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# Content Optimization with Multi-Arm Bandits & How to Title Presentations

Guest Talk  
CSCI 4830  
Special Topics in Computer Science  
Data Driven Design  
2021-03-18

Brad Weiner  
Director of Data Science  
CU Boulder

# Me

- Call me Brad
- Director of Data Science at CU Boulder
- I use institutional data to inform decision-making
- Excited to chat with you today and beyond
- First time teaching on Zoom, if you have questions, please just interrupt.



# Today's Discussion

- Quick Introduction
- Apartment Hunting in Springfield
- Learning vs. Earning in User Experience
- Frequentists and Bayesians
- Questions
- Open Ended Data Science Questions



# Finding an Apartment in Springfield

Buy Rent Sell Home Loans Agent finder



Manage Rentals Advertise Help Sign in

Boulder, CO For Rent \$400-\$1.4k 1+ bd, 1+ ba Apartments More Save search Schools Draw

**\$1.4K**  
1 bd, 1 ba  
590 sqft

Updated today

**\$1,345+/mo**  
Buffalo Canyon | 730 29th St, Boulder, CO 80303

Updated today

**\$1,200+/mo**  
4 bds 3 ba 950 sqft - Apartment for rent  
2995 Colorado Ave #72DKGFn1, Boulder, CO 80303

Updated yesterday

**\$745+/mo**  
Sterling Boulder Apartments | 2985 Aurora Ave, Boulder, CO 80303

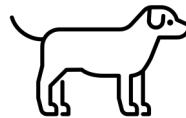
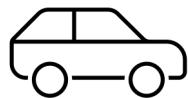
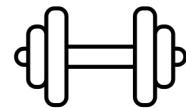
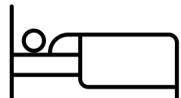
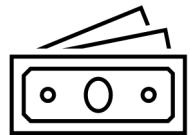
**\$1,200+/mo**  
1 bd 1 ba 660 sqft - Apartment for rent  
505 27th Way #35569508, Boulder, CO 80305

**\$1,335/mo**  
1 bd 1 ba 640 sqft - Apartment for rent  
4977 Moorhead Ave #W210, Boulder, CO 80305

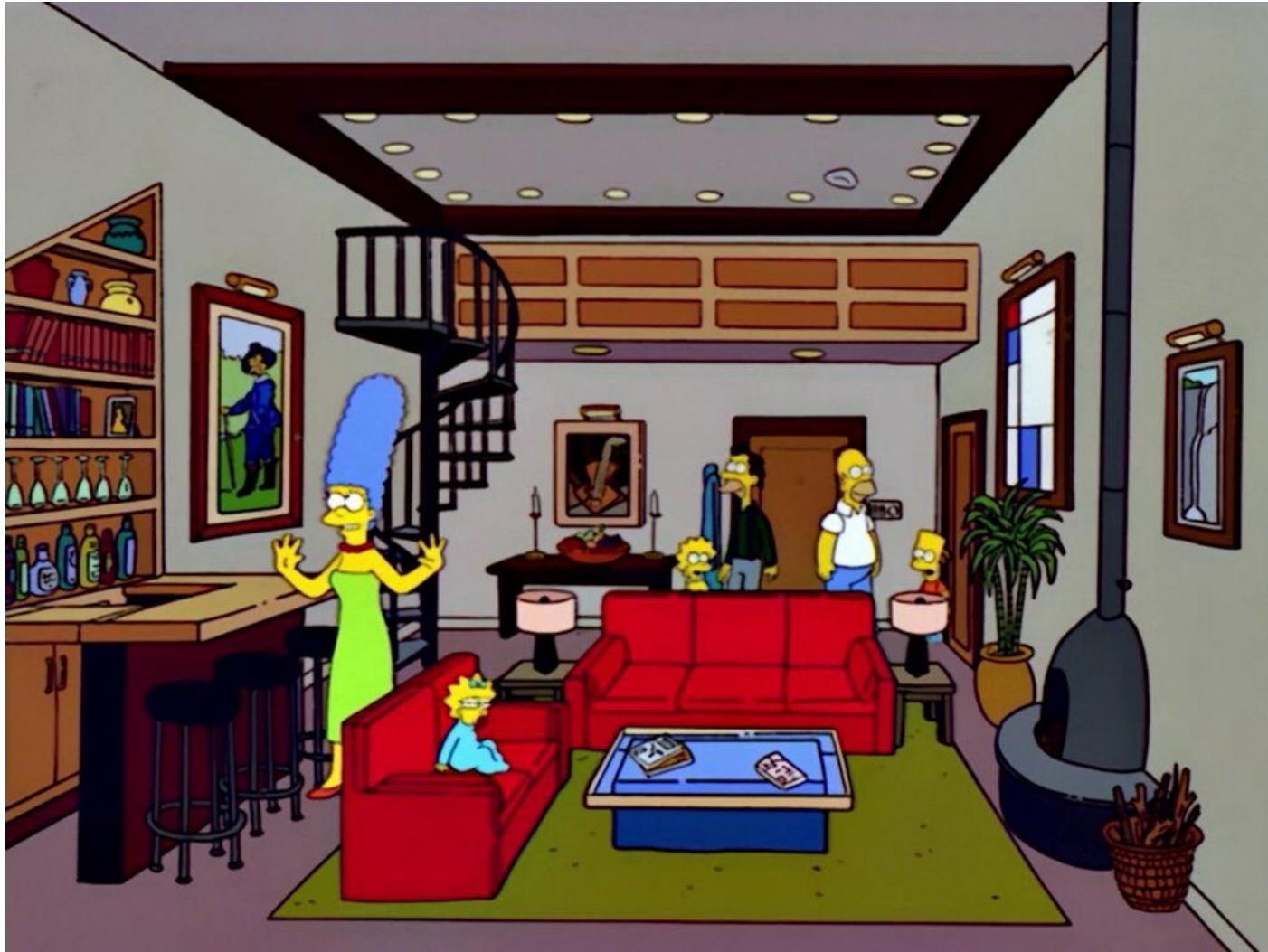


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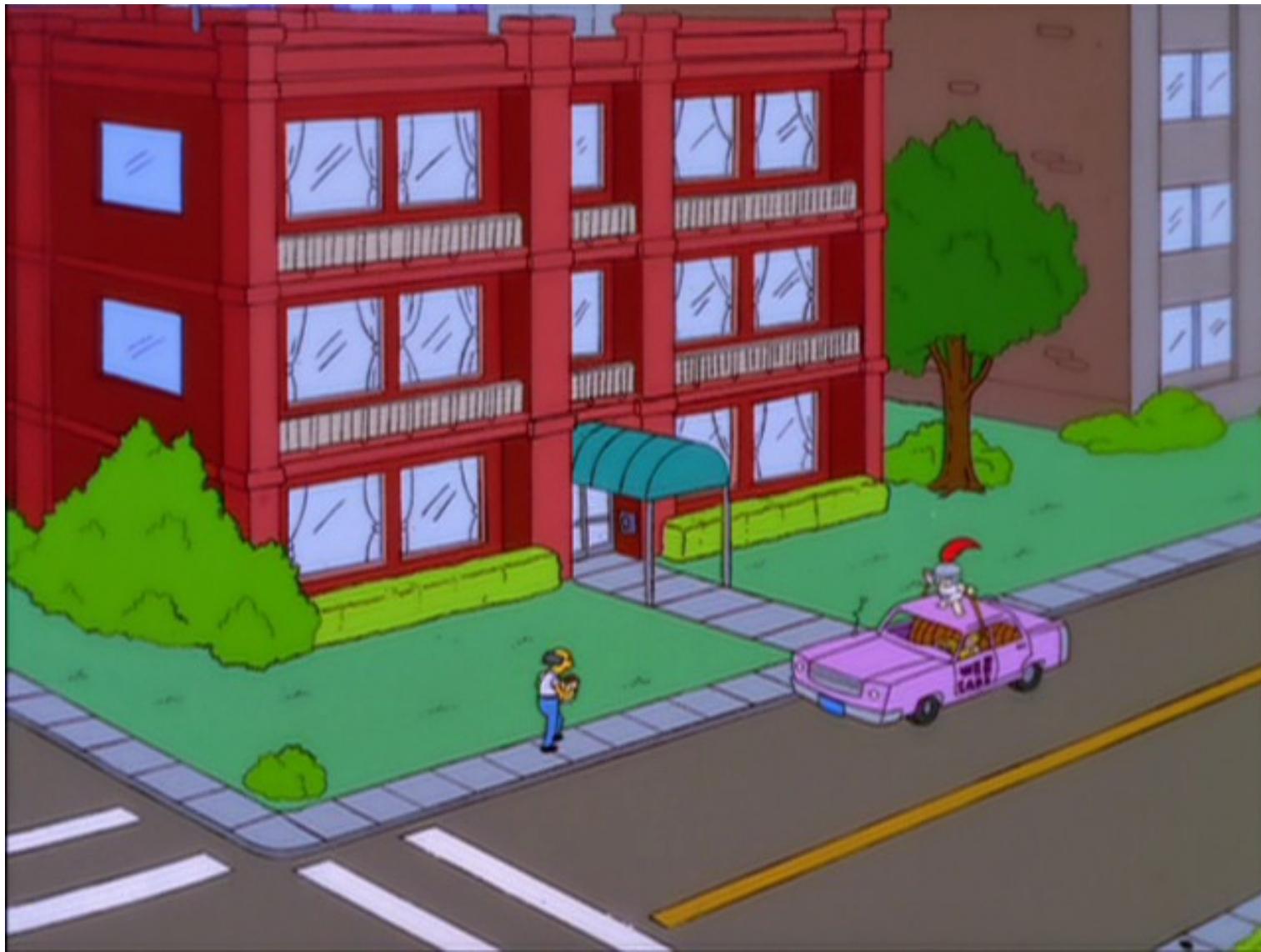
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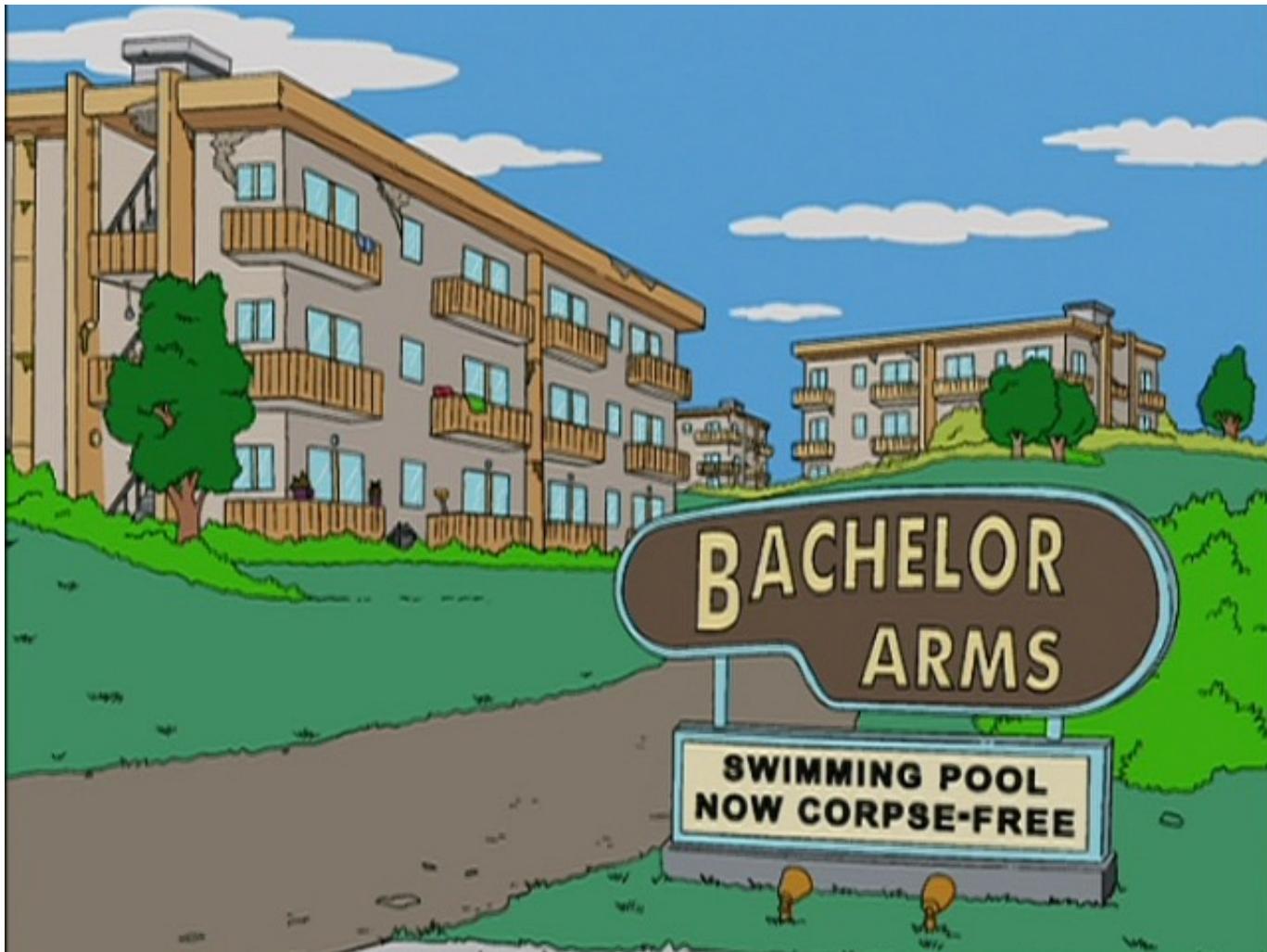
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# Question: When Do You Stop Looking and Put Down a Deposit?

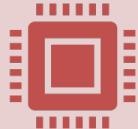


# The challenge:

- If you deposit too early, you may miss out on a better apartment
- If you keep looking, you'll never find an apartment



# Some Knowledge Here:



This is a well-known computer science problem called the **explore-exploit tradeoff**



Computers can scan through nearly limitless choices. How do we maximize the expected value from a selection?



# Multi-Arm Bandits (MAB)



- Multi-arm bandits are algorithms that seek to maximize an expected payout
- They are intended for the most rapid move toward the “exploit” decision
- There are a variety of strategies for algorithms to switch from explore to exploit





Which machine  
has highest  
expected reward?



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THIS IS EPSILON( $\epsilon$ )



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Let's exploit that  
knowledge and  
win some money!



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## SIMULATION

Source Code:

[https://gist.github.com/robinvanemden/30969b48a44c2742a18ae14861793741#file-epsilon\\_greedy\\_animation-r](https://gist.github.com/robinvanemden/30969b48a44c2742a18ae14861793741#file-epsilon_greedy_animation-r)



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Are there other  
ways I could  
explore then  
exploit?



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# Multi-Arm Bandit Solutions

- Changes to Explore/Exploit Ratio (Epsilon)
  - Do all exploring first
  - Gradually reduce the explore (Epsilon) rate over time
- Changes to Bandit Selection
  - Contextual bandits that choose the “correct” machine based on gambler’s information
- Different Algorithmic Approach
  - Thompson Sampling (Bayesian)



# An Oversimplified Description of Statistical Approaches

## Frequentist

- Assumes that with a large enough sample size, the point estimate (usually mean) gives the best guess at the whole population

## Bayesian

- Assumes that the “right” answer is actually a range of probabilities from a distribution which can change and be updated



## SIMULATION

Source Code:

[https://gist.github.com/robinvanemden/30969b48a44c2742a18ae14861793741#file-thompson\\_sampling\\_animation-r](https://gist.github.com/robinvanemden/30969b48a44c2742a18ae14861793741#file-thompson_sampling_animation-r)



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# Experiments in Web Design



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Which content  
has highest  
expected  
engagement?



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# A/B Split Test vs. Multi-Arm Bandit



Develop a randomized statistical test to understand which among multiple options is “significantly” better

Pro: You get a definitive answer and your organization learns

Con: It takes time and requires a robust sample size



Deploy an algorithm that programmatically selects the current “winner”

Pro: Your users are getting the benefit of the current, “best” version and the highest engagement rate

Con: The results might not provide a clear organizational answer



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# Key Takeaways



Randomized experimentation is critical. You should deploy as many *useful* experiments as your organization can effectively absorb



There are multiple approaches, and the main question is “Are you trying to *understand* or to *maximize*?”



Understanding the mechanics of these methods is helpful, but you don't need to be a statistician to use Google or Optimizely





# Questions



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# Data Science Questions



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# Sources

Zillow

Simpsons images are protected by copyright and used here under fair use/educational guidelines

Interactive Bandits:

<https://pavlov.tech/2019/03/02/animated-multi-armed-bandit-policies/>

Original R Code for Interactive Bandits:

<https://gist.github.com/robinvanemden/30969b48a44c2742a18ae14861793741>

Updated R Code for Interactive Bandits:

<https://gist.github.com/bradweiner/96593a8e7a34c03c0a92db33fdc64f75>

Algorithms to Live By

Christian, B., & Griffiths, T. (2016). Algorithms to live by: The computer science of human decisions.

\* Note that the interactive bandits in lecture were slightly repurposed, but otherwise copied from Github gist from Robin van Emden



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# Stable Location

This presentation can be found at:

[https://bradweiner.info/files/mab\\_presentation.pdf](https://bradweiner.info/files/mab_presentation.pdf)

Bandit Simulations:

[https://bradweiner.github.io/multi\\_arm\\_bandit\\_presentation/](https://bradweiner.github.io/multi_arm_bandit_presentation/)

Github Repo:

[https://github.com/bradweiner/multi\\_arm\\_bandit\\_presentation](https://github.com/bradweiner/multi_arm_bandit_presentation)

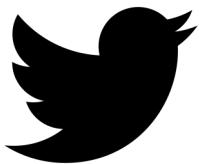


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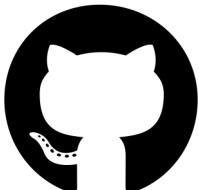
# Contact Information



brad.weiner@colorado.edu



@brad\_weiner



<https://github.com/bradweiner>



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