRTs and SSA are examples of this
  - Genetic algorithms
- Optimization techniques (maximize a function)
  - Mixed-integer linear programming
- Gradient-based
  - Deep learning

3 Different Approaches

- Classical AI
  - Represent the problem
  - Search for solution
- Machine learning
  - Use data or world experience to guide search
  - Knowledge represntation=metric
  - Search=optimization on metric
- Robotics
  - Satisficing search---reasonable solution quickly!
  - Robust control—make stability guarantees

Future Research

- Solve problems with bigger search spaces
  - Multi-agent problems often fall into this category!
- Handle search spaces with lots of local minima
- Reduce the amount of specialized data and domain knowledge required; increase the amount of general common-sense knowledge all systems have access to
- Handle dynamic, rapidly changing problem spaces
  - Robot problems often fall into this category!
- Using deep learning to handle other types of AI problems

Create a General Intelligence

- Many AI systems that can be trained to solve a specific problem in a narrow range of scenarios (a sandbox)
- Goal: create an intelligent system that can robustly handle a wide range of problems
- Be able to acquire data online and adapt to changing circumstances

Current State of AI/HRI

A humorous look at the present state of AI, robotics, and HRI:

https://youtu.be/rDyTsGtk5BY

2023 AI Predictions

- LLMs running out of high quality language data
- Greater availability of autonomous robotaxi rides
- More research on humanoid robots
- Foundation models for robotics
- AI changing the nature of search
- LLM operation jobs availability
- More research on AlphaFold
- More semiconductor suppliers enter the market

(Forbes)

Final Thoughts

- Thank you for taking the course
- I really enjoy hearing your presentations and seeing your final projects; they give me research ideas for the future.
- If you want publishing suggestions about where you could submit your final project to, please contact me after the semester.