

A man wearing a light-colored cowboy hat and a red long-sleeved shirt is riding a dark horse. He is looking off to the side with a serious expression. The background is a desert landscape with a large, flat-topped rock formation under a clear blue sky.

DECISION MAKING AND THE BANDIT PROBLEM

Starring Noel Welsh

A *myna* Production



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



WHY ARE
WE **HERE?**

WHAT DO
DATA SCIENTISTS
DO?

Metric
(sign-ups, revenue, etc)

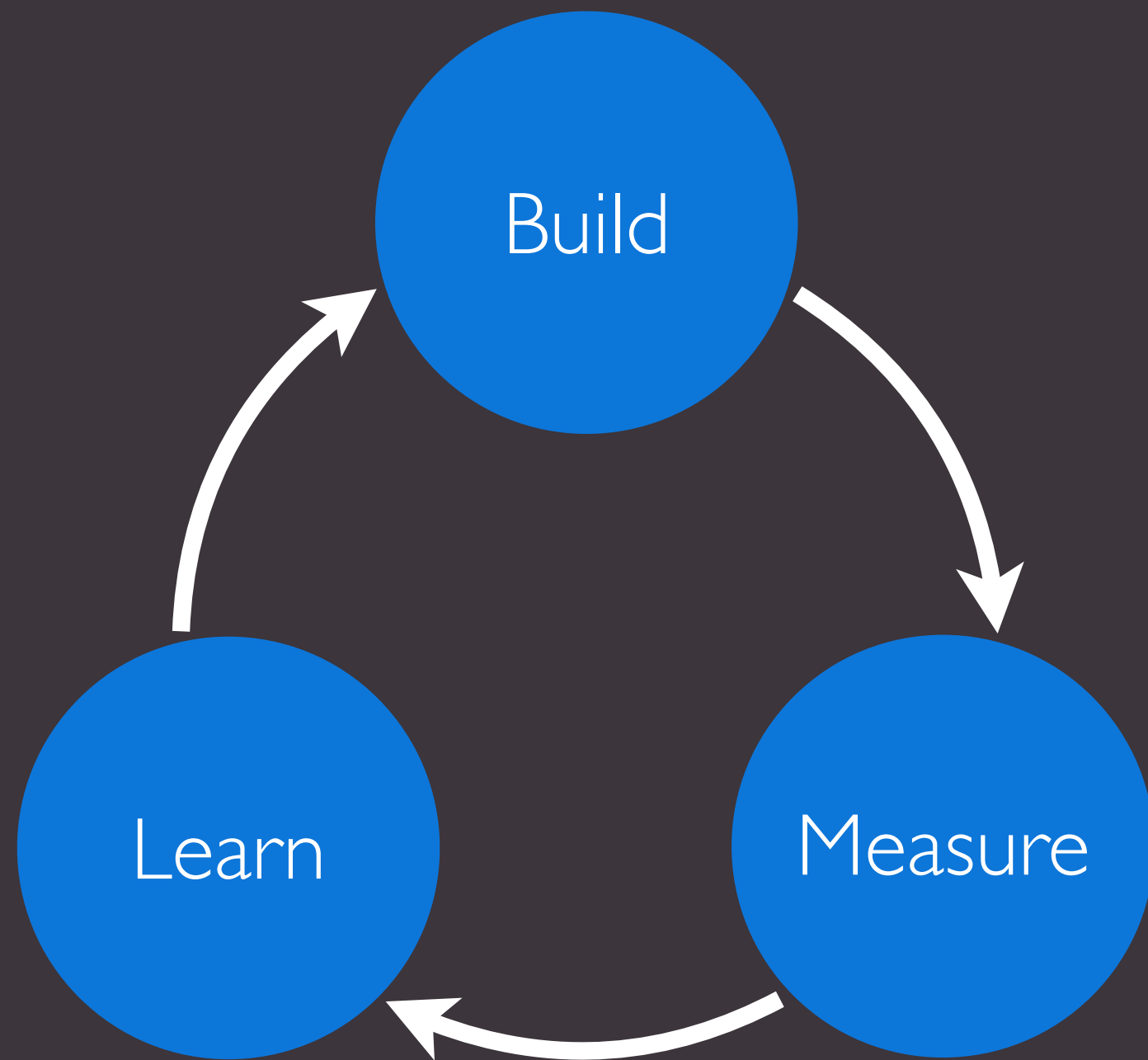


Make this happen



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!

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For more typewriter news
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k arms (or variants)

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Select a variant

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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

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Views: 1
Reward: 0
Average: 0

Good Variant

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Views: 1
Reward: 0
Average: 0

Bad Variant

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Views: 1
Reward: 1
Average: 1

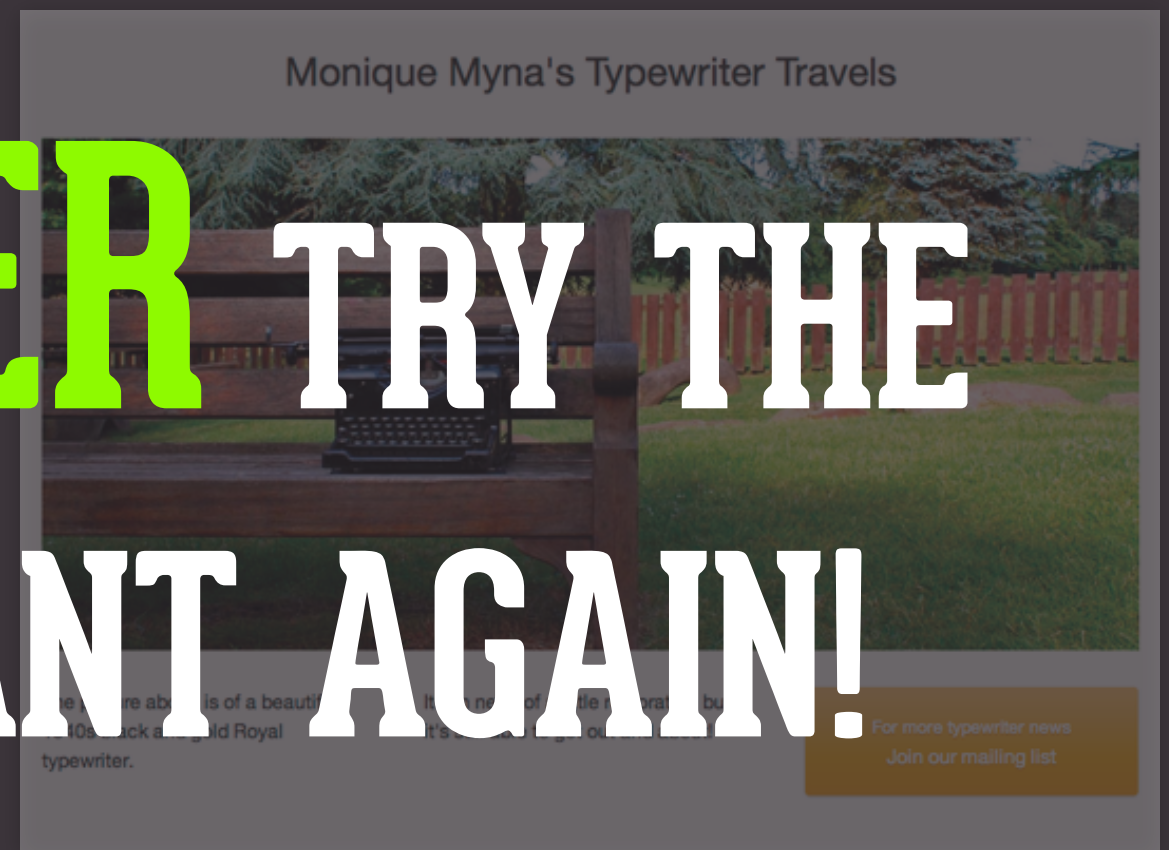


Good Variant

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**

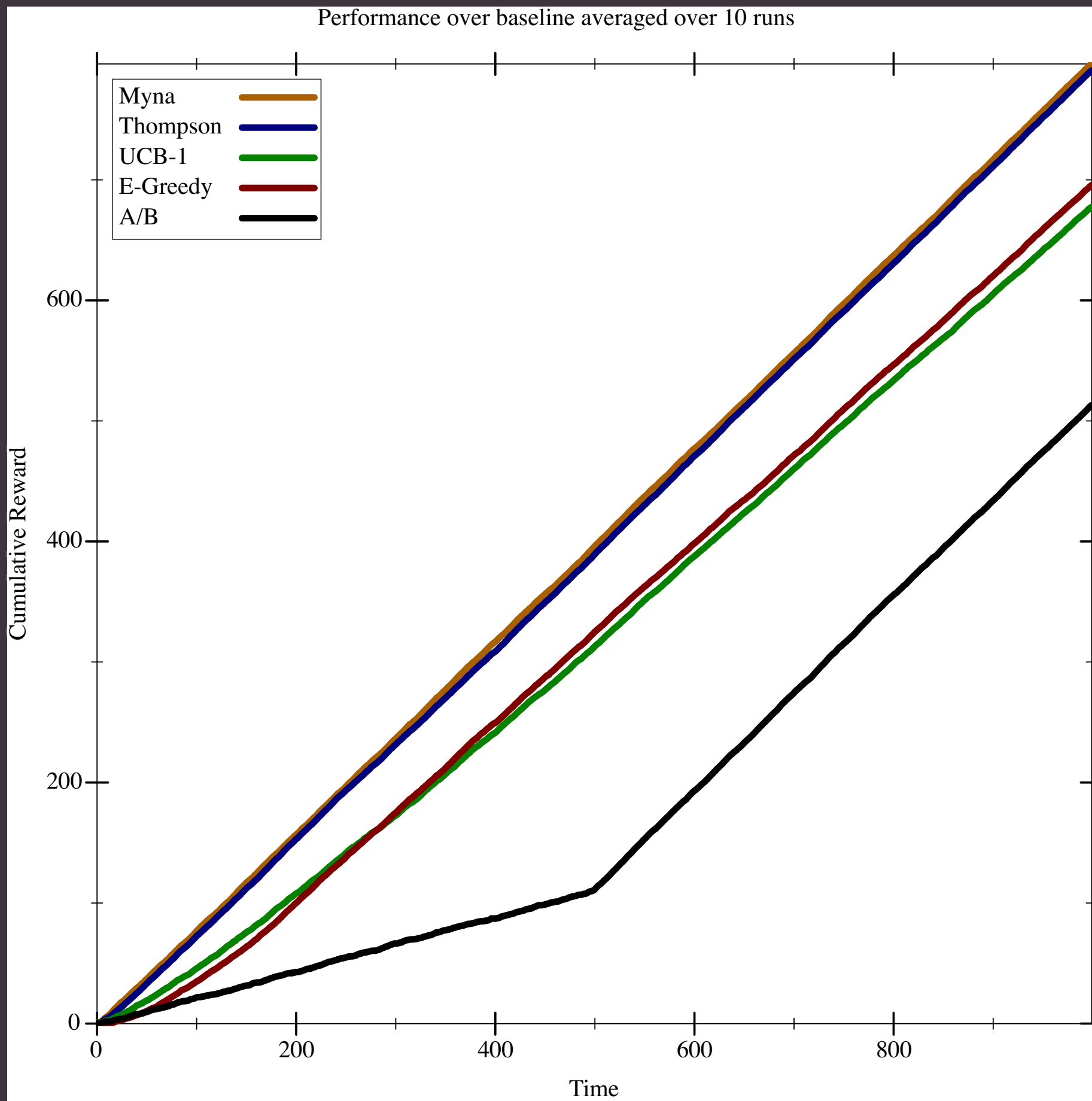
THOMPSON SAMPLING

$$\forall i, p_i \sim \text{Beta}(\theta_i)$$

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**

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

μ^* : expected reward of best arm

r^i : reward at time i

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

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**

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

[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

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

PREDICTABLE
[BUT NON-STATIONARY]
REWARDS

LOTS MORE

**[COMBINATORIAL BANDITS,
LINEAR OPT etc.]**

The background of the slide features a dramatic sunset sky with orange, yellow, and purple clouds. In the center, a silhouette of a cowboy on a horse is visible. In the foreground, a large silhouette of a dinosaur, possibly a T-Rex, is shown in profile, facing right. The text is overlaid on this scene.

THANK YOU!
NOW GO FORTH AND
ENGAGE IN
BANDITRY

MORE:

noelwelsh.com &

mynaweb.com

CREDITS

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