EMBRACING THE DARK ART OF MATHEMATICAL MODELING IN GAME AI

Dave Mark – Intrinsic Algorithm
Kevin Dill – Lockheed Martin

Mathematical Modeling Can Be Easy!

- More than just a “bucket of floats”
- Yes, it is complex
- (But so is behavior!)
- Organized construction leads to understandable complexity
- Often, more art than science
- (But so is behavior!)

Intrinsic Algorithm

AI GAME PROGRAMMERS GUILD

LOCKHEED MARTIN

Mathematical Modeling Can Be Fun!!

Brenda G Brathwaite @br
Following

All the fun of balancing is figuring out what numbers matter, what weight to give to them and the basic shape of the curve you're hoping for

Brenda G Brathwaite @br
Following

I love balancing games and trying diff formulas. ((If anyone followed my twitter feed before asking me on a date, I would never get a date).

Christopher Pratt @chrispratt24 5h

@br Do you find it's heavy calculations or more trial and error?

Brenda G Brathwaite @br
Following

@chrispratt24 It's determining the relationship of one number to another, and finding out which number rules them all. Something has to be..

Retweeted by Dave Mark

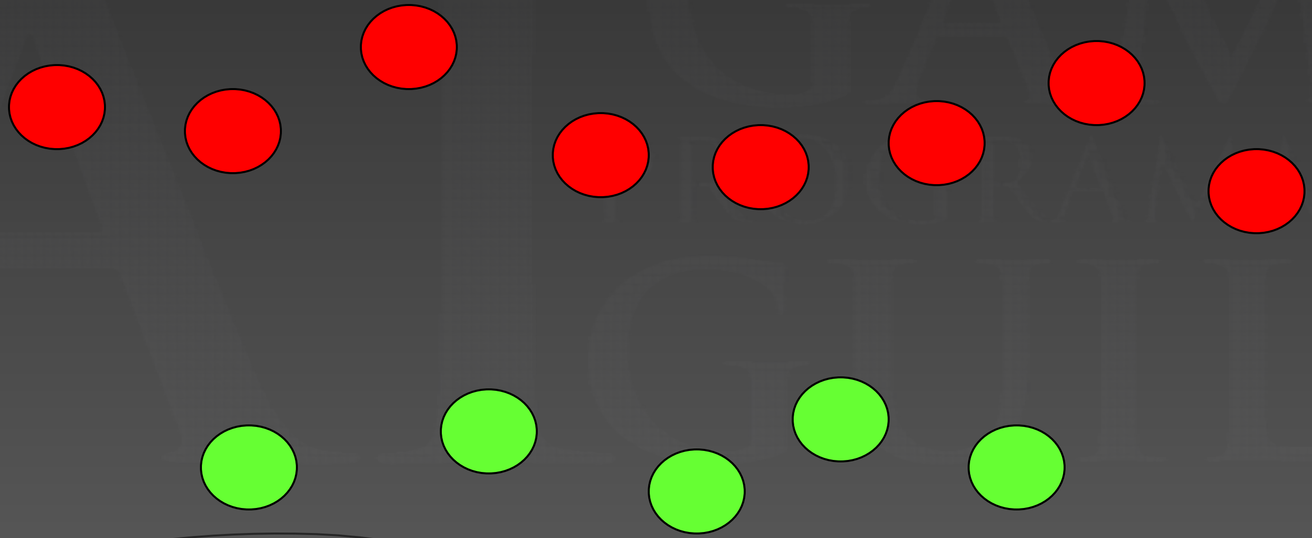
Brenda G Brathwaite @br
Follow

@chrispratt24 ... the basis from which other numbers are balanced.

Know when to walk away…

- Design Decision:
  "Enemies don't always fight to the death"
- Enemies can sometimes retreat
  - Flat % chance
    - Is random… therefore looks random
    - Not realistic
  - Situational random
    - Based on circumstances
    - Circumstances are flexible and dynamic

Know when to walk away…



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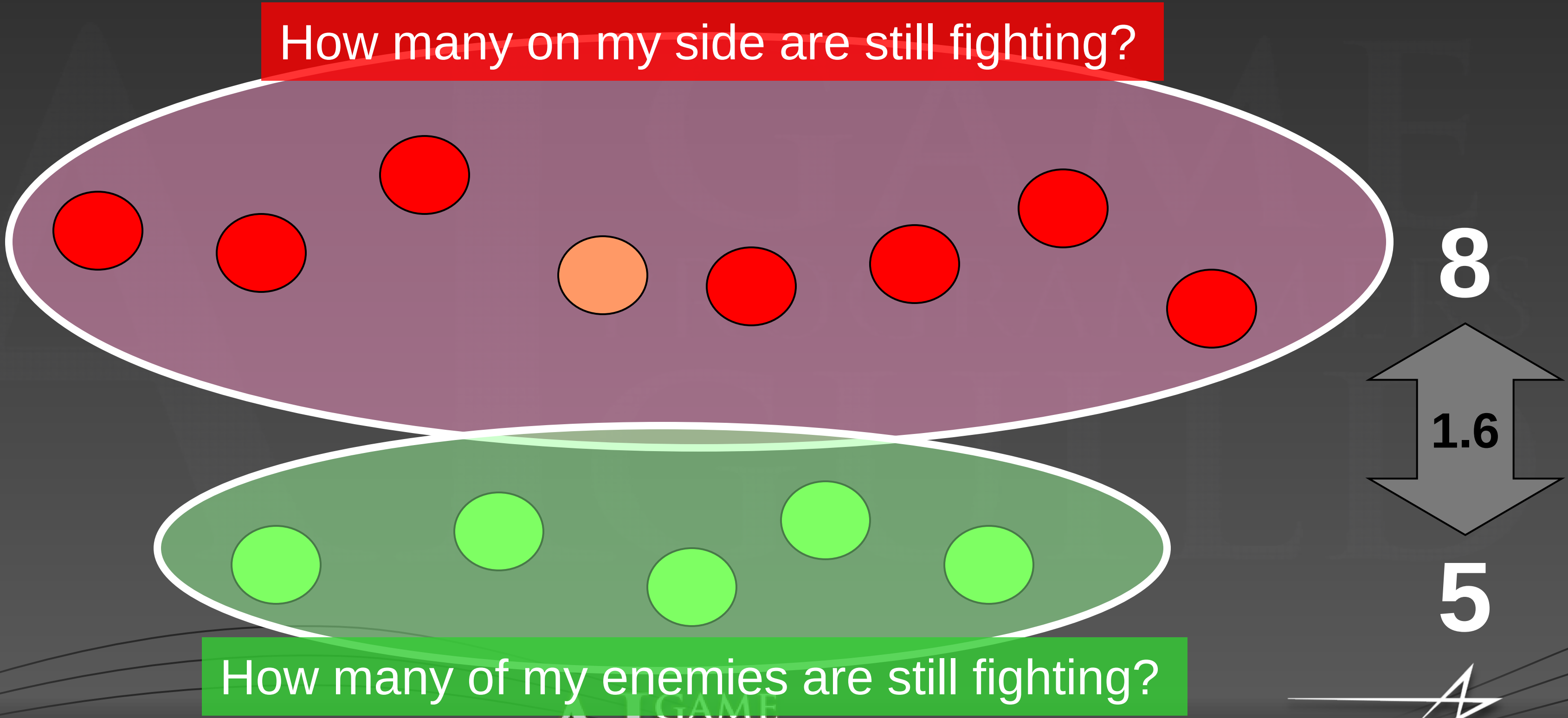
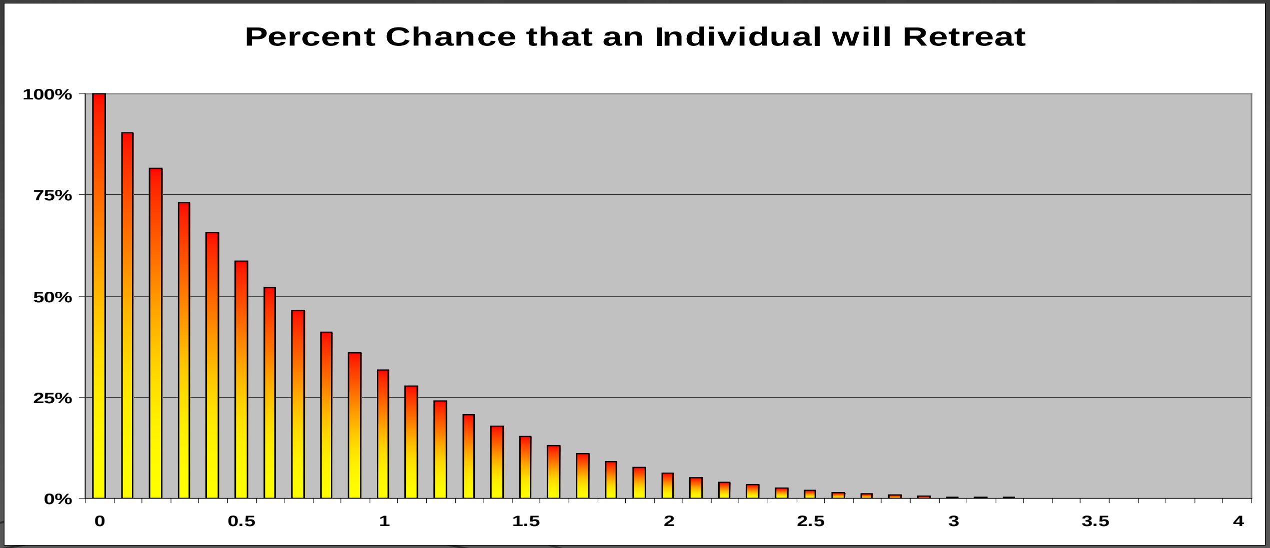


Know when to walk away…

$$PercentChance = (4 - Ratio)^3 / (4^3)$$



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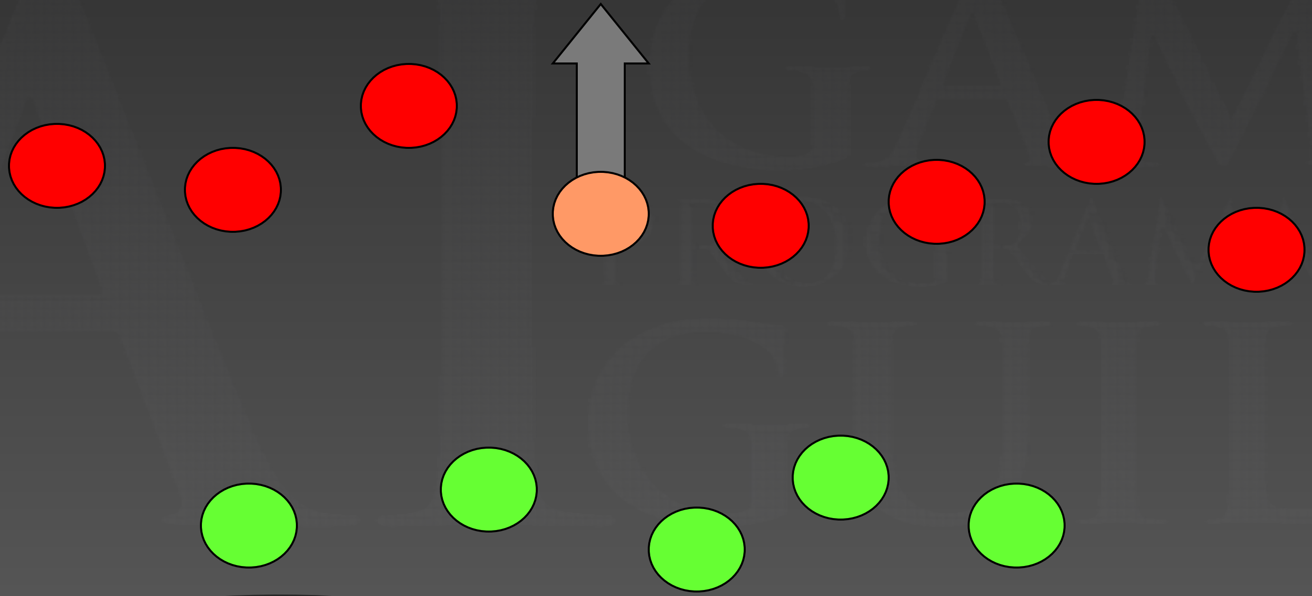
Know when to walk away…

$$PercentChance = (4 - Ratio)^4 / (4^4)$$

$$PercentChance = (4 - 1.6)^4 / (4^4)$$

$$PercentChance = 13\%$$

Know when to walk away…



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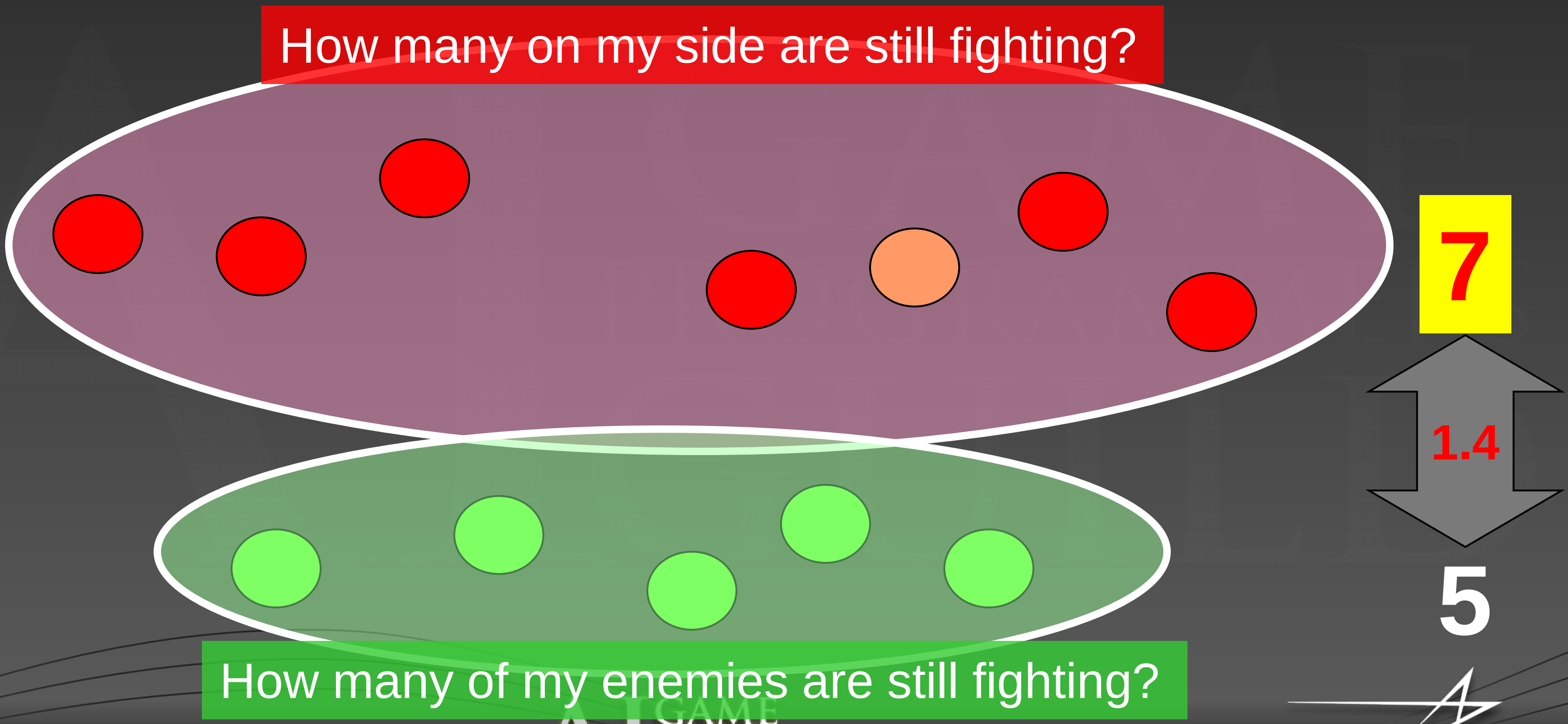


Know when to walk away…

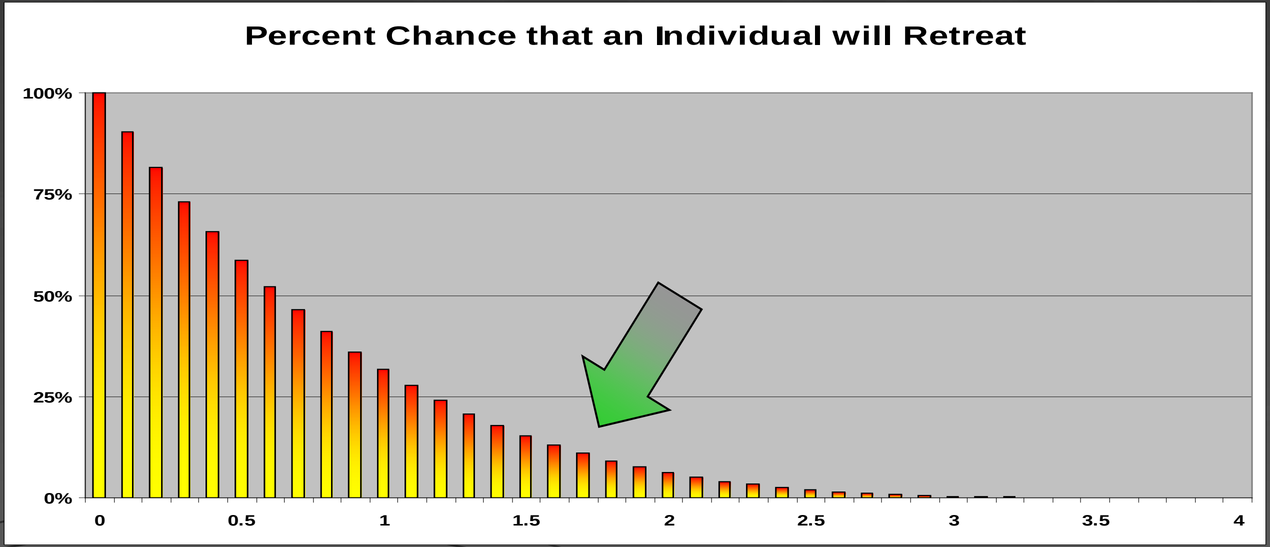
$$PercentChance = (4 - Ratio)^4 / (4^4)$$

$$PercentChance = (4 - 1.4)^4 / (4^4)$$

$$PercentChance = 18\%$$

Know when to walk away…

$$\text{PercentChance} = (4 \times \text{Ratio})^4 / (4^4)$$



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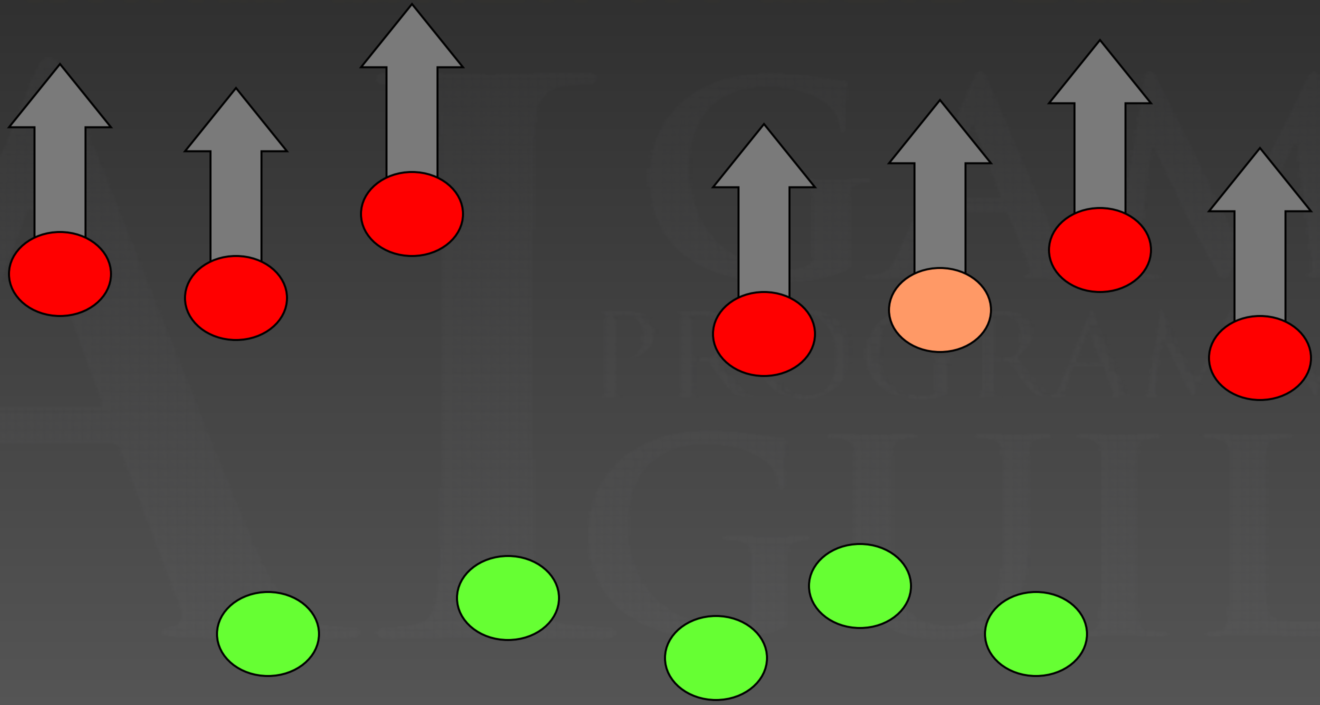

Know when to walk away…

PercentChance =

$$((\text{MaxRatio} - \text{Ratio})^k \times \text{MaxPct}) / (\text{MaxRatio}^k)$$

	MaxPct	k
In Forest	1.00	4
In Goat Field	0.75	6
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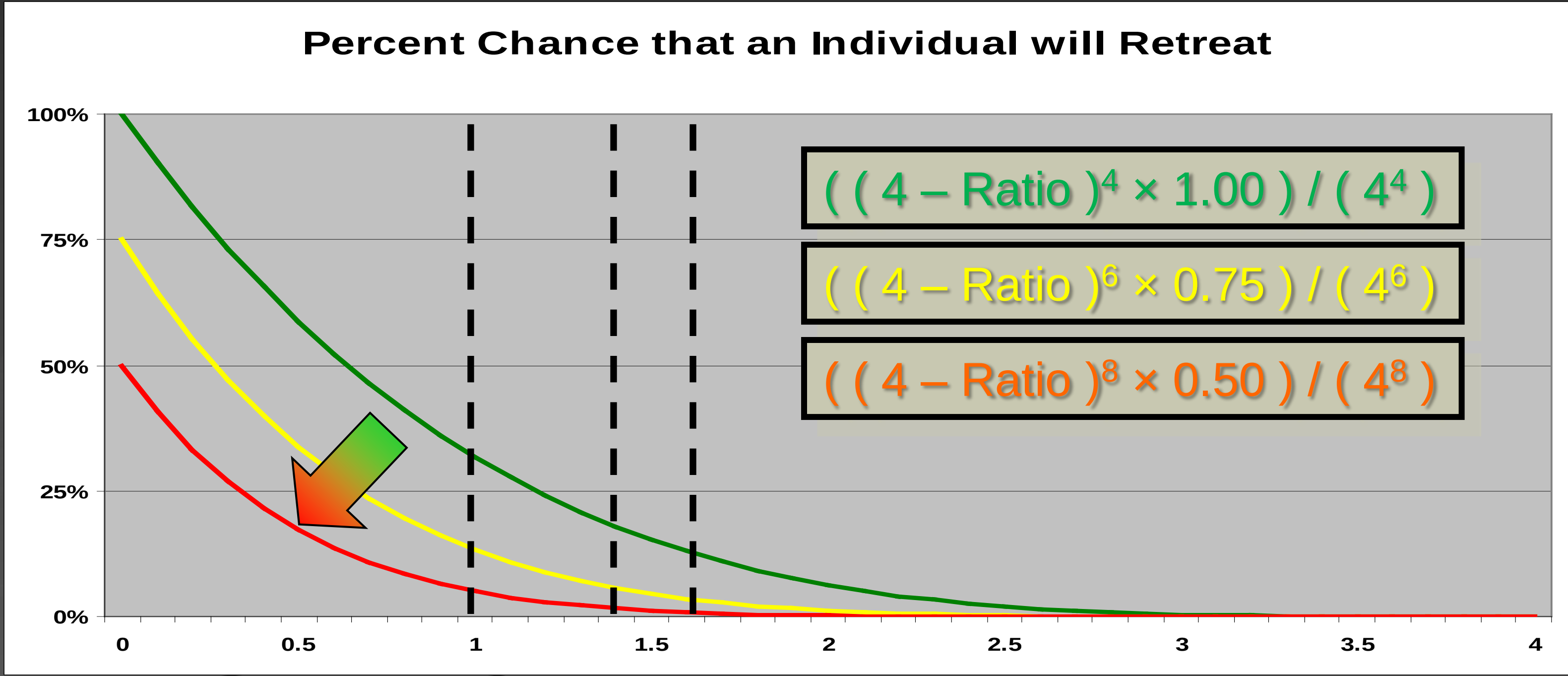
Know when to walk away...



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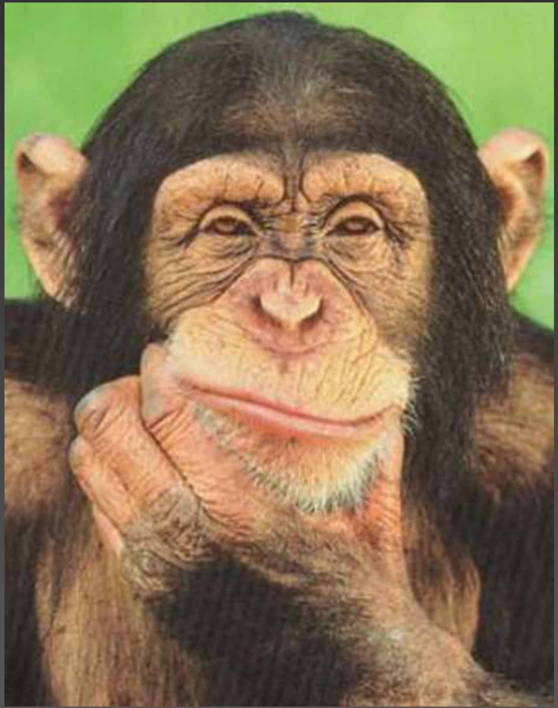
Know when to walk away…

- Factors to Consider
  - Number of allies
  - Number of enemies
  - Proximity to Base
  - Strength of allies
  - Strength of enemies
  - My own health
  - Proximity of my leader



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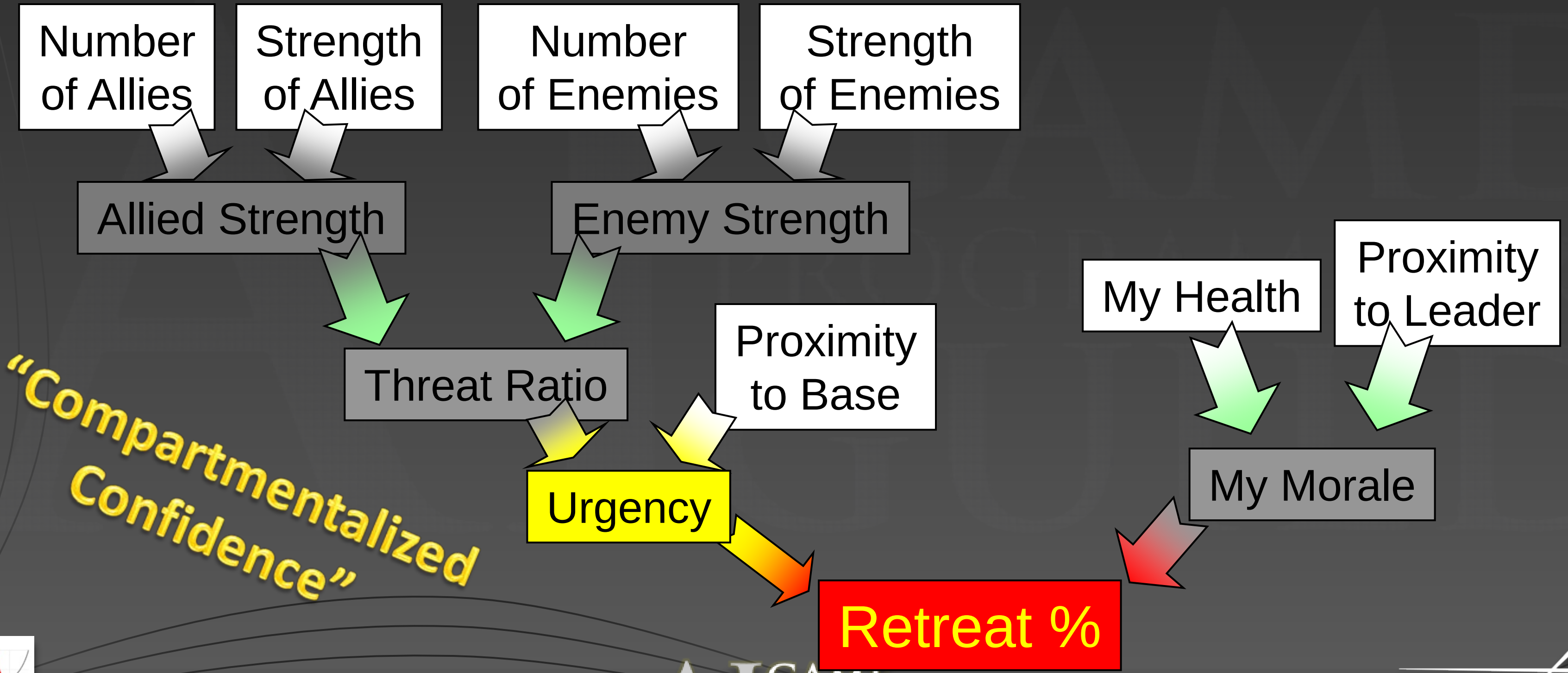
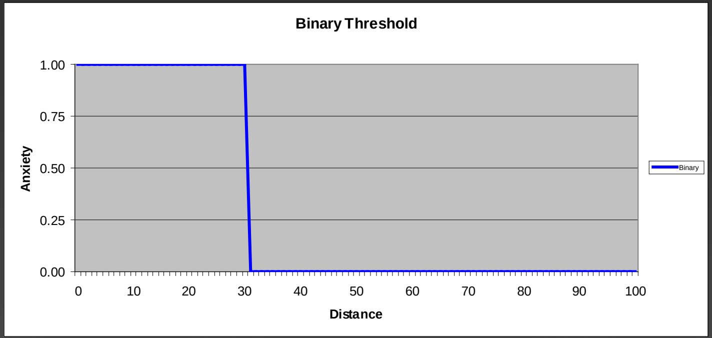
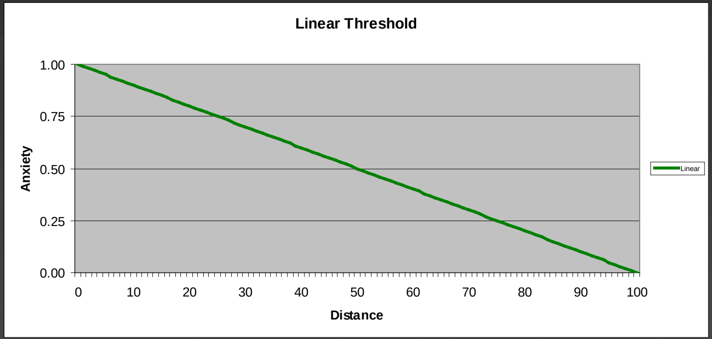
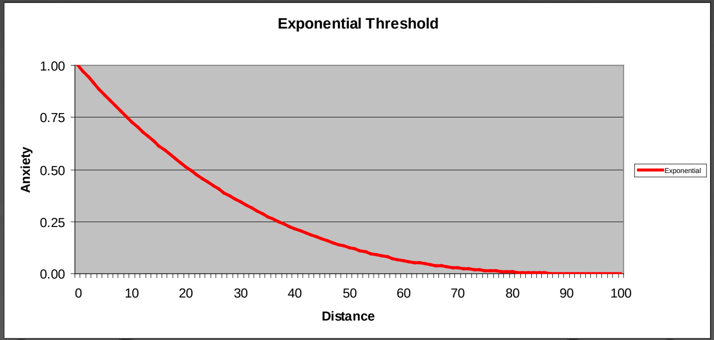


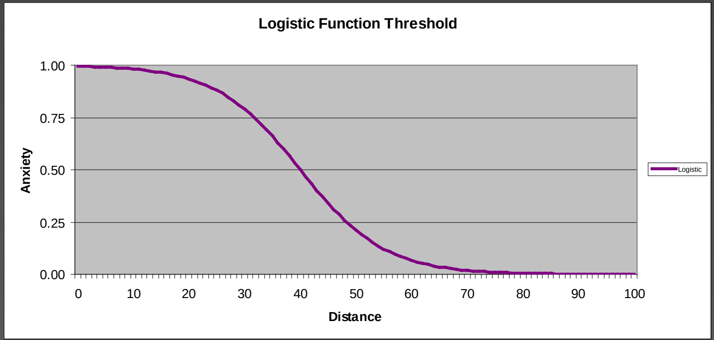
Types of Curves

2010 AI Summit Talk: Improving AI Decision Modeling Through Utility Theory









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Multiple Factors – Multiple Curves

- Each decision factor can have its own mathematical model
- Each model is completely atomic
- Only the result is passed on farther into the process

Relevant Example

Shopping for a Flight

- 6 Considerations
  - Price
  - Comfort
  - Total Length of Itinerary
  - Nearness to Preferred Departure Time
  - On-time Rate
  - Brand Loyalty

"Weighted Sum"

- Passenger Preference
  - [0..3]
- Itinerary Score
  - [-127..+127]
- Itinerary Rating = Sum (Pref. × Scores)

$$Rating = \sum_{i=1}^{6} (Pref_i \times Score_i)$$

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We seem to have a difference of opinion…

Satisfaction	x	Preference	=	Score
50	x	1	=	50
50	x	3	=	150
50	x	0	=	0

We seem to have a difference of opinion…

Satisfaction	x	Preference	=	Score
–70	x	1	=	–70
–70	x	3	=	–210
–70	x	0	=	0

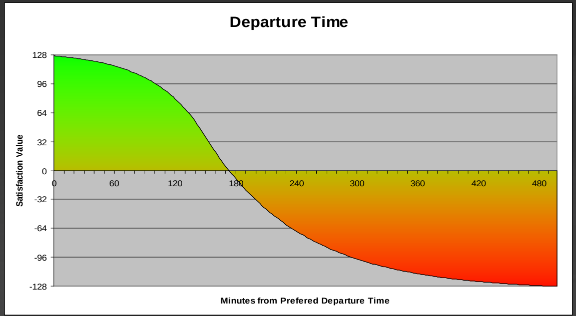
Adding It All Up

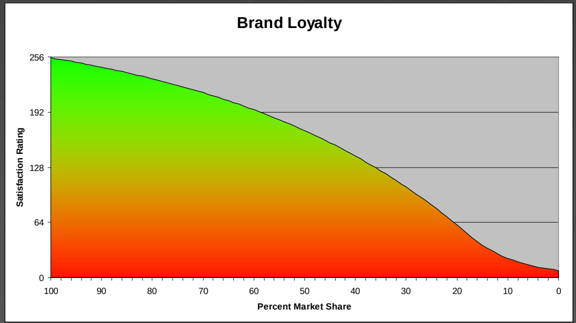
Category	Preference	x	Satisfaction	=	Score
Price	3	x	50	=	150
Comfort	1	x	-30	=	-30
Duration	1	x	80	=	80
Dep. Time	2	x	25	=	50
On-Time %	0	x	-100	=	0
Loyalty	2	x	50	=	100
				Total:	350

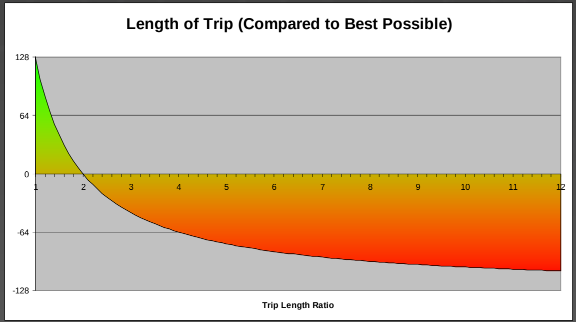
Adding It All Up

Category	Preference	x	Satisfaction	=	Score
Price	3	x	–25	=	–75
Comfort	1	x	40	=	40
Duration	1	x	90	=	90
Dep. Time	2	x	25	=	50
On-Time %	0	x	200	=	0
Loyalty	2	x	–60	=	–120
				Total:	–15

Here a curve, there a curve…







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How Satisfying is This?

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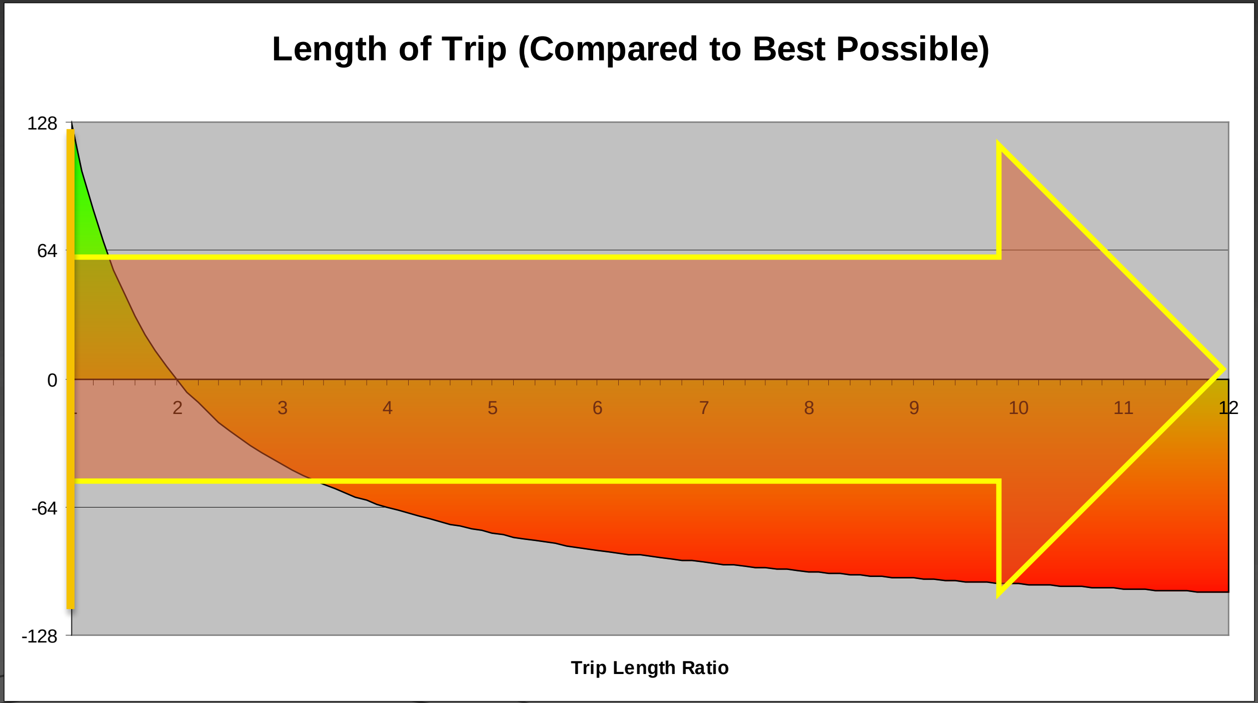
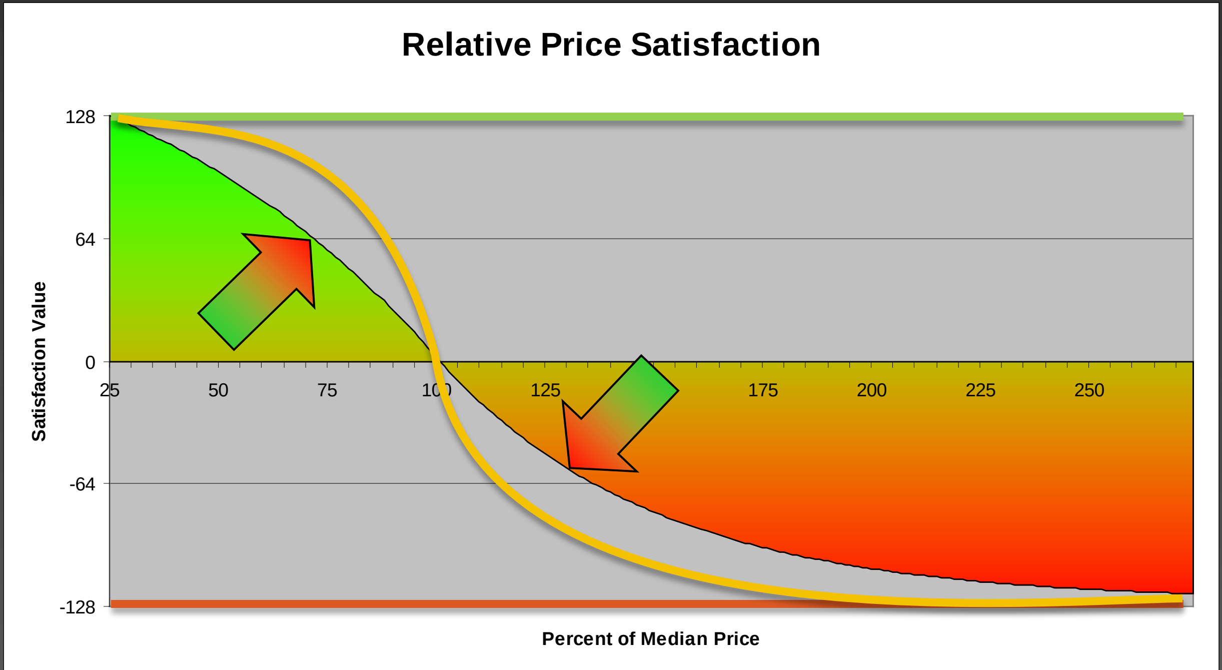


Normalization, Normalization, Normalization!

- All preferences on the same scale (0..3)
- All satisfaction curves on the same scale (-127..+127)
- Because range is fixed
  - Endpoints have consistent meaning
  - Changes to "satisfaction" models happen *inside* each component
  - Comparisons *between* components can remain unchanged

"Compartmentalized Confidence"

How Satisfying is This?



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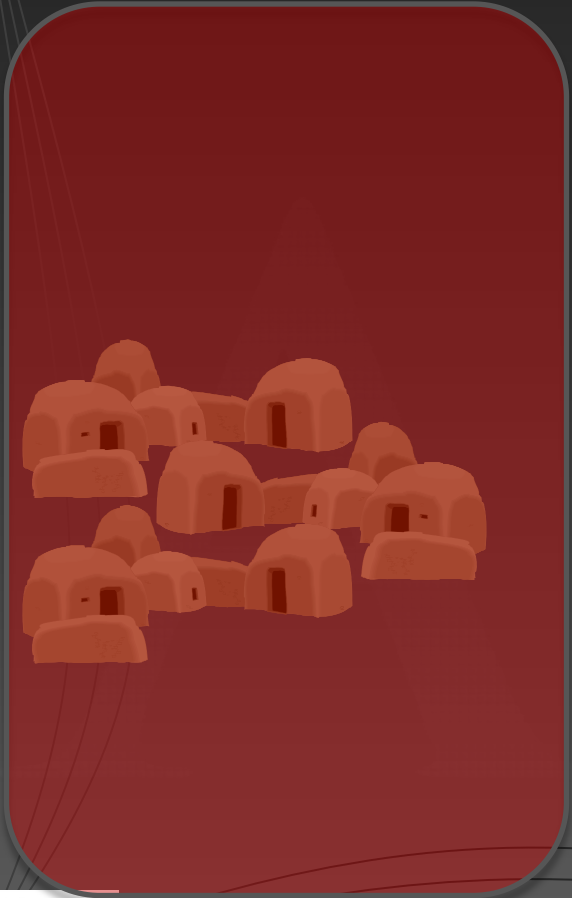
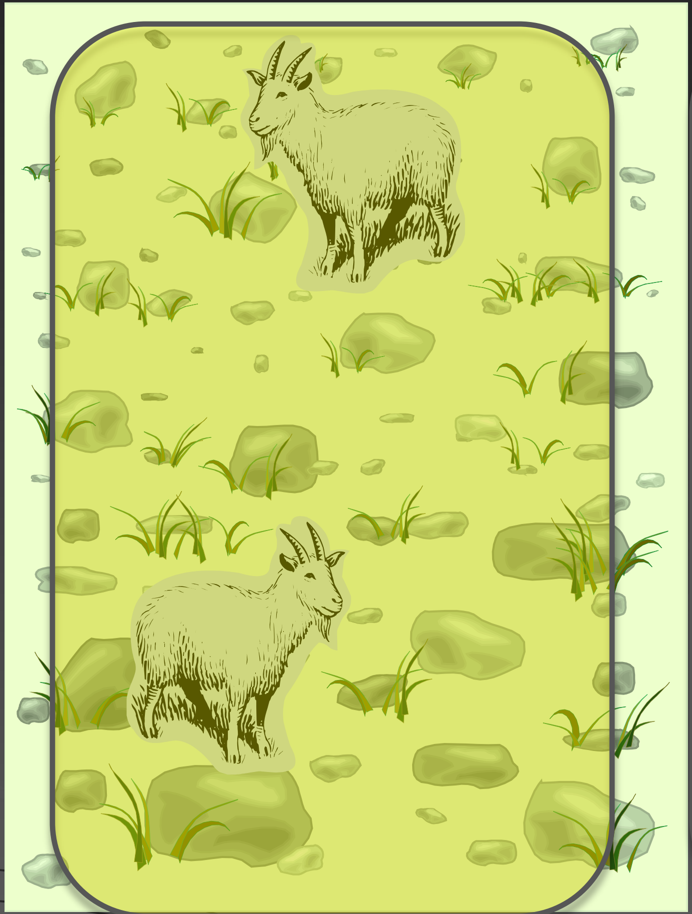
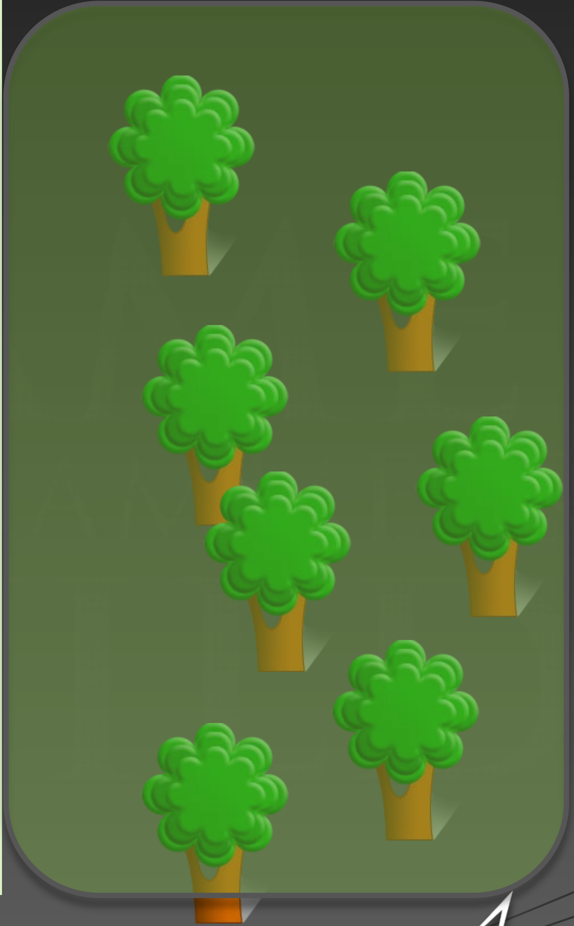
Gimme whatcha got…

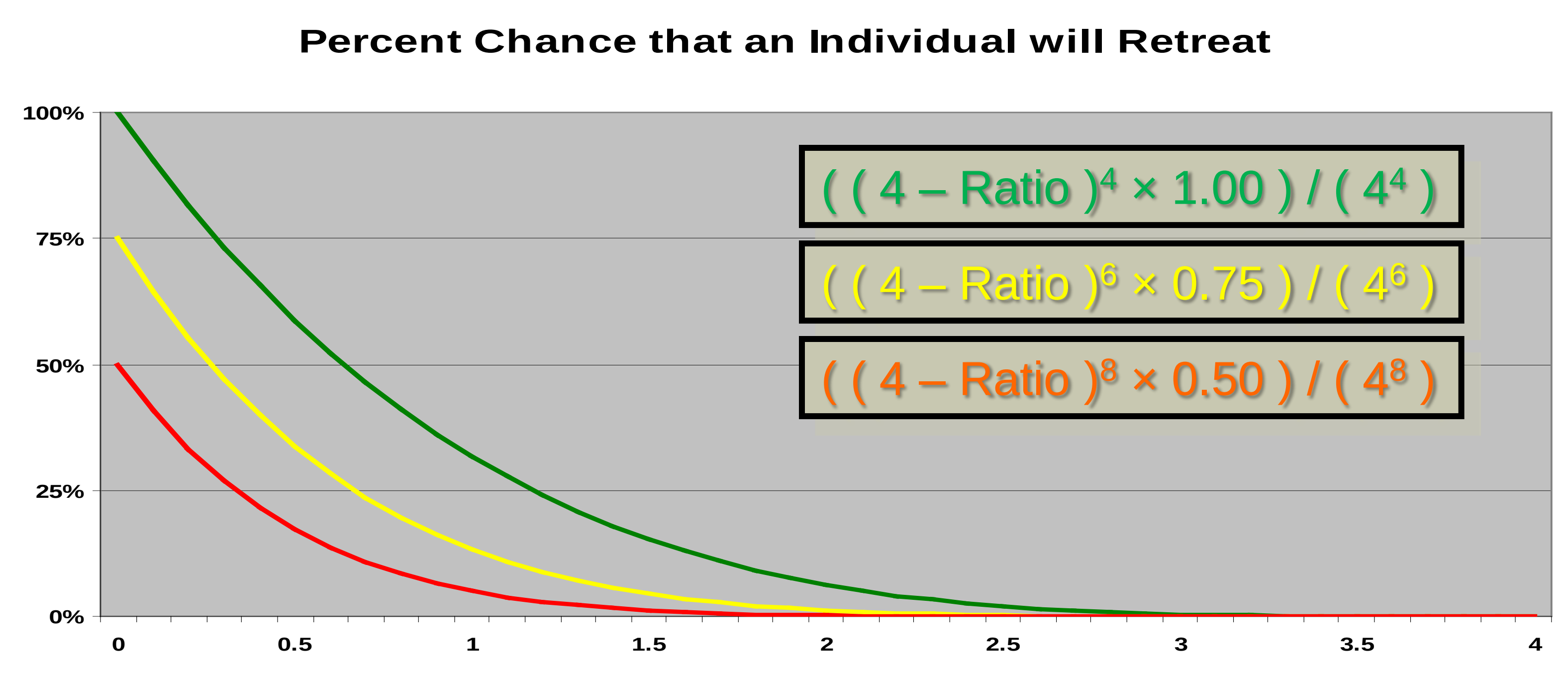
- Data flows *through* the model
- Treat each step like a black box
  - Define what the output *means*
  - Process inside the box to define that *meaning*
  - Use the output as if the *meaning* is intact







Adjusting Curves with Curves



Adjusting Curves with Curves

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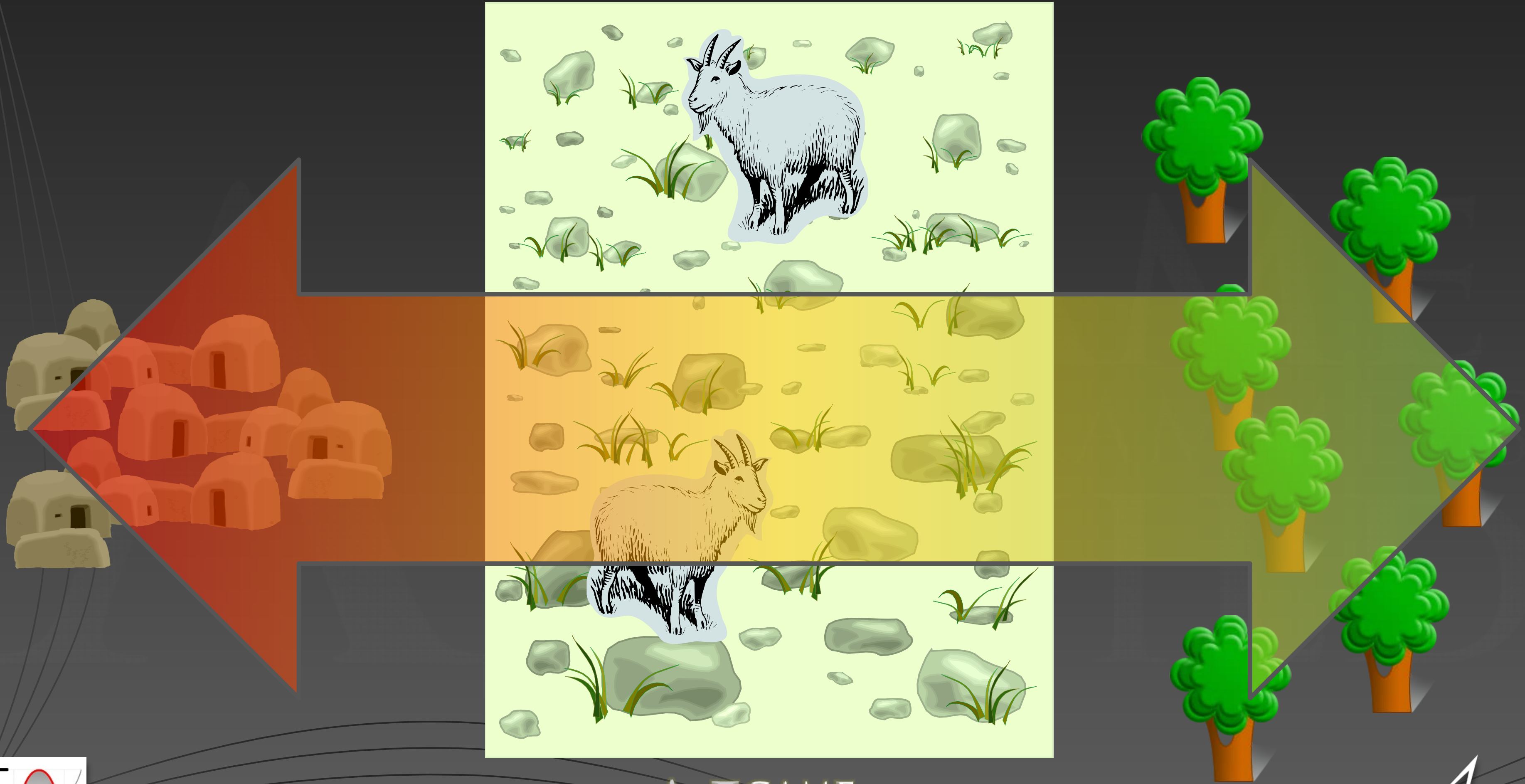
???



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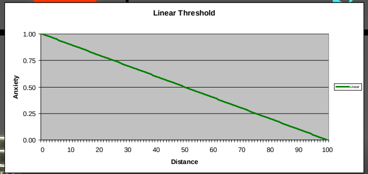

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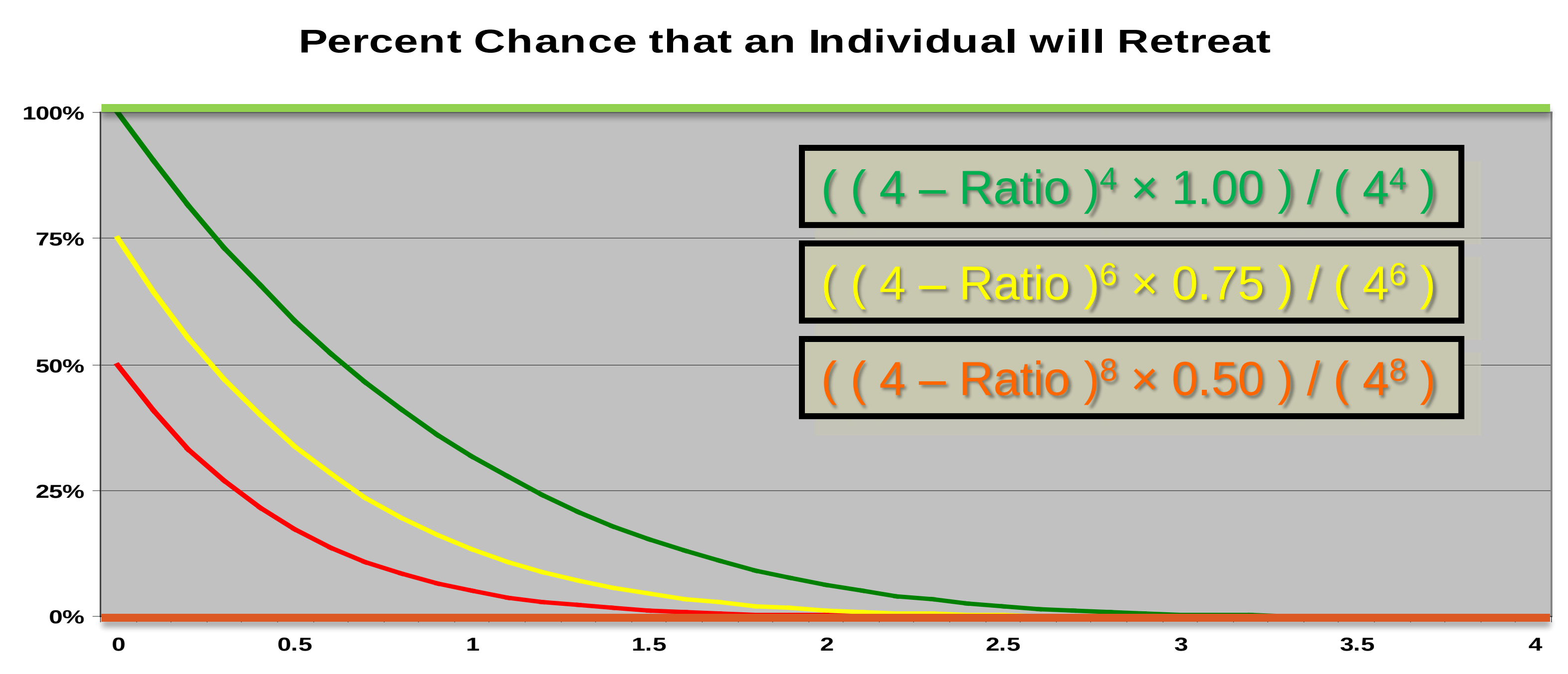
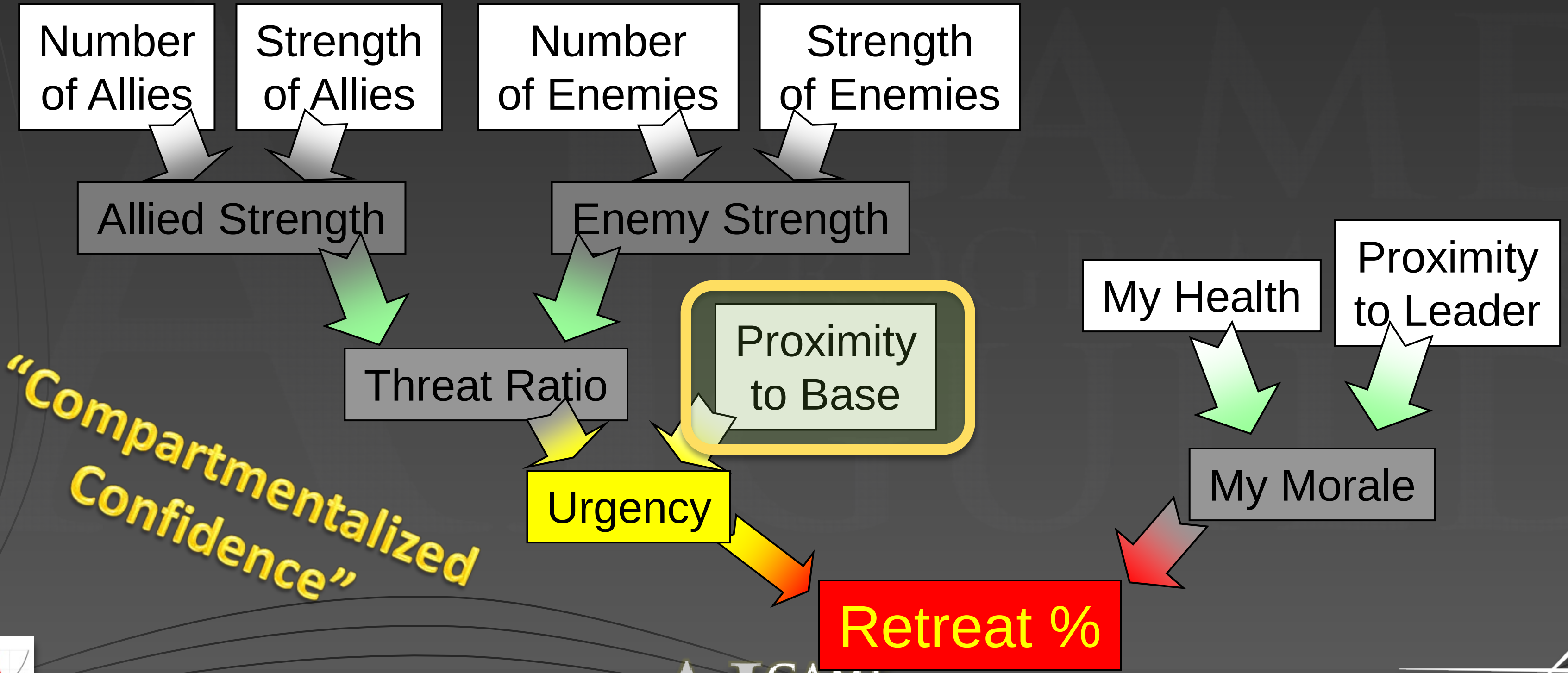
Adjusting Curves with Curves



Don’t Mind Me… I’m Tweaking



Mathematical Topography

- Adding information together constructs a "landscape"
- Each component is separate
  - Modeled individually
  - Deforms the *total* landscape
- Visualize the total effect

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Mathematical Topography is Not New

- Generating a "landscape"
- The Sims "Happyscape"
- "Hill-climbing" to select
- RTS influence maps

Modular Considerations

- Guard Patrol Location
  - Close to the castle
  - Close to me
  - Not close to other guards

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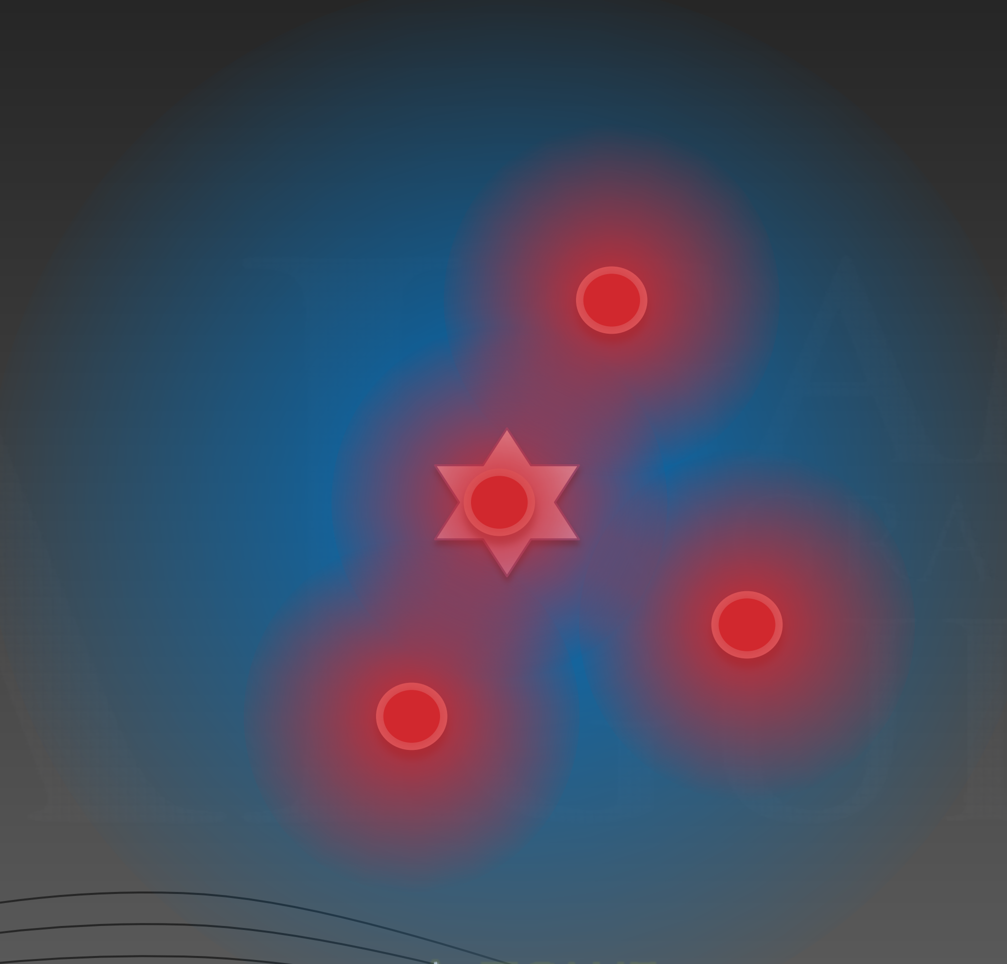
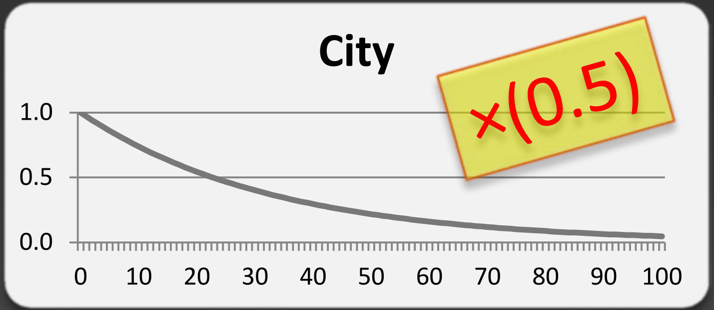
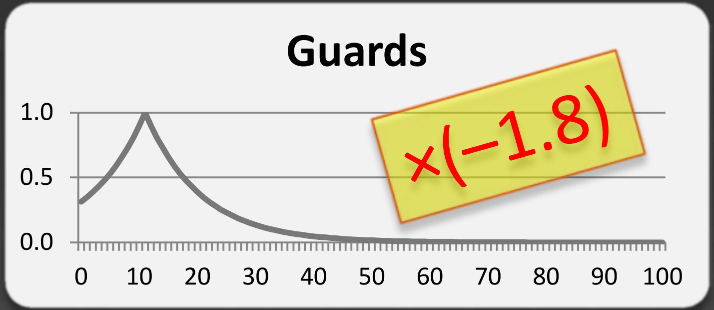
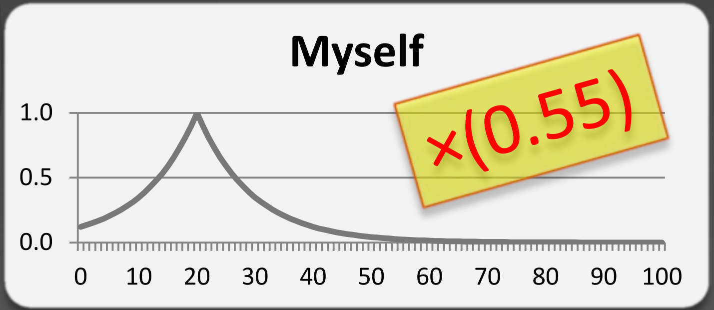
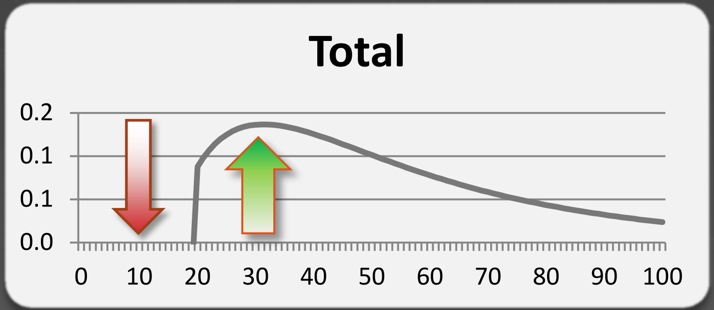


A Mathematical Landscape



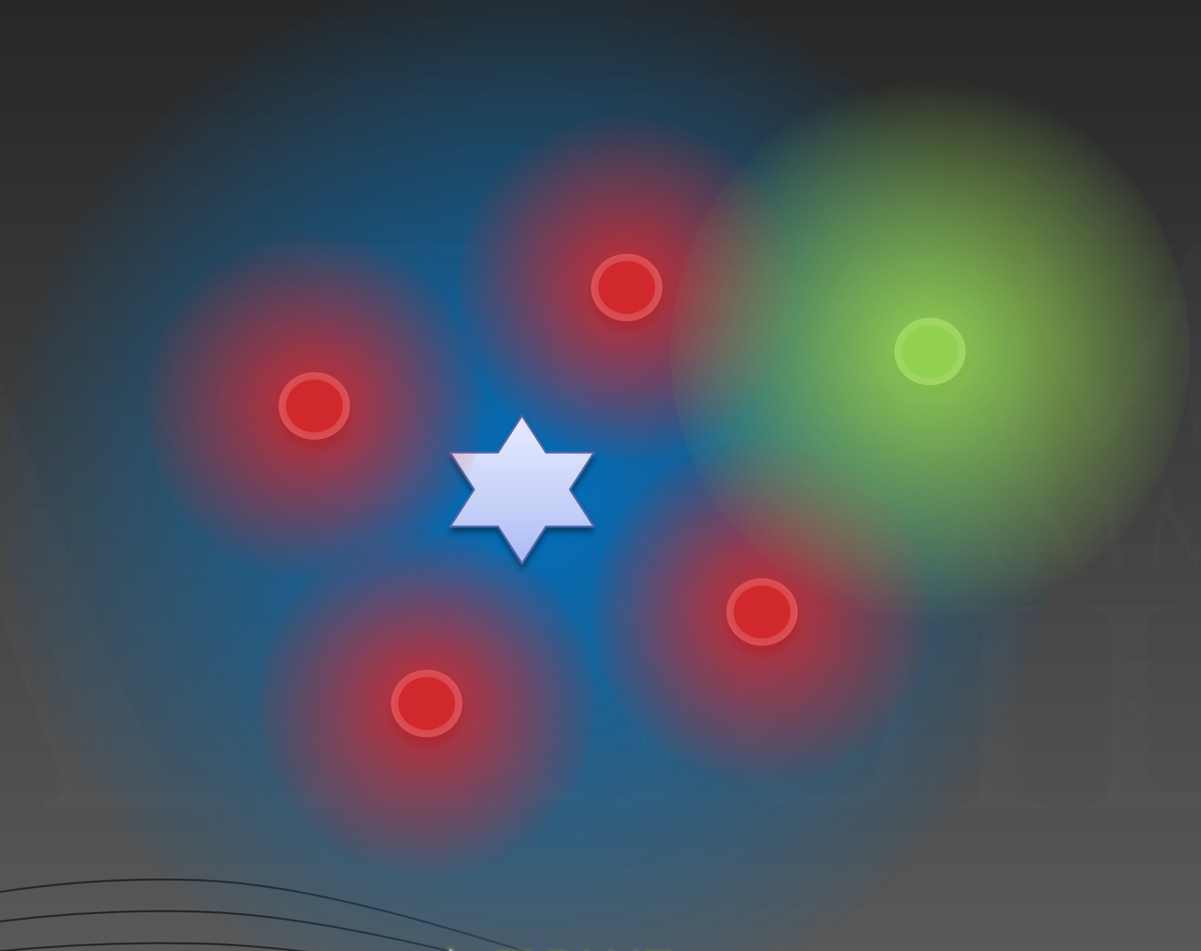






Modular Considerations

- Guard Patrol Location
  - Close to the castle
  - Close to me
  - Not close to other guards
  - Close to civilians



Modular Considerations

- Guard Patrol Location
  - Close to the castle
  - Close to myself
  - Not close to guards
  - Close to civilians
  - Close to monsters

×(–1)

- Civilian Wander
  - Close to the castle
  - Close to myself
  - Close to guards
  - Close to civilians
  - Away from monsters

×(–1)

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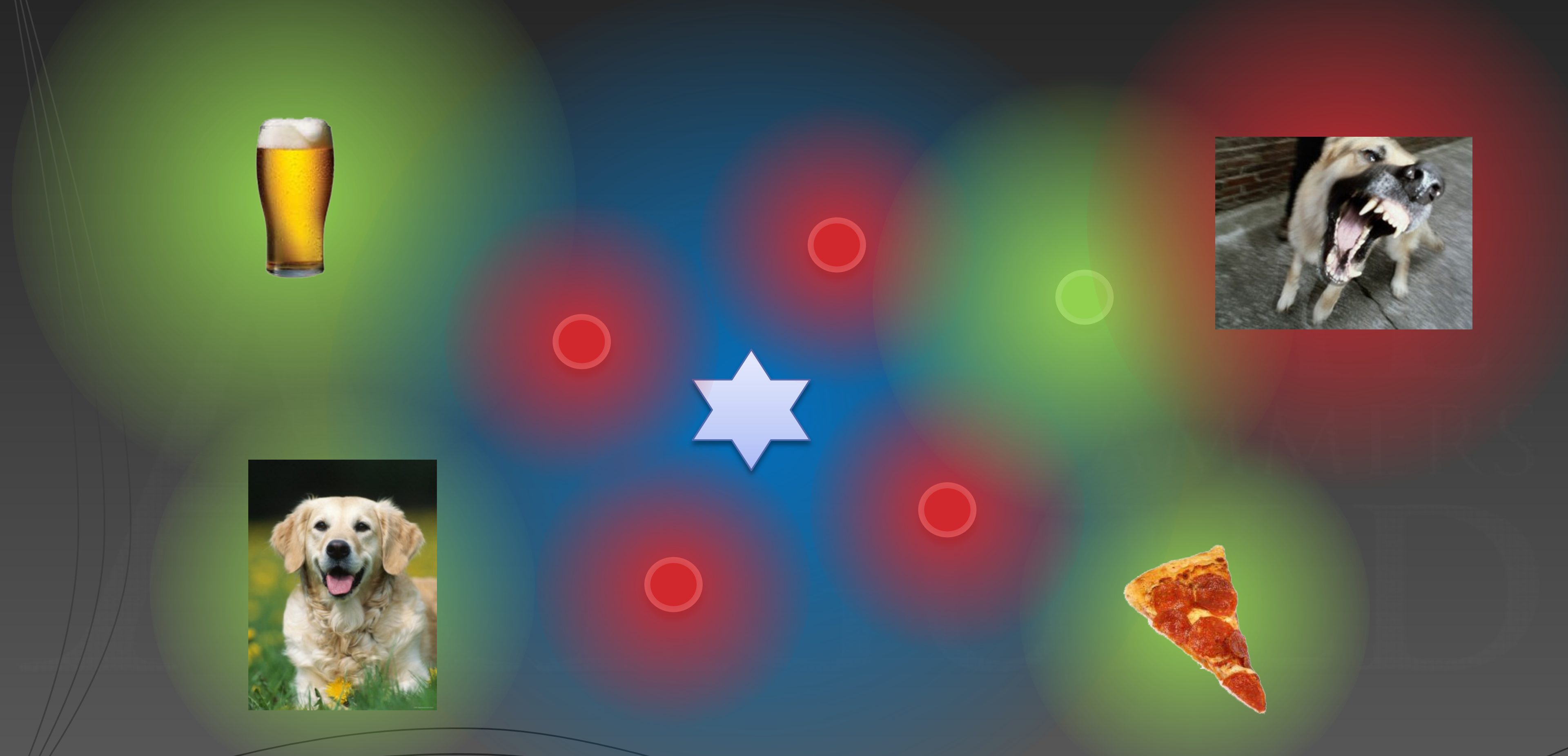
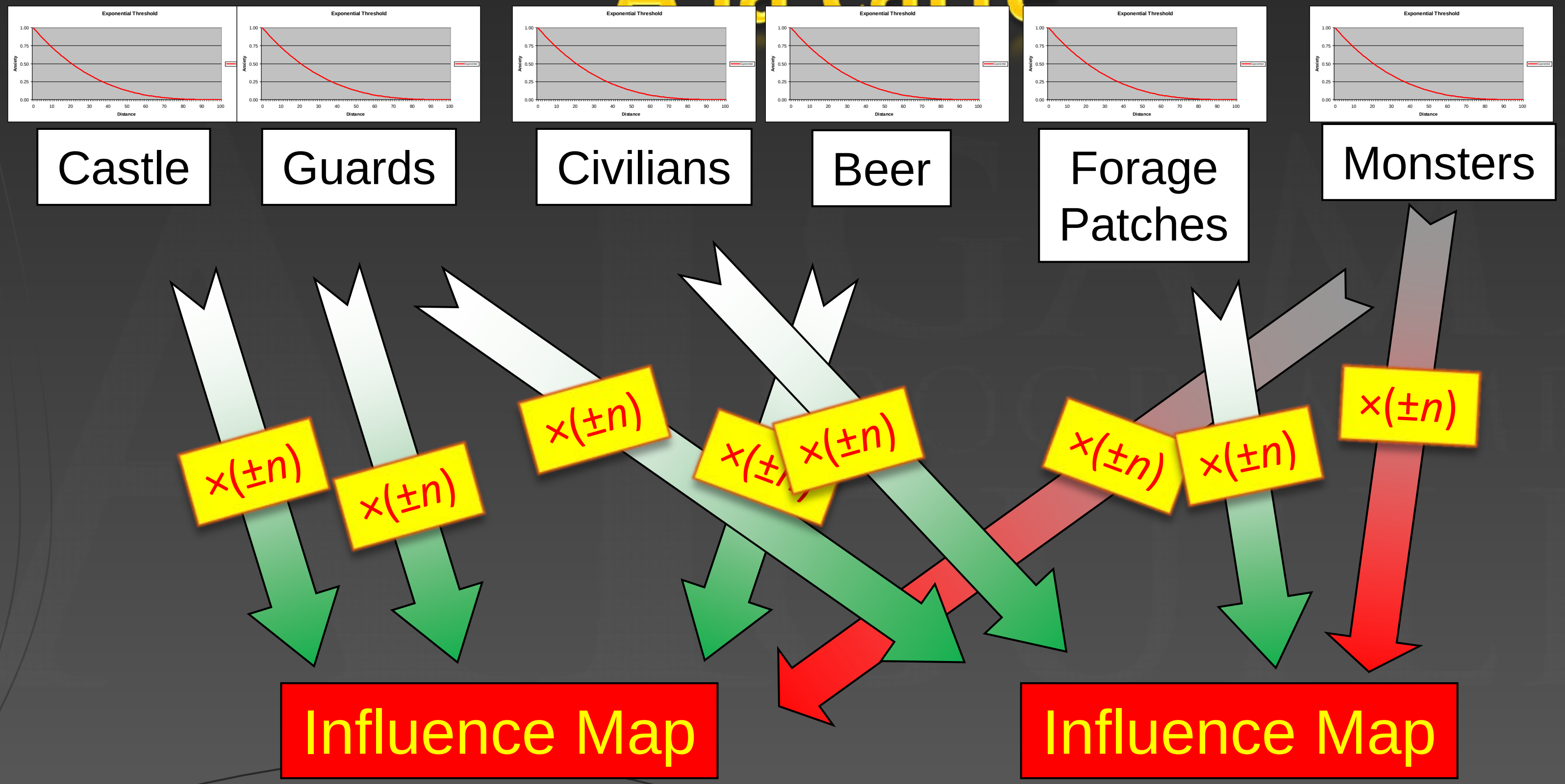
Modular Considerations

- Monster Location
  - Away from the castle
  - Close to myself
  - Not close to other guards
  - Close to civilians

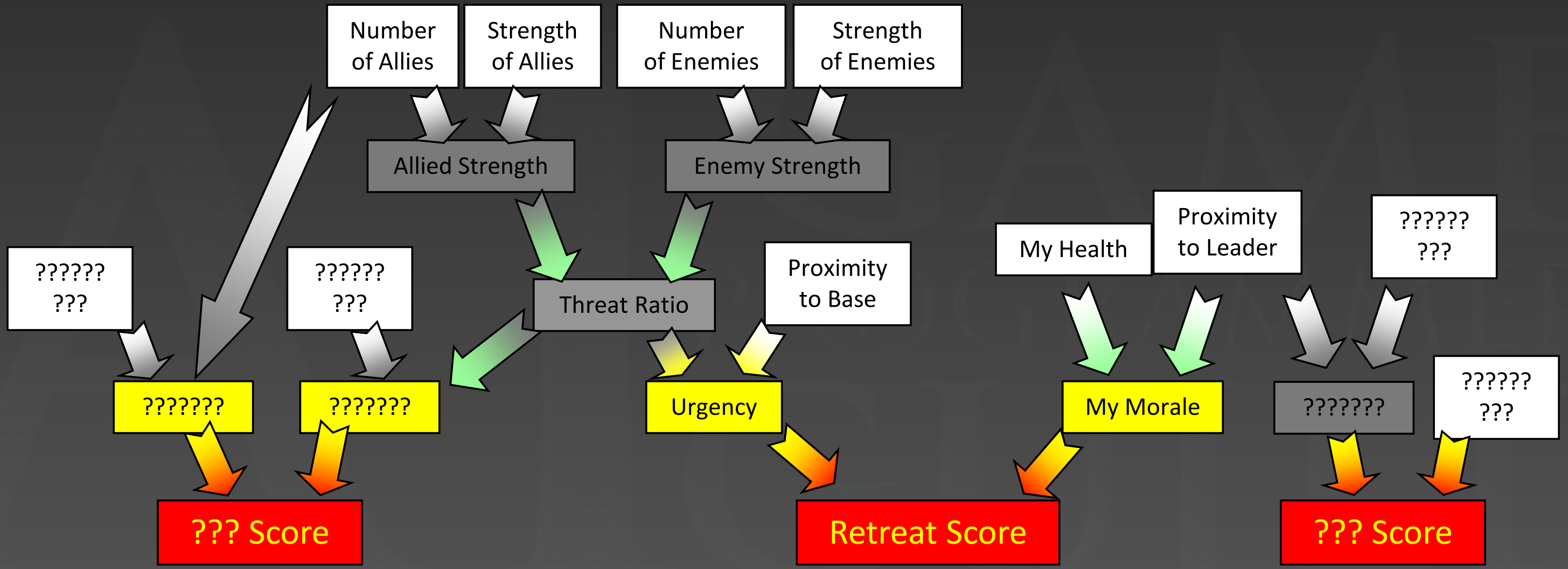
×(–1)



A la carte


Castle
Guards
Civilians
Beer
Forage Patches
Monsters
×(±n)
Influence Map
Influence Map

The Value of Consistency



The Value of Consistency

- If output values are consistent
  - They can be used in multiple places
  - They can be compared meaningfully
    - Scale of importance is the same
    - Bigger is better
  - Unified selection methods can be used

Picking a Winner

- Highest score
  - Always the "best" selection
  - Always the same selection given criteria
- Random from top *n*
- Weighted random from top *n*
- Weighted random from all choices

Mathematical Modeling Takeaways

- Utility-based AI can handle large numbers of potential selections dynamically
- Consistent design patterns help define a coherent structure
- Craft "considerations" that handle a specific component of the decision process

Mathematical Modeling Takeaways

- It’s more than a “bucket of floats”
- Select mathematical formulas to convert raw data into meaningful values
- Normalize!
  - “Black box” output is consistent
  - Use defined ranges & scales
  - Can be combined seamlessly with other black boxes

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Questions!!

Dave Mark

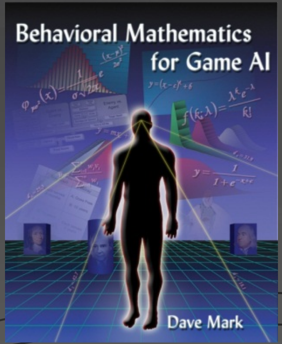
Intrinsic Algorithm LLC

Dave@IntrinsicAlgorithm.com

www.IntrinsicAlgorithm.com

IADaveMark on:

Yahoo – AIM – Skype – Twitter



Kevin Dill

Lockheed Martin

KDill4@gmail.com

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AI Game Programmers Guild

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