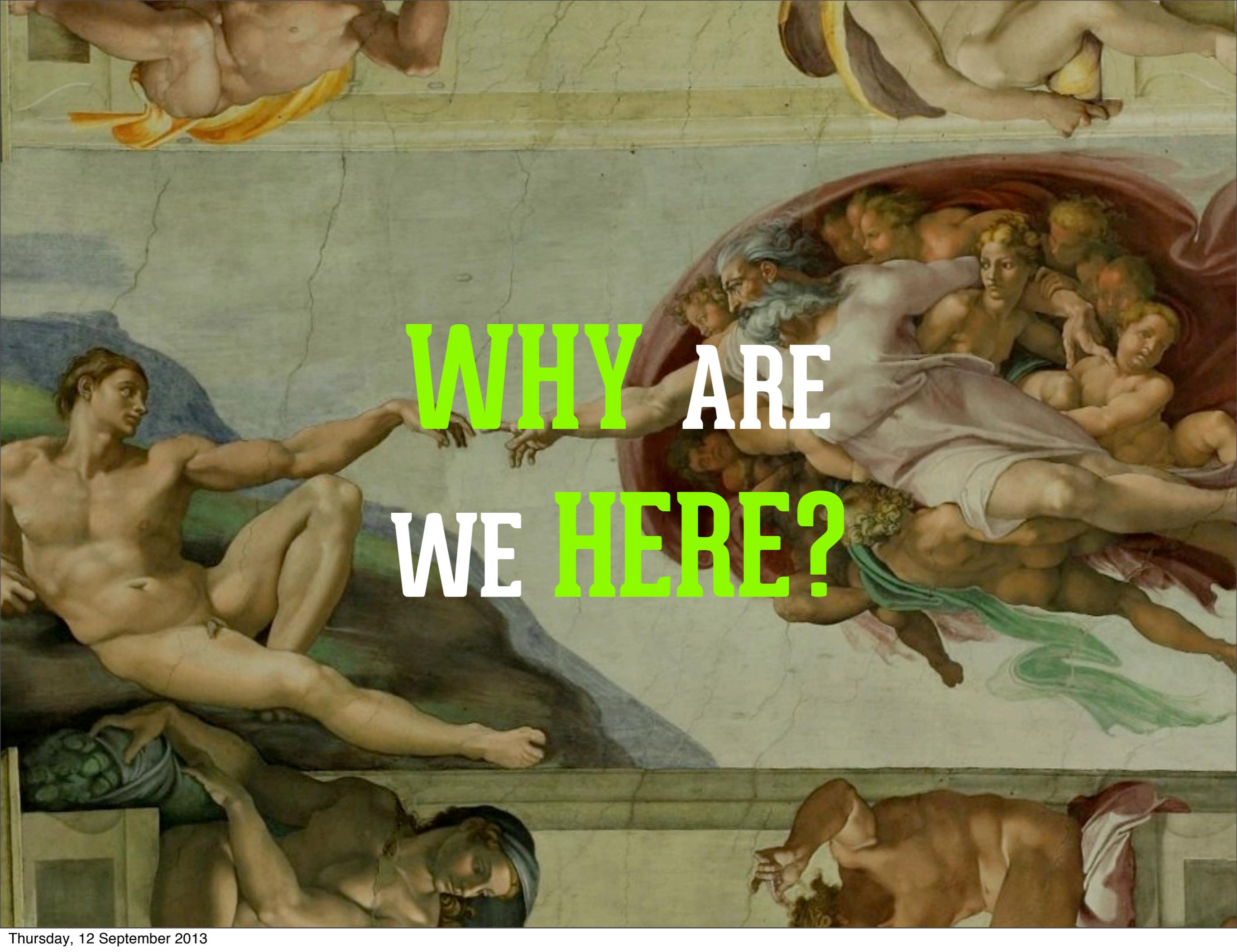


A photograph of a cowboy wearing a large white cowboy hat and a red long-sleeved shirt, standing next to a dark brown horse. They are in a desert setting with large, layered rock formations in the background under a clear blue sky.

DECISION MAKING AND THE BANDIT PROBLEM

Starring Noel Welsh

A myna Production

A detail from Michelangelo's 'The Last Judgment' fresco on the Sistine Chapel ceiling. It depicts a scene of divine judgment where the souls of the dead are being weighed in the balance of justice. In the center, Christ the Judge sits enthroned, surrounded by angels. To his left, St. Peter holds the keys of the kingdom of heaven. Below them, the damned are shown in various states of torment, some being pulled apart by demons. The blessed are shown entering the gates of heaven. The scene is filled with dramatic lighting and anatomical detail.

**WHY ARE
WE HERE?**

BANDIT ALGORITHMS

[AN OVERVIEW]

**TAKE ACTION
AUTOMATICALLY**

SELECT ADS

RECOMMEND NEWS STORIES

CHOOSE BETWEEN ALGORITHMS

ETC.

#1

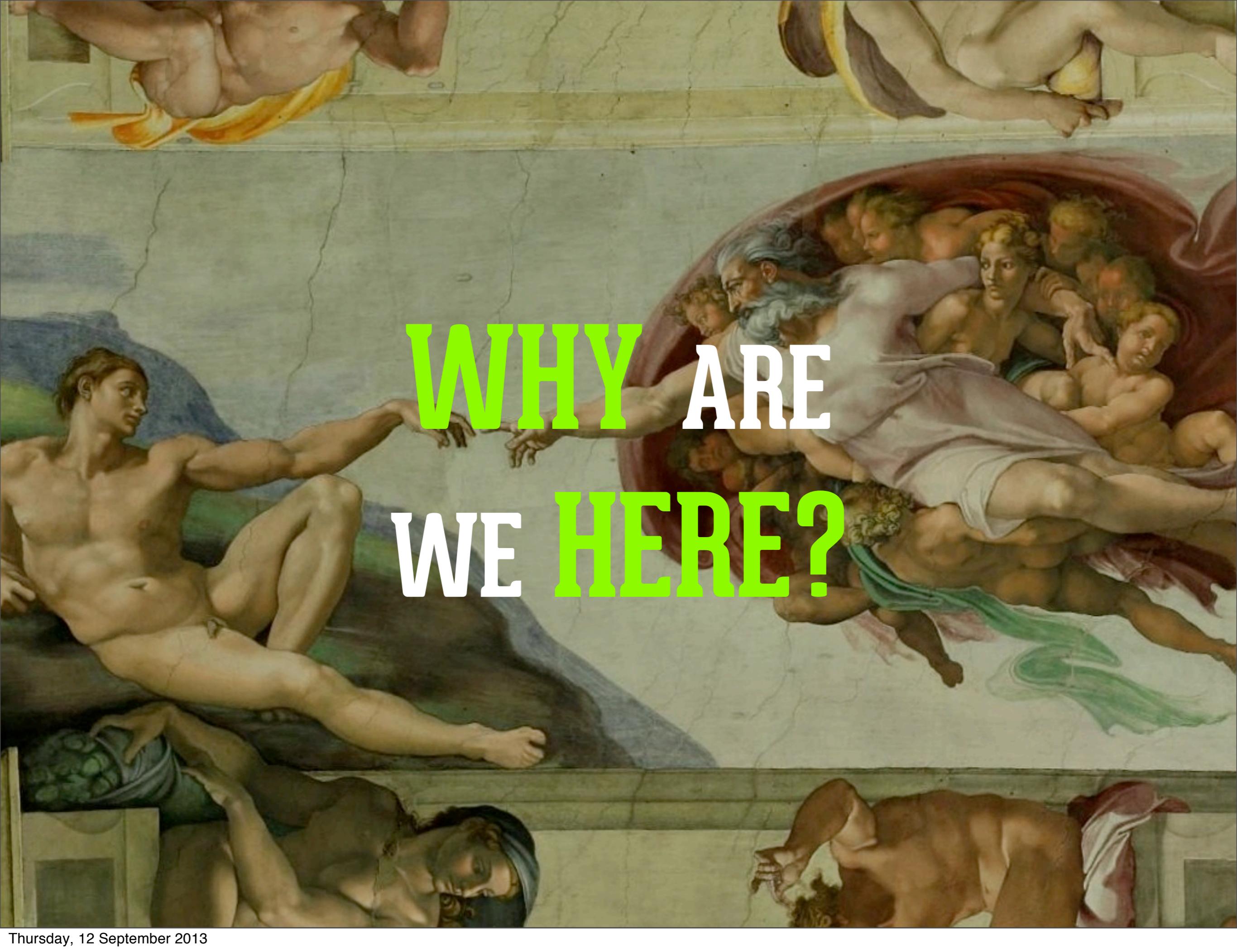
Maximise reward over
time

#2

Personalisation
[Use structure in the
problem]

#3

Brief overview of other
areas

A detail from Michelangelo's 'The Last Judgment' fresco on the Sistine Chapel ceiling. It depicts a scene of divine judgment where the souls of the dead are being weighed in the balance of justice. In the center, Christ the Judge sits enthroned, surrounded by angels. To his left, St. Peter holds the keys of the kingdom of heaven. Below them, the damned are shown in various states of torment, some being pulled apart by demons. The blessed are shown entering the gates of heaven. The scene is filled with dramatic lighting and anatomical detail.

**WHY ARE
WE HERE?**

WHAT DO
DATA SCIENTISTS
DO?

Metric
(sign-ups, revenue, etc)

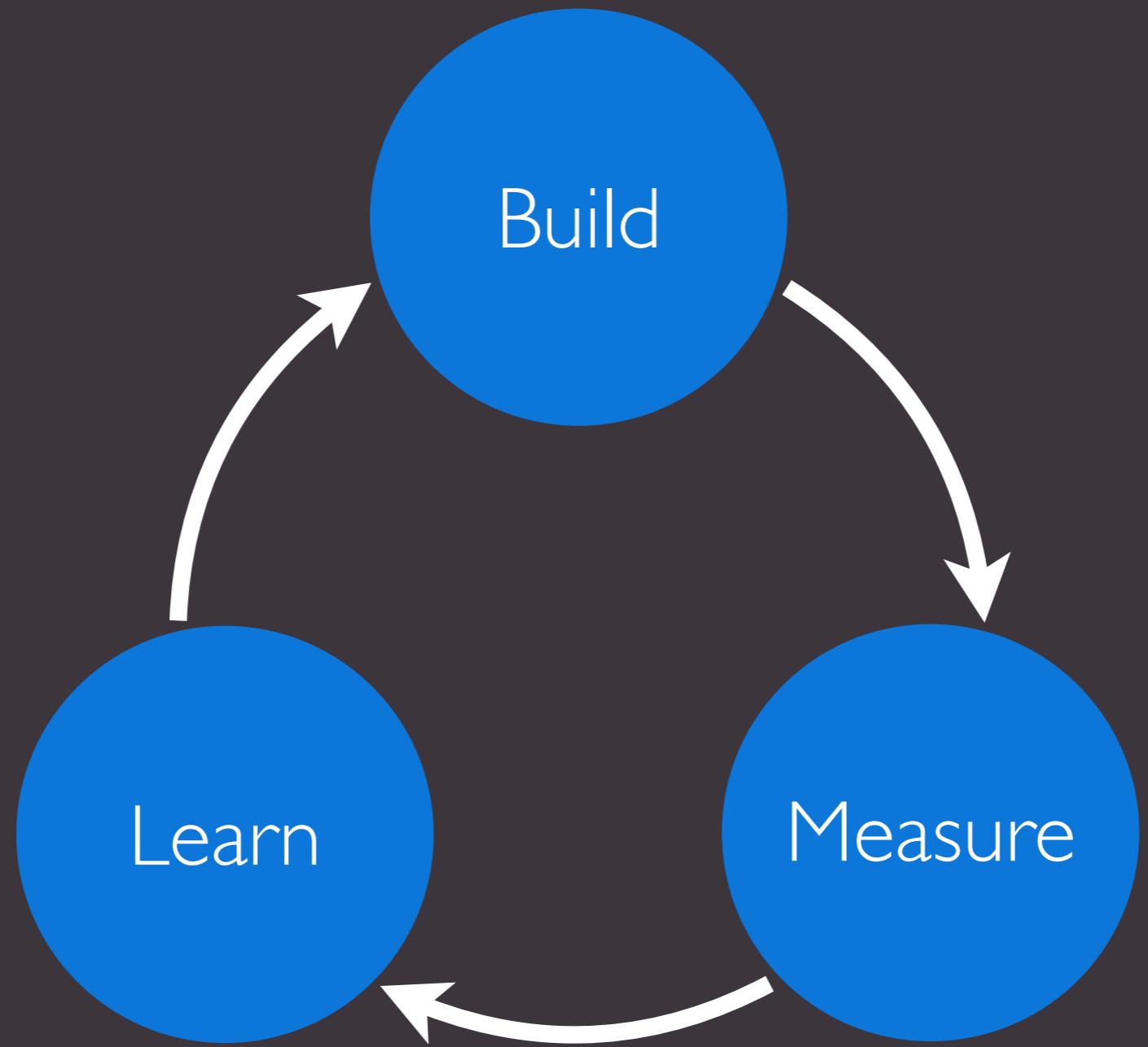


Make this happen



HOW?

EFFECTIVE ACTION





FASTER IS BETTER



THE BANDIT PROBLEM

[EST 1952... OR 1933]

Monique Myna's Typewriter Travels



The picture above is of a beautiful 1940s black and gold Royal typewriter.

It's in need of a little restoration but it's still able to get out and about!



Monique Myna's Typewriter Travels



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For more typewriter news
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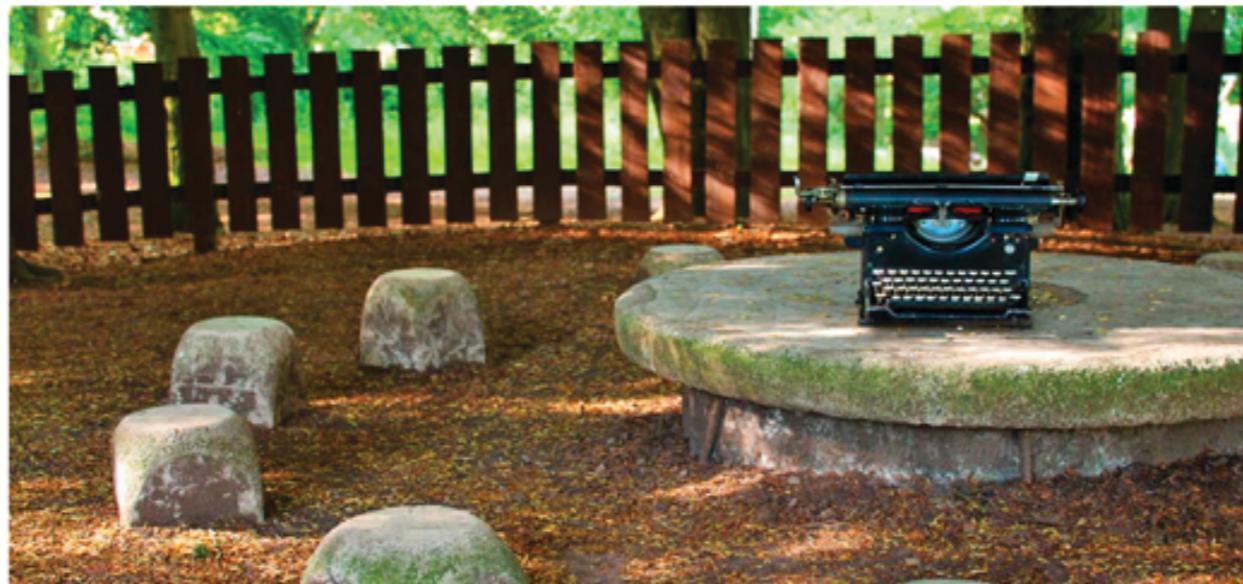
k arms (or variants)

Monique Myna's Typewriter Travels



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Typewriter Travels



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Select a variant

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Typewriter Travels

For more typewriter news
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Receive a reward

REPEAT

**MAXIMISE TOTAL
REWARD**

HOW?

**DISPLAY VARIANT WITH
HIGHEST AVERAGE
REWARD**

Good Variant

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Bad Variant

Monique Myna's Typewriter Travels



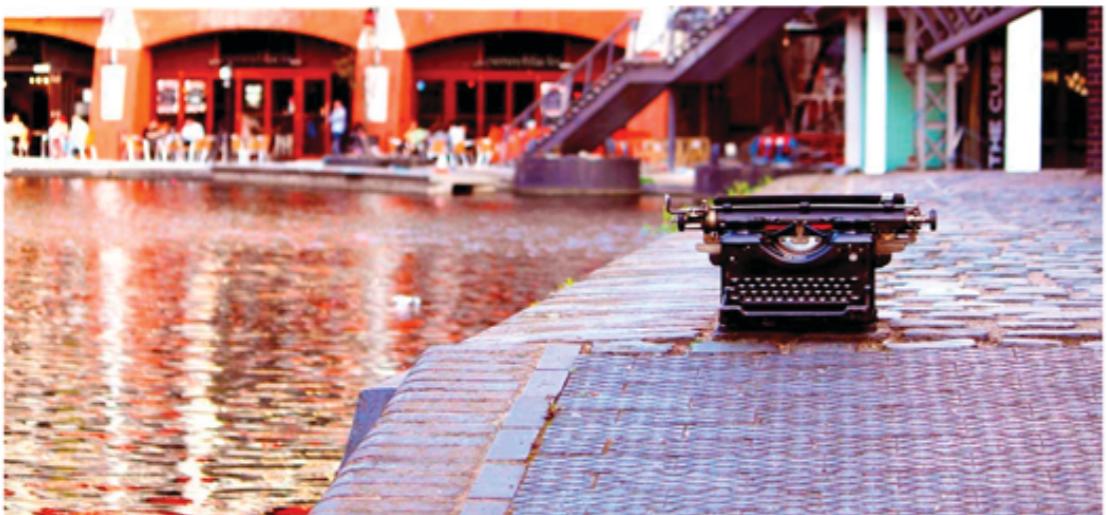
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Good Variant

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Bad Variant

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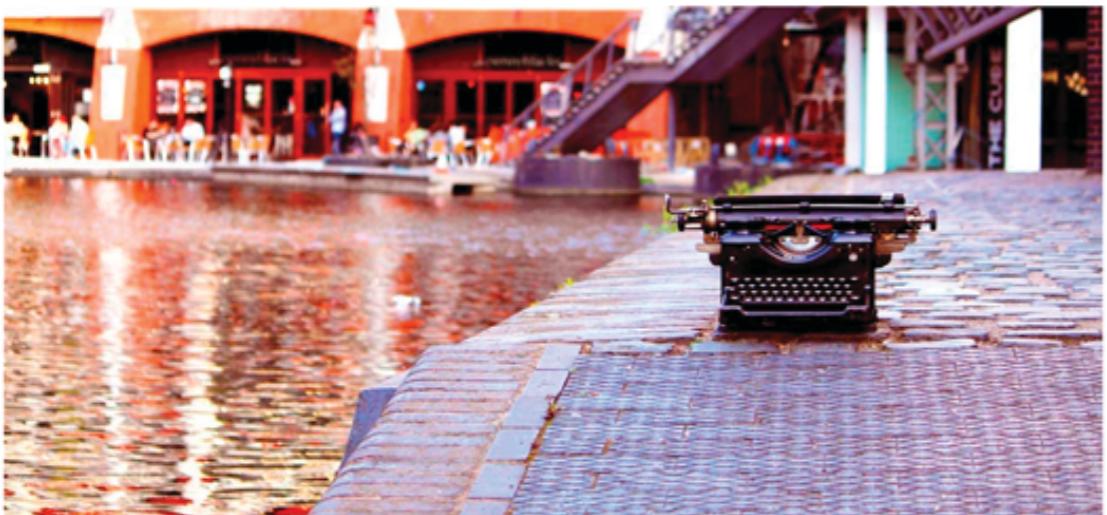
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Views: 1
Reward: 0
Average: 0

Good Variant

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Bad Variant

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Views: 1
Reward: 0
Average: 0

Views: 1
Reward: 1
Average: 1

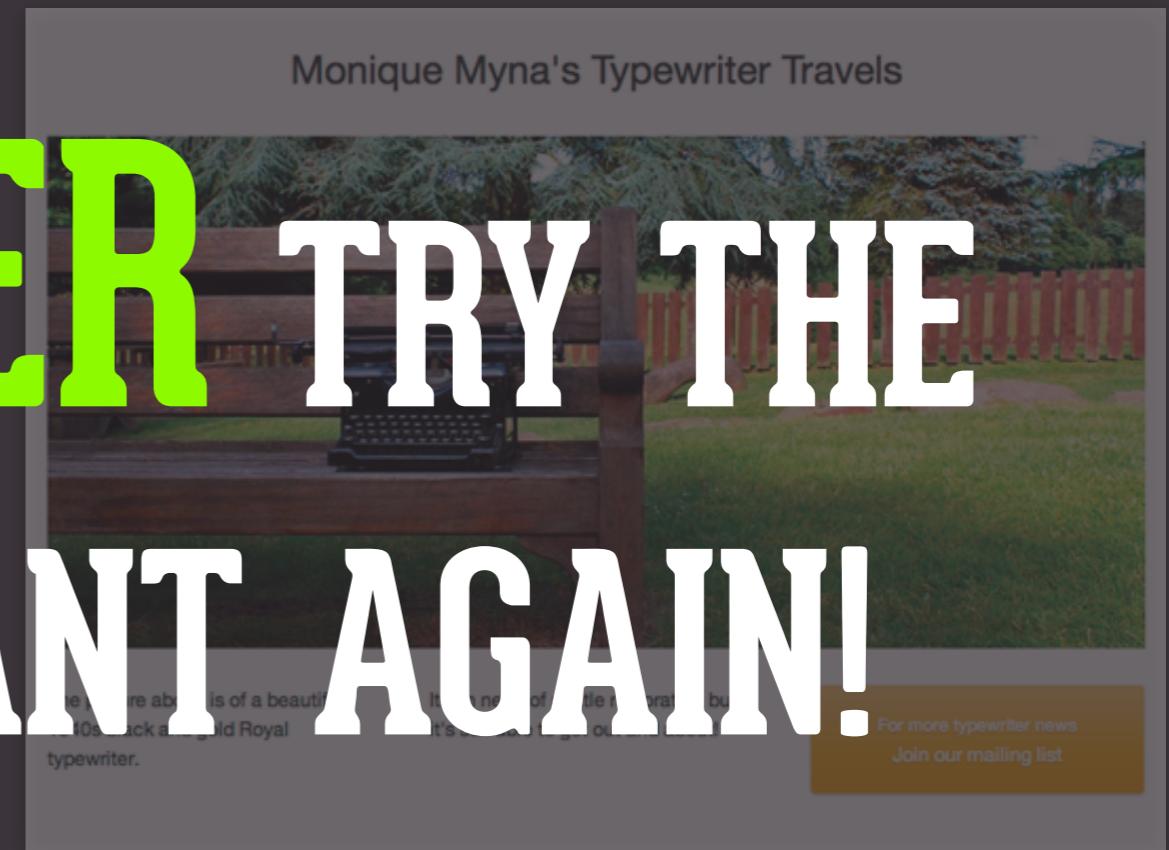


OOPS!

Good Variant



Bad Variant



Views: 1

Reward: 0

Average: 0

Views: 1

Reward: 1

Average: 1

**BALANCE EXPLOIT
AND EXPLORE**

EXPLOIT
TRY THE VARIANT THAT
HAS WORKED BEST IN
THE PAST

EXPLORE
TRY OTHER VARIANTS
TO SEE IF THEY'RE
BETTER

E-GREEDY

10% EXPLORE
90% EXPLOIT

Don't like 10% and 90%? Change it.

THOMPSON SAMPLING

**BAYESIAN APPROACH
USING
PROBABILITY
MATCHING**

Select arm in proportion
to probability it will
receive the highest
reward

$$P(\text{arm}_i) \propto P(r_i > r_1, \dots, r_j))$$

r_i is the reward of arm_i

**Binary reward: Beta
Prior**

**Gnarly integration:
Monte Carlo**

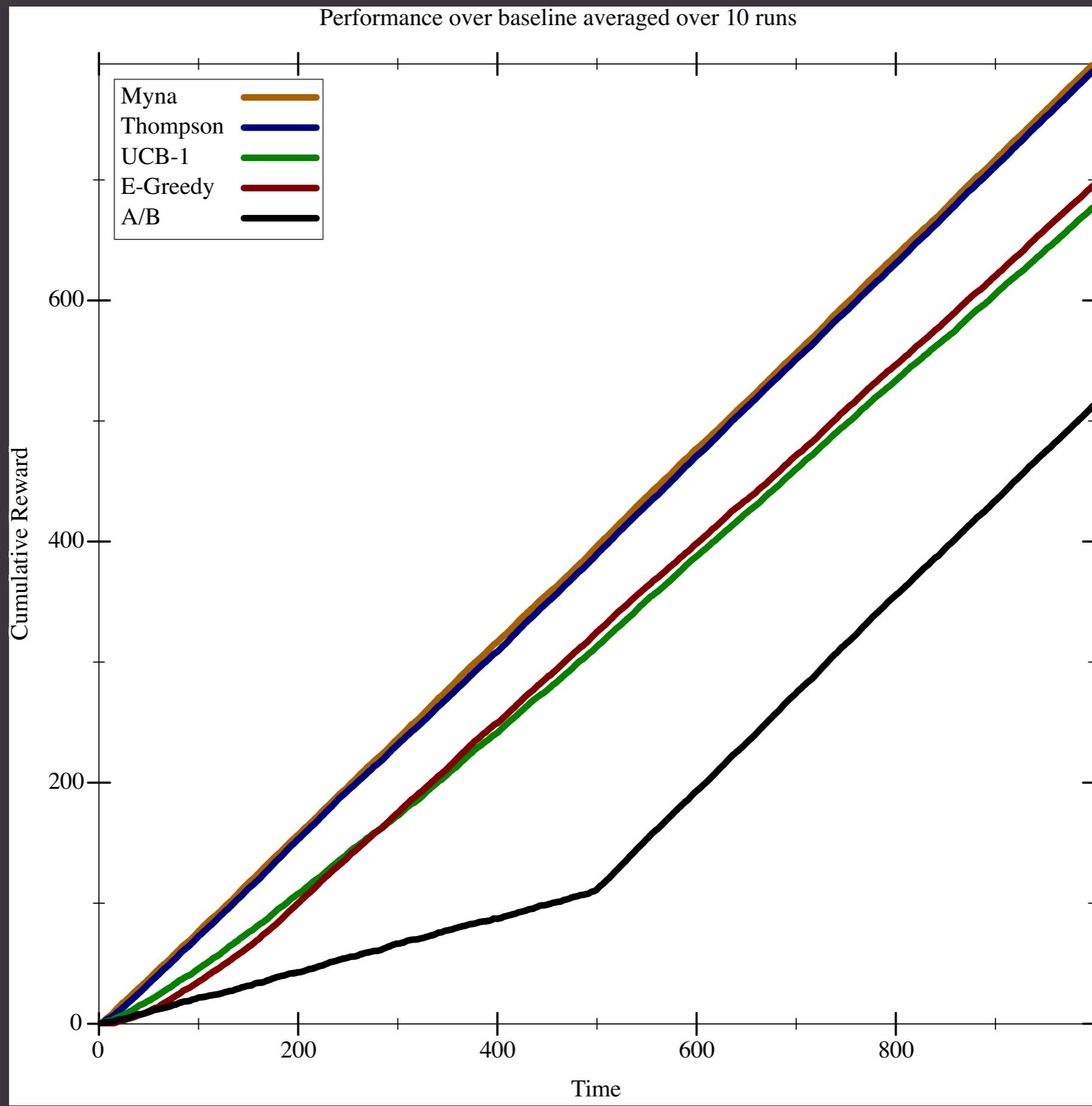
THOMPSON SAMPLING

$$\forall i, p_i \sim Beta(\theta_i)$$

choose arm_i with $p_i > p_j, \forall j \neq i$

**ONE SAMPLE IS
ENOUGH!**

**OTHER
ALGORITHMS E.G.
UCB-1, KL-UCB**



IN PRACTICE
THOMPSON SAMPLING IS
SUPERIOR

THEORY

**MINIMISE EXPECTED
REGRET**

$$Regret(T) = \mu^* T - \mathbb{E} \left[\sum_{i=1}^T r^i \right]$$

μ^* : expected reward of best arm

r^i : reward at time i

$$\text{Regret}(T) = \Omega(\log(T))$$

THOMPSON SAMPLING IS OPTIMAL

[Kaufmann, Korda, & Munos, 2012;
Agrawal and Goyal, 2012]

ADDING STRUCTURE

**EXAMPLE:
EACH USER HAS A
PROFILE**

IN GENERAL,
RECEIVE A
CONTEXT VECTOR
AT EACH DECISION

**ASSUME REWARD IS
LINEAR FUNCTION
OF CONTEXT**

$c_i \in \mathbb{R}^d$: context at time i

$\bar{\mu} \in \mathbb{R}^d$: linear payoff function

$c_i^T \bar{\mu}$: expected payoff

**DO SAME
PROBABILITY
MATCHING
AS BEFORE**

Put prior on payoff
function. E.g. Gaussian

Create likelihood function
over rewards. E.g. Gaussian

$$\text{Regret}(T) = \Omega\left(d\sqrt{T}\right)$$

[Agrawal & Goyal, 2013]

ESSENTIALLY
BING'S CTR PREDICTION
ALGORITHM
[Graepel et al, 2010]

OTHER BITS AND PIECES

BEST ARM IDENTIFICATION

FIND WITH HIGH
PROBABILITY
ARM[S] WITH HIGHEST
EXPECTED REWARD

NON-STATIONARY REWARDS

**ADVERSARIAL
REWARDS SET
ARBITRARILY**

$$\text{Regret}(T) = \Omega\left(\sqrt{T}\right)$$

PREDICTABLE [BUT NON-STATIONARY] REWARDS

LOTS MORE
[COMBINATORIAL BANDITS,
LINEAR OPT etc.]

A silhouette of a cowboy wearing a hat and holding a rifle, riding a horse. They are positioned in the center of the frame, set against a vibrant sunset or sunrise sky filled with orange, yellow, and purple clouds.

THANK YOU!
NOW GO FORTH AND
ENGAGE IN
BANDITRY

MORE:

noelwelsh.com &

mynaweb.com

CREDITS

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