The Art of Game AI:
Sculpting Behavior with Data, Formulas, and Finesse

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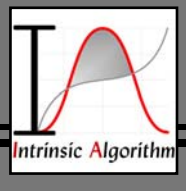
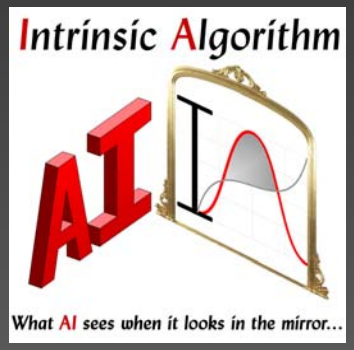
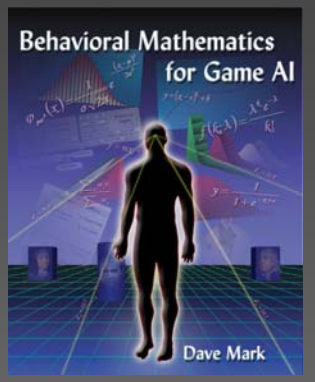


"Reducing the world to mathematical equations!"

Dave Mark

- President & Lead Designer of
  Intrinsic Algorithm LLC
  - Game Studio
  - AI Consulting Company
- Author of
  Behavioral Mathematics for Game AI
- Co-founder of
  AI Game Programmers Guild
- Organizer and co-host of the
  AI Summit at GDC 2009
  (soon to be 2010!)





AI GAME PROGRAMMERS GUILD

AI Summit
GDC 2009

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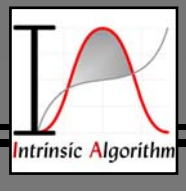
Premises/Disclaimers

The examples you will see are only scratching the surface.

There is no way to show concrete implementation in a 1-hour lecture.

We want to make you *think* about what you *can* do.



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What makes a game a game?

"A game is a series of interesting choices."

- Sid Meier

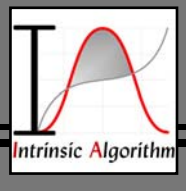
AI *is* Your World!

Boring AI = Boring World

Deep AI = Immersive World

Repetitive AI = Monotonous World

Dynamic AI = Dynamic World



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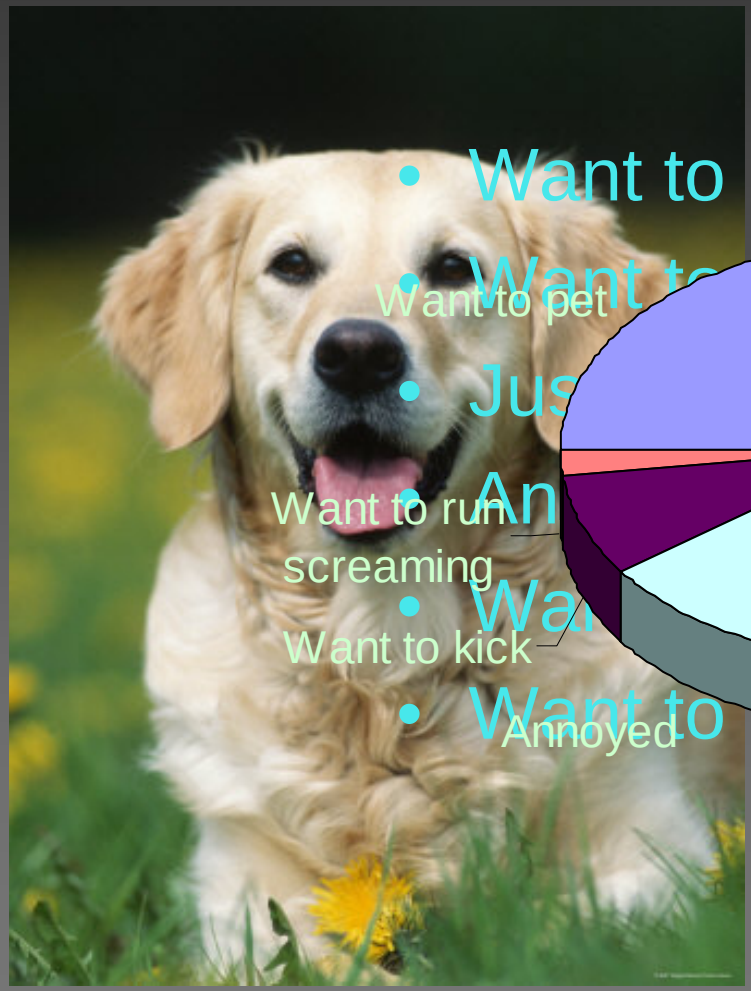
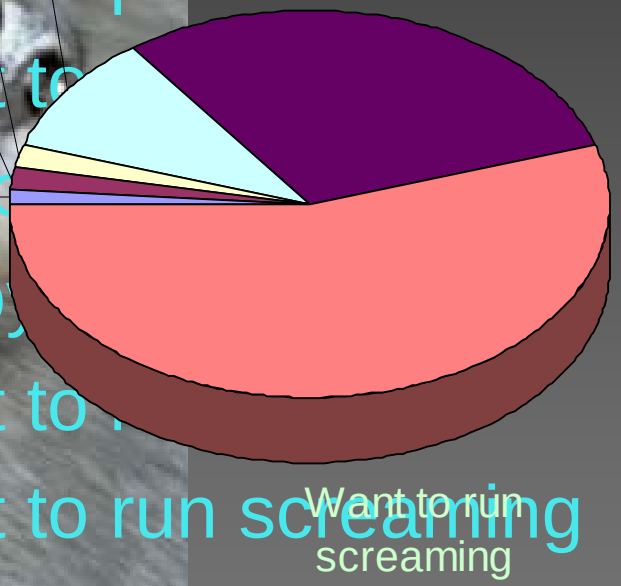
What is your reaction?



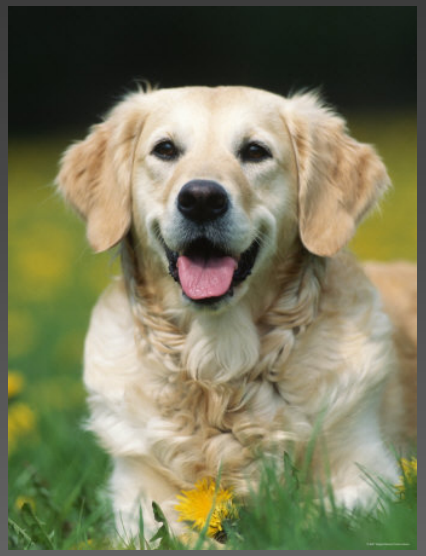
- Want to pet
- Want to
- Jus
- An
- Wa
- Want to kick
- Want to run screaming
- Annoyed

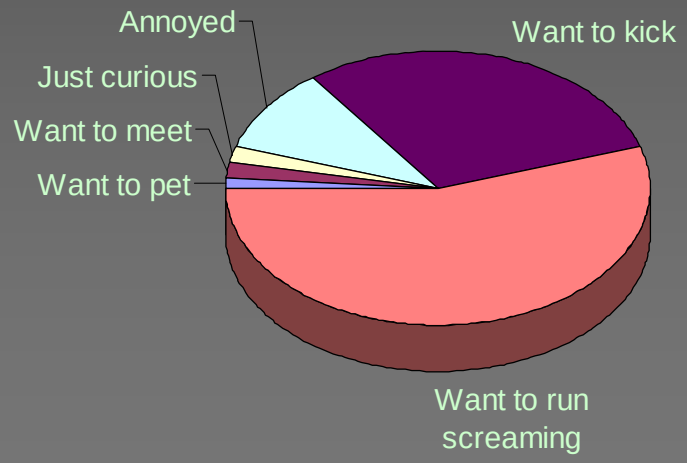
Now what is your reaction?

- Want to pet
- Want to
- Just
- Annoy
- Want to
- Want to run screaming



Varieties of Reactions





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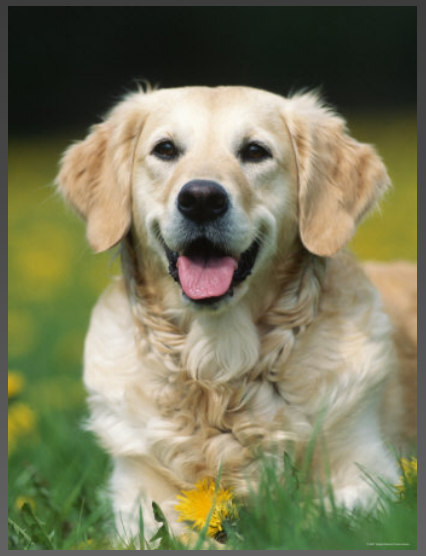
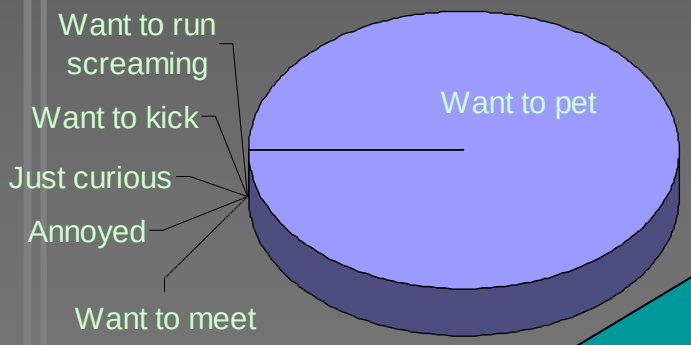
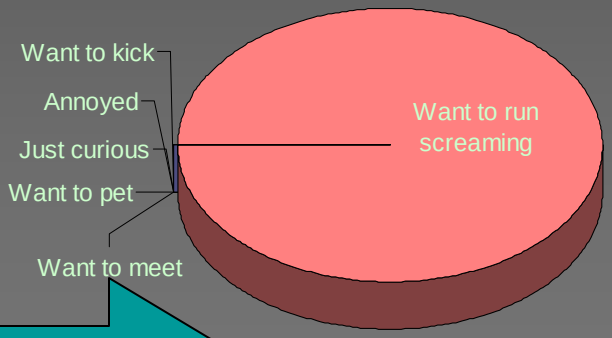
Same Model for All Agents







Extreme Reactions

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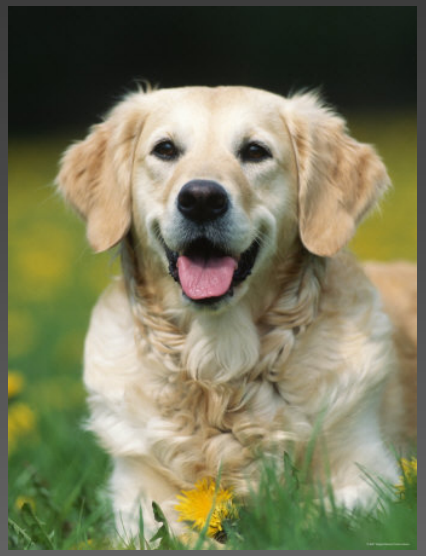
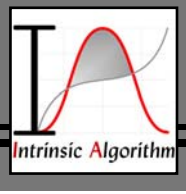
Varieties of Reactions



- Differences Exist
- Don't need to know why
- Need to simulate that difference do exist
  - Not completely random selection
  - Must be reasonable

How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
- Allowing for more than one possible result



How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
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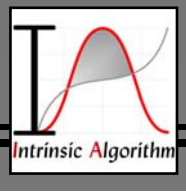
Processing One Piece of Info

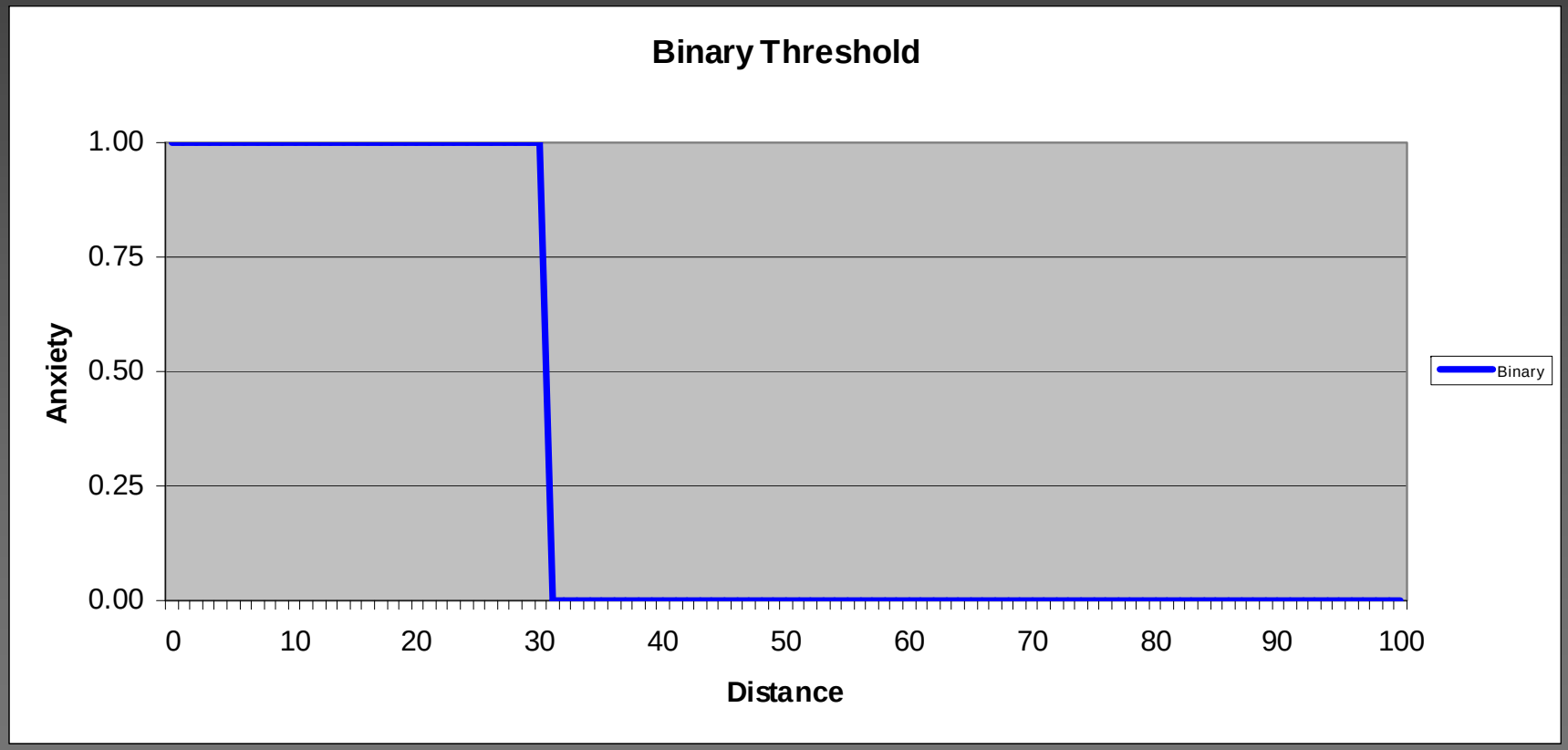
Simple example:

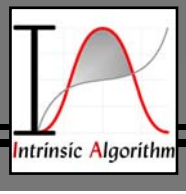
As the distance changes, how much anxiety do you have?



Simple Rule

If distance <= 30





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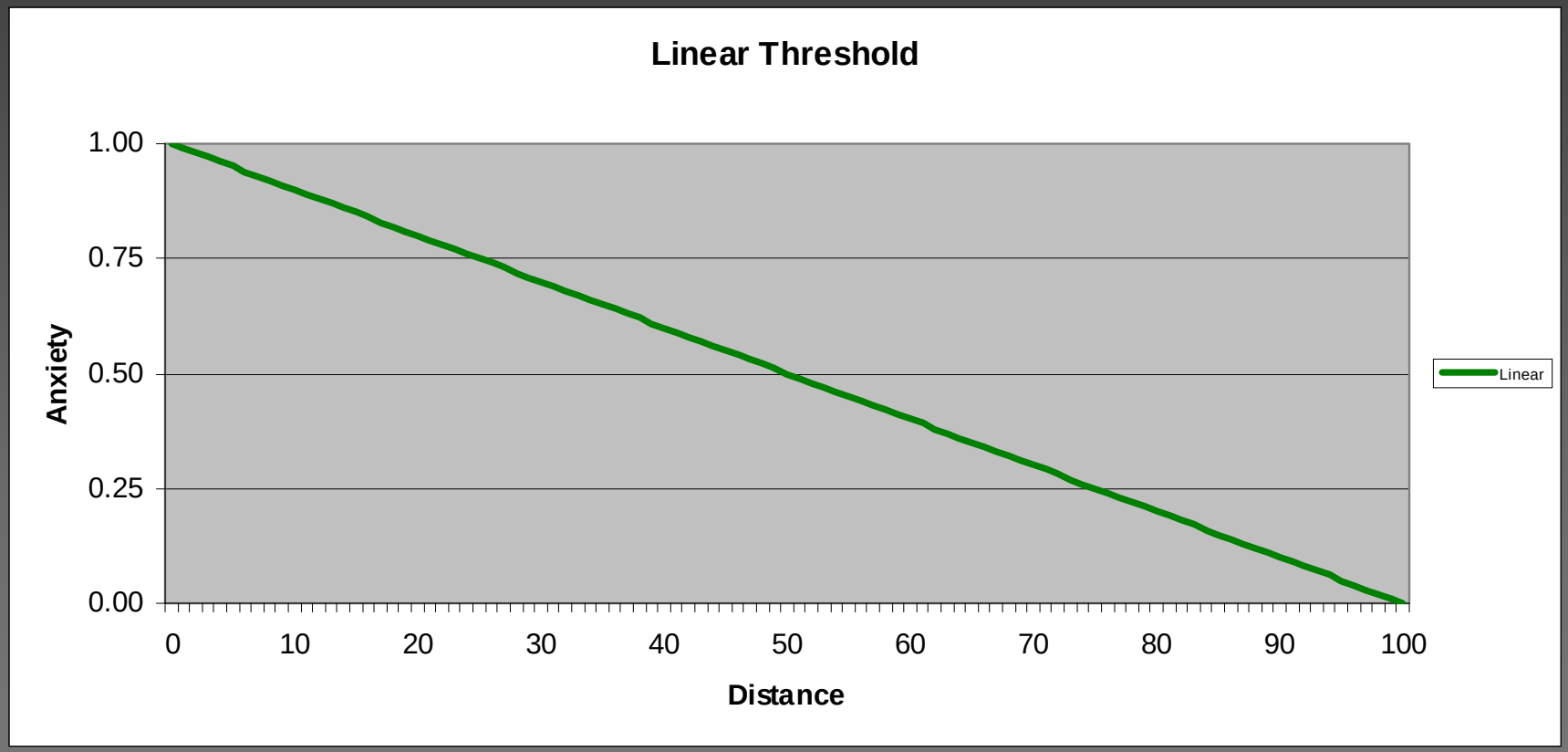
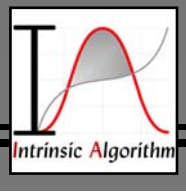
Linear Formula

Anxiety = (100 – distance) / 100





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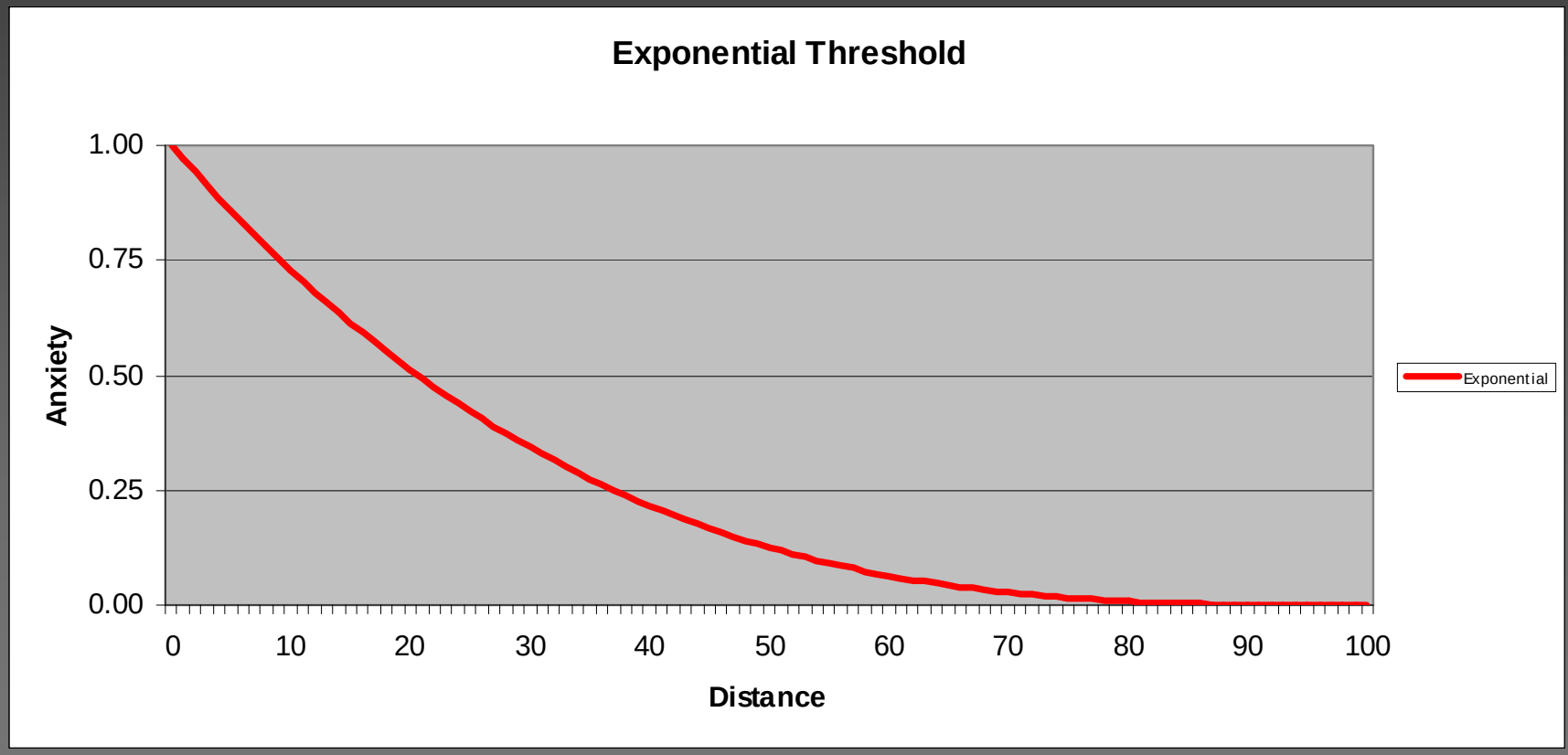
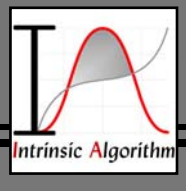
Exponential Formula

Anxiety = $(100 - \text{distance}^3) / (100^3)$





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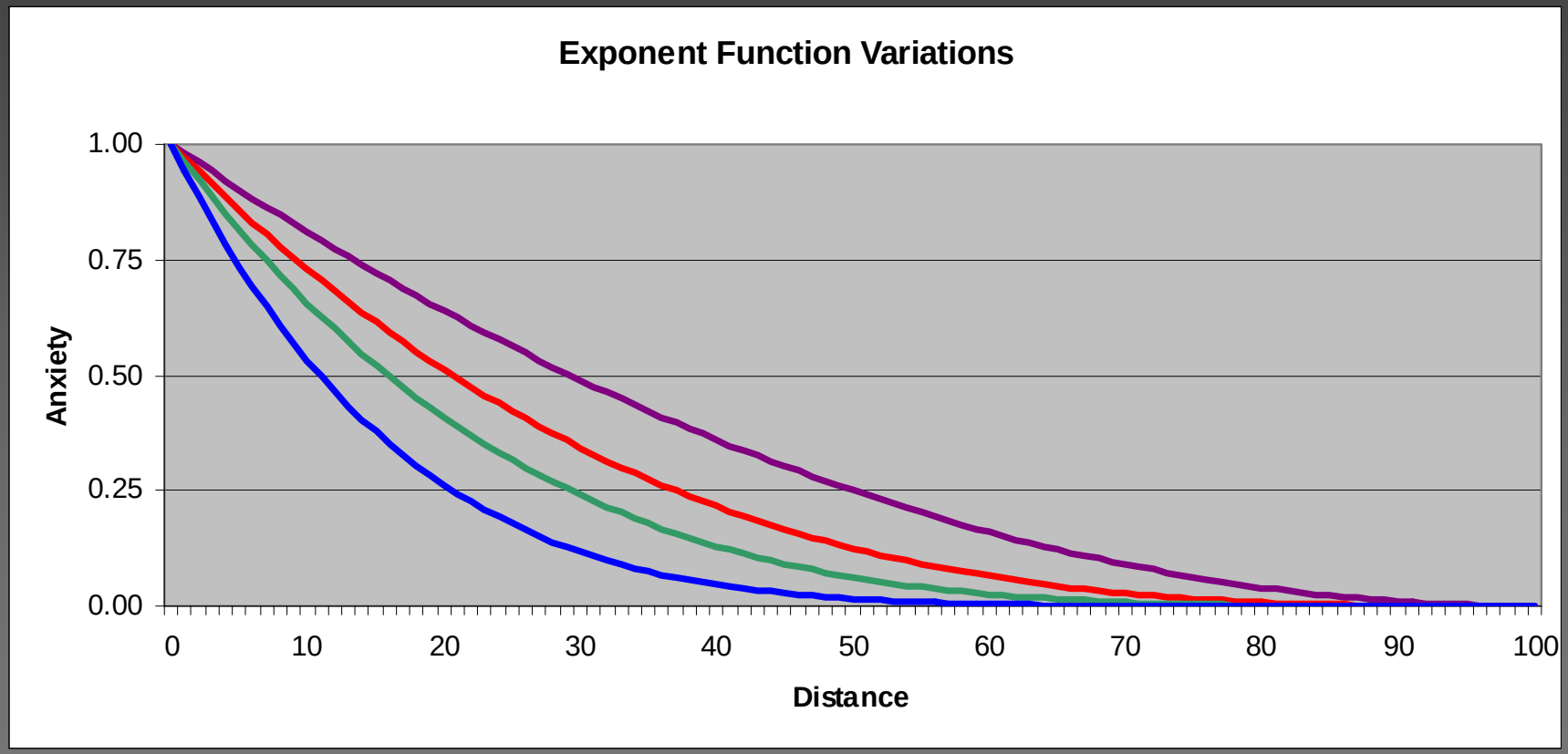
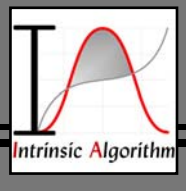
Threshold / Linear/ Exponential

Changing Exponents

Exponents of 2, 3, 4, 6





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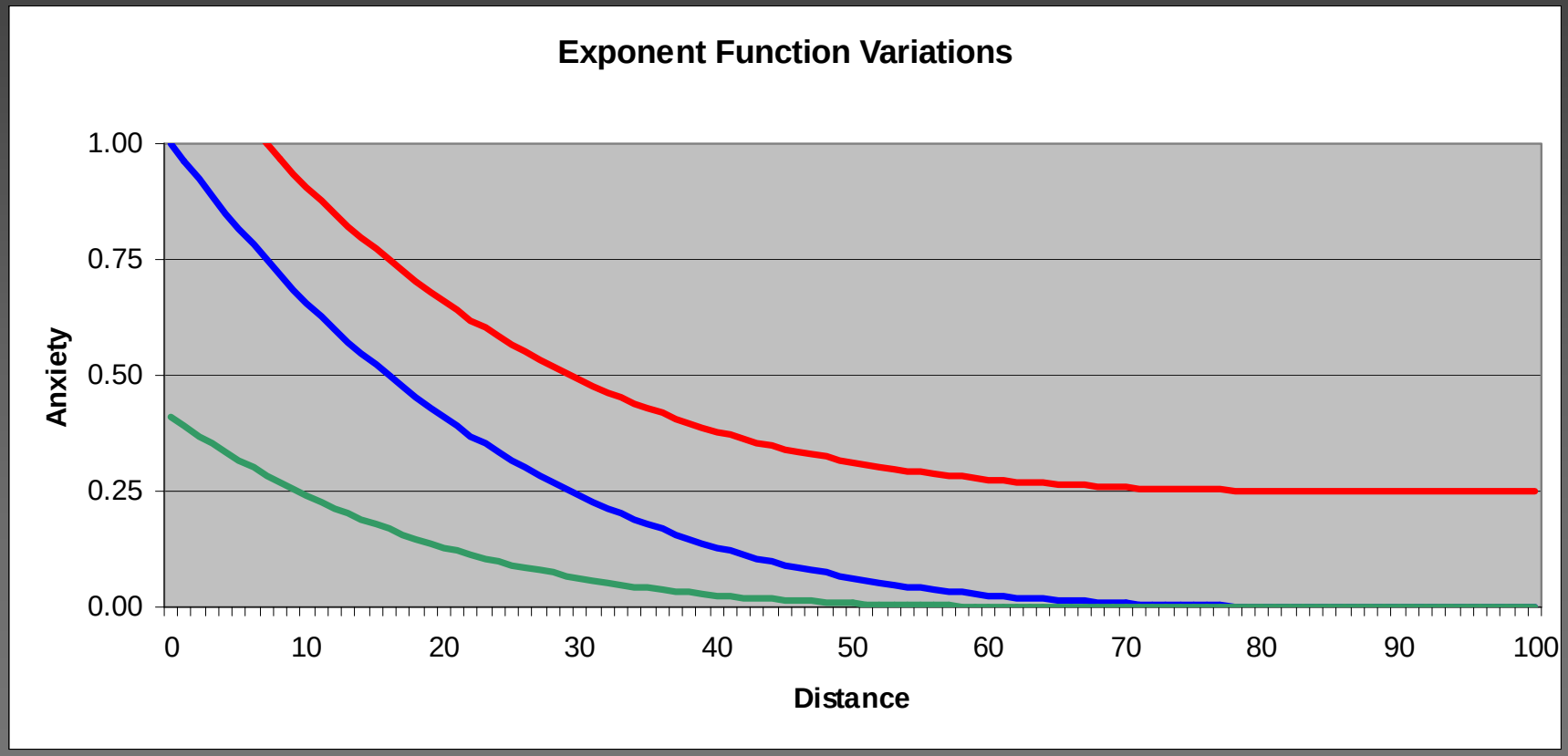
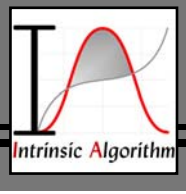
Shifting the Curve





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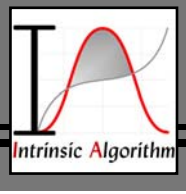
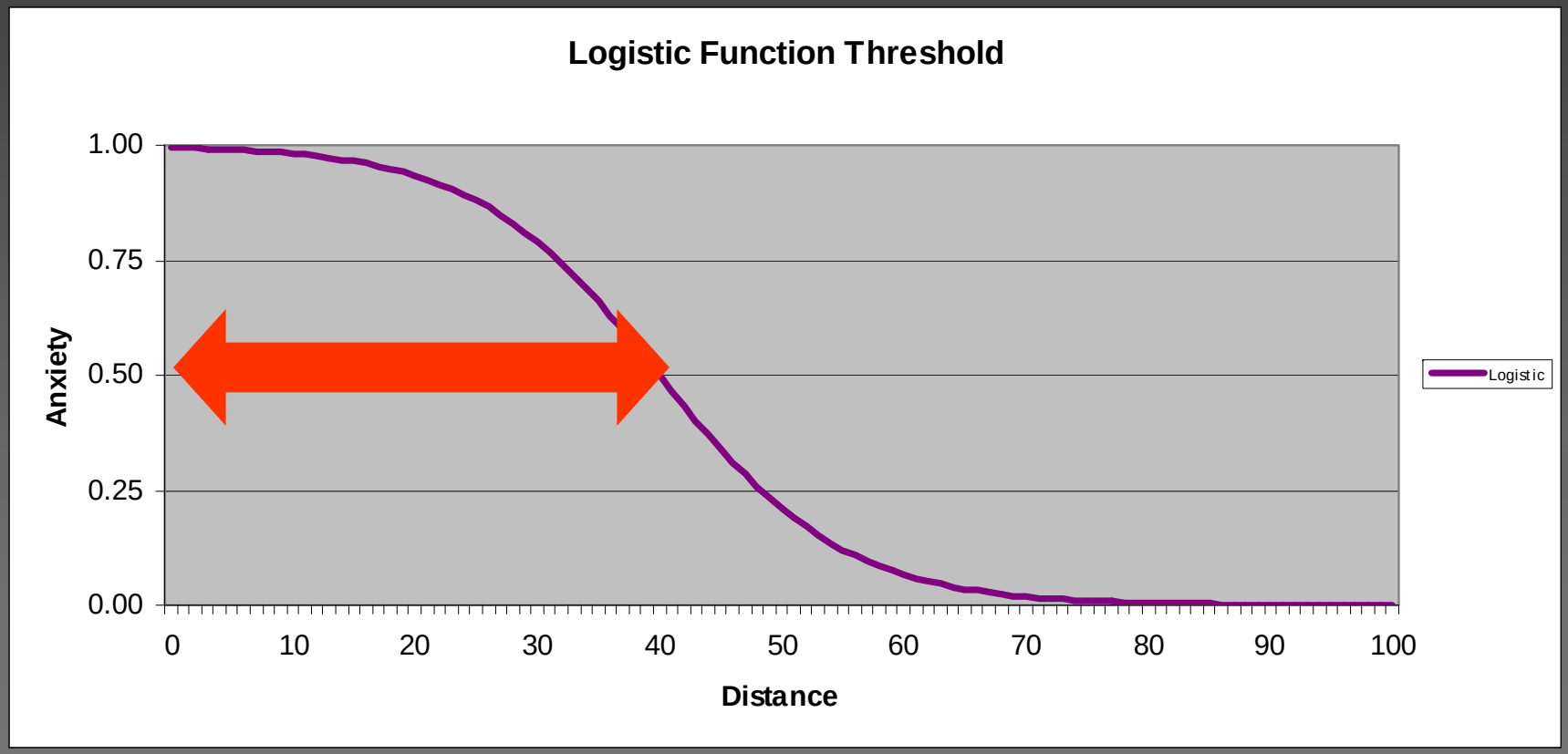
Logistic Function

$$y = \frac{1}{1 + e^{-x}}$$

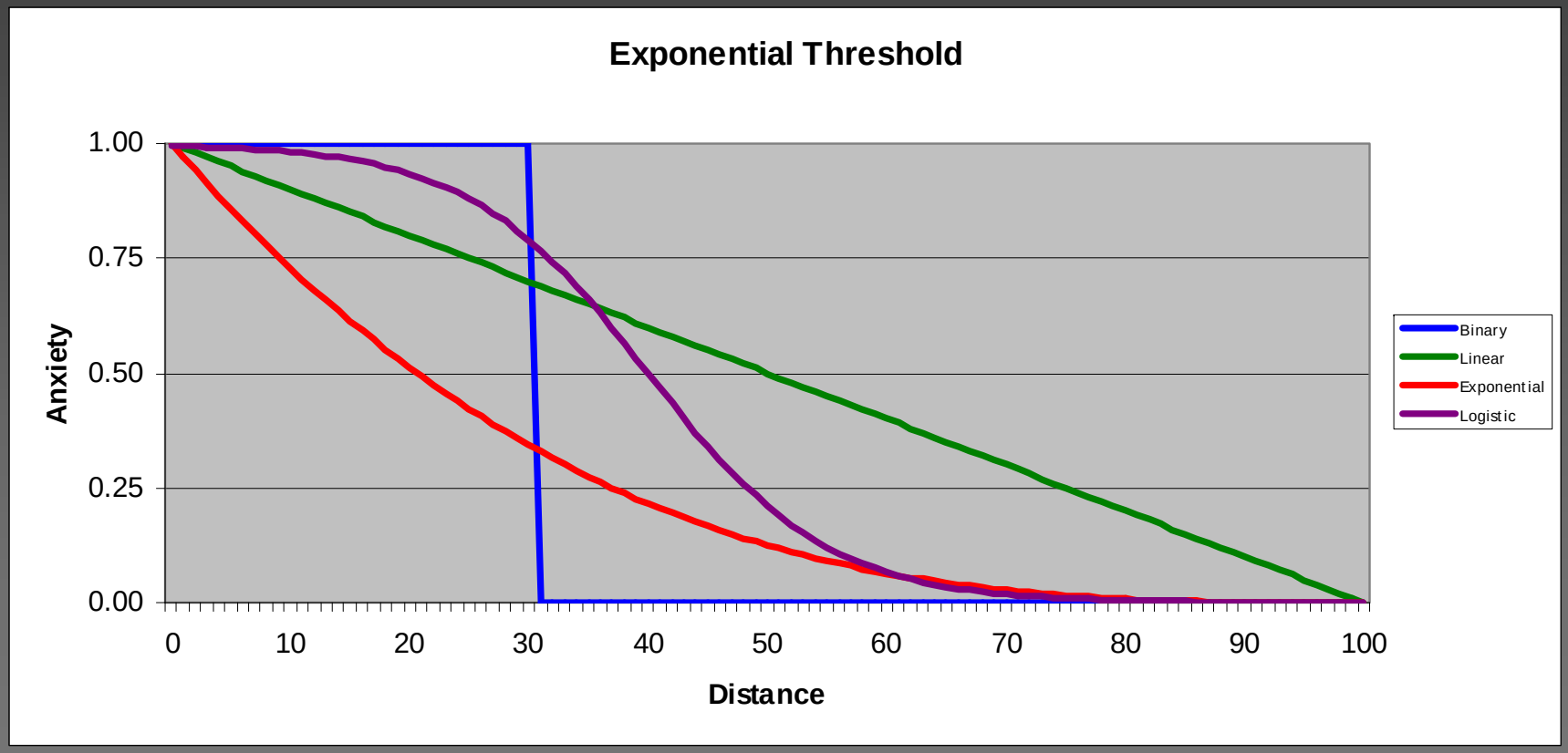


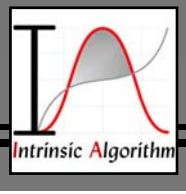
Logistic Function

Anxiety = $1/(1+(2.718 \times 0.45)^{distance+40})$



Curve Comparison





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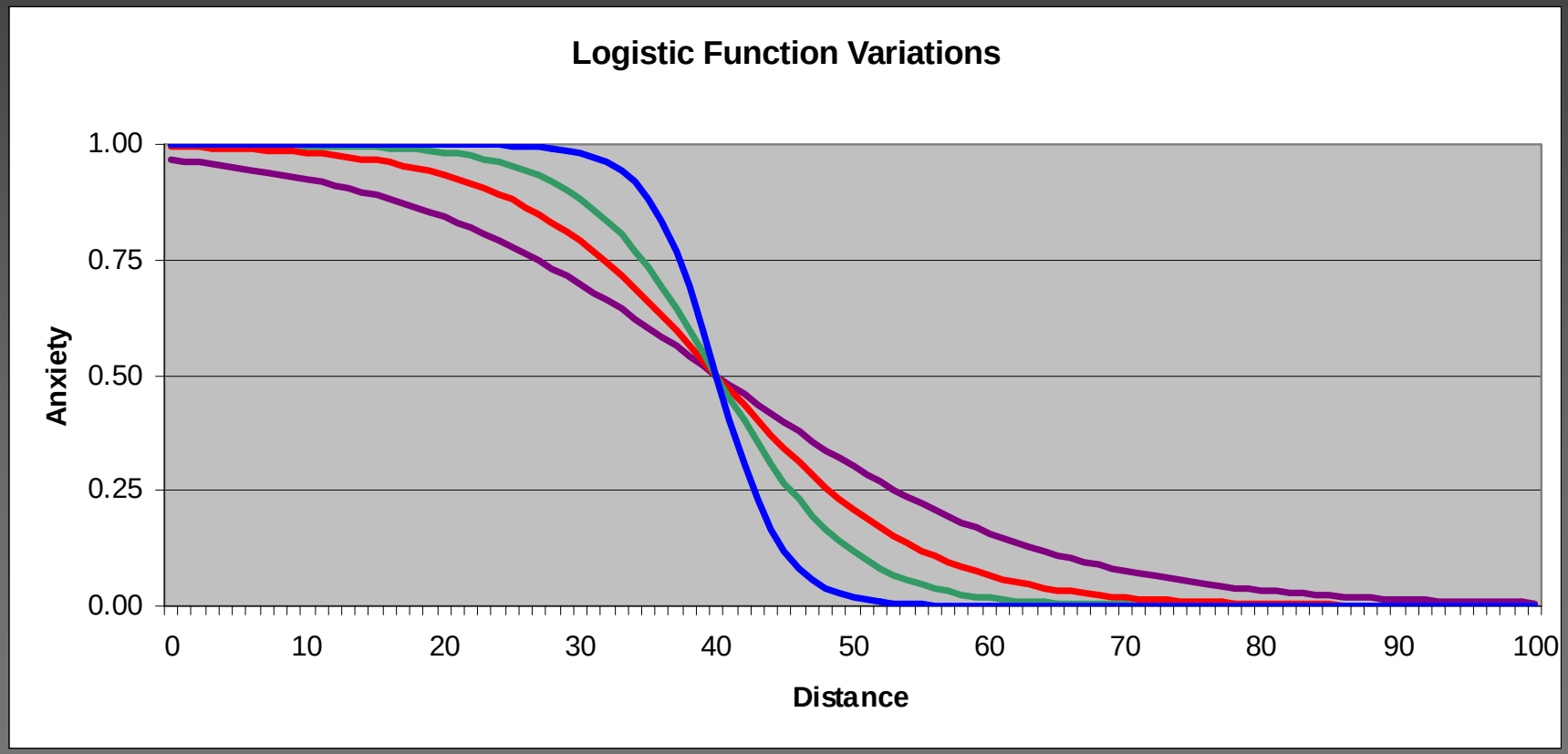
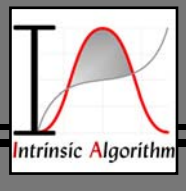
Variations on the Logistic Curve





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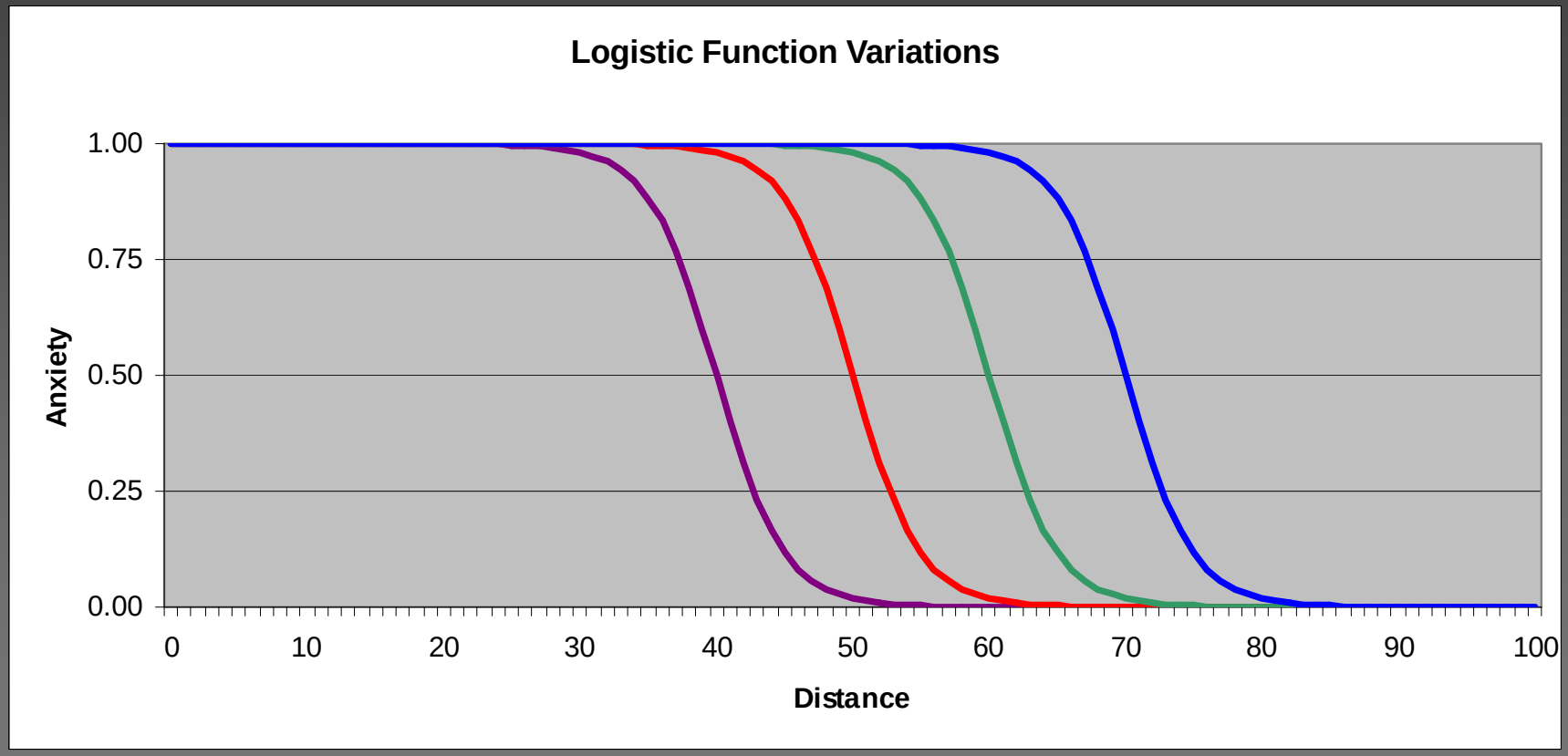
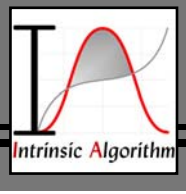
Shifting the Logistic Function





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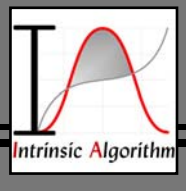
How Can We Express Information?

- Increasing or Decreasing?
- Rates of change
  - Steady or Variable?
  - Inflection Point?
- Amount of change
  - Constrained or Infinite?
  - Asymptotic?

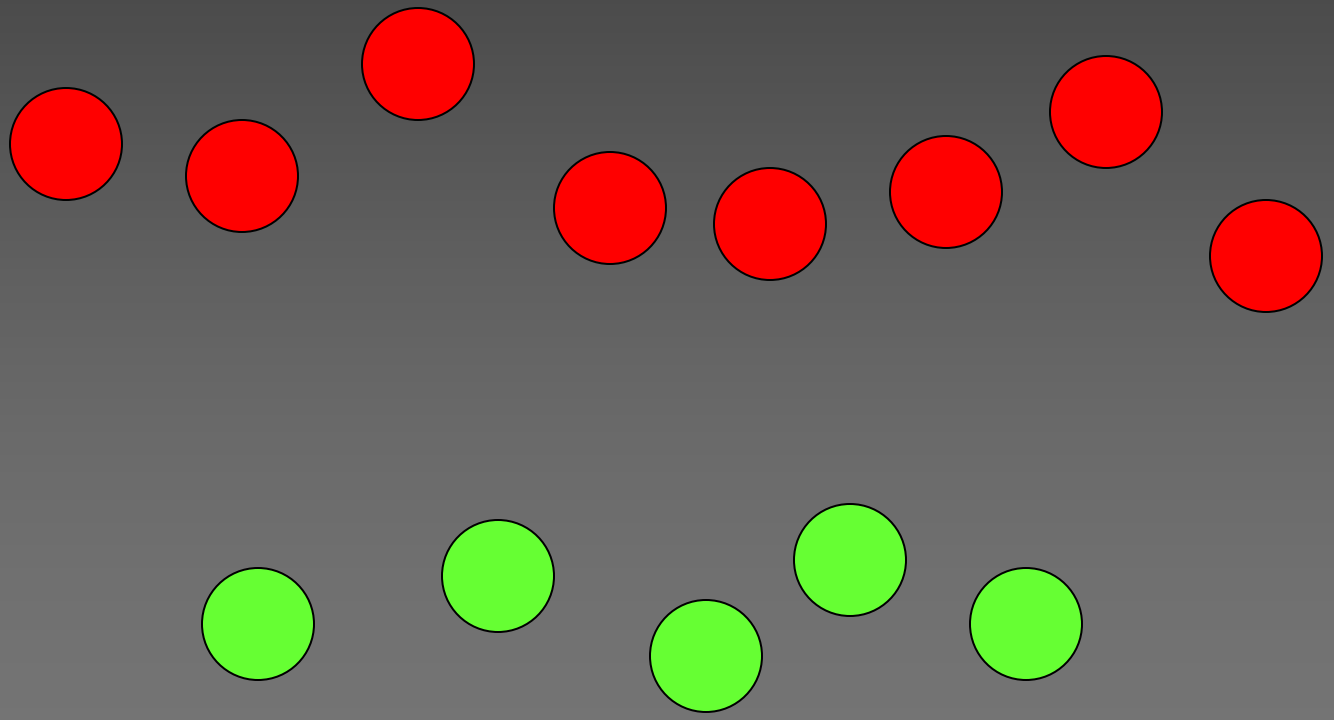


Know when to walk away…

- 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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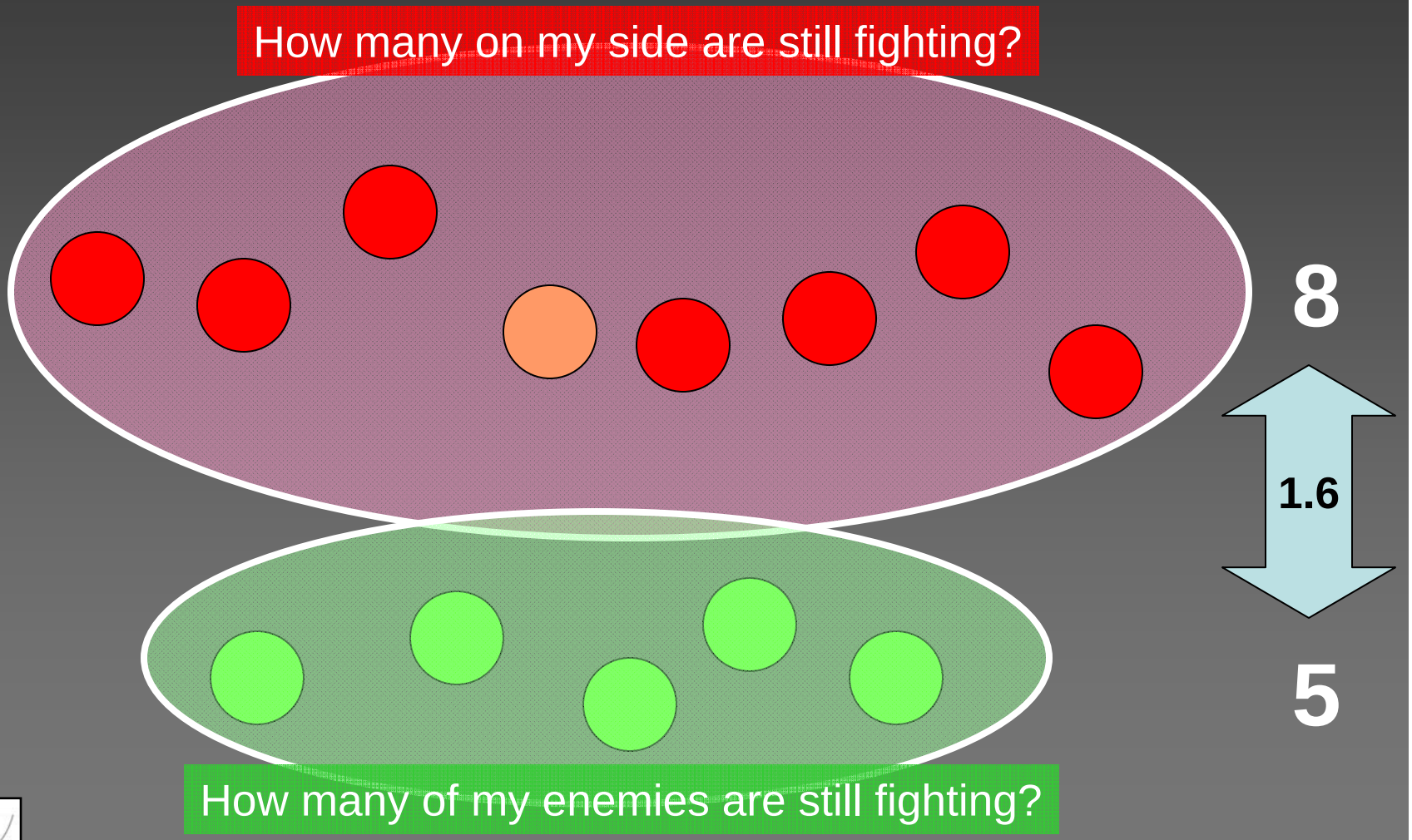

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Intrinsic Algorithm

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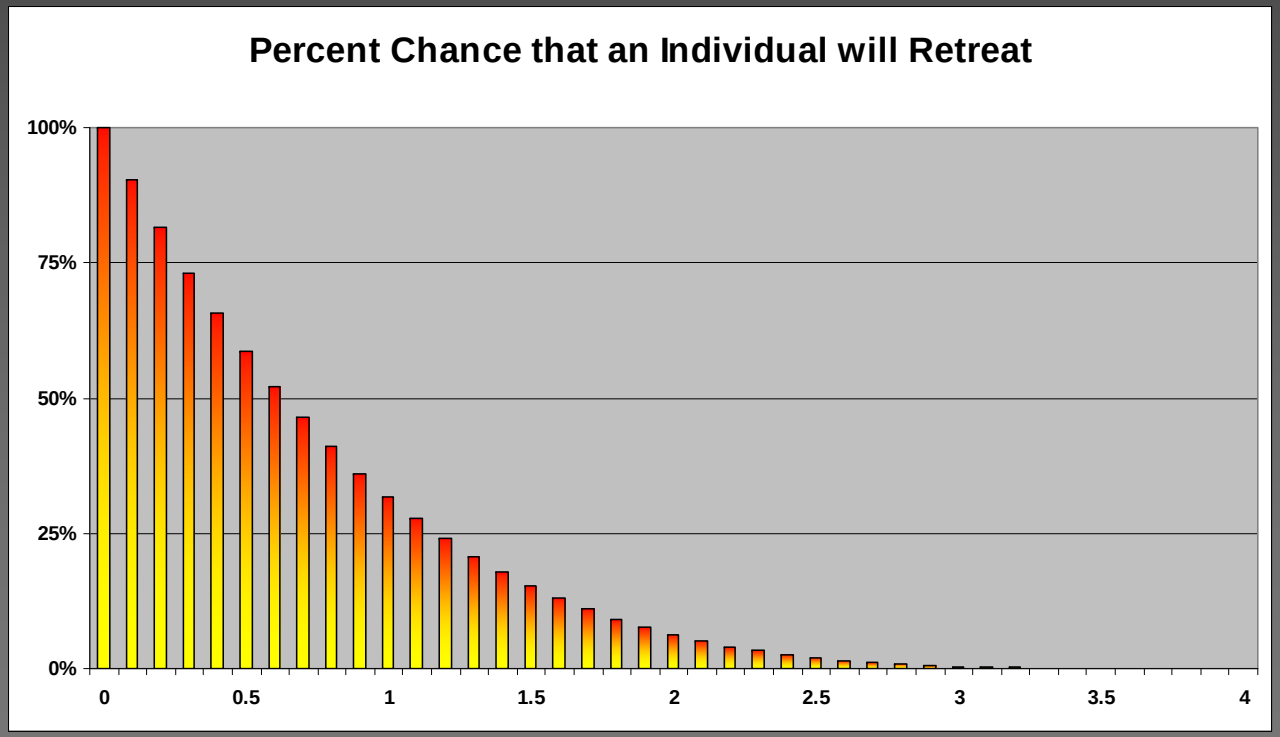
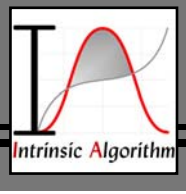
Know when to walk away…

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





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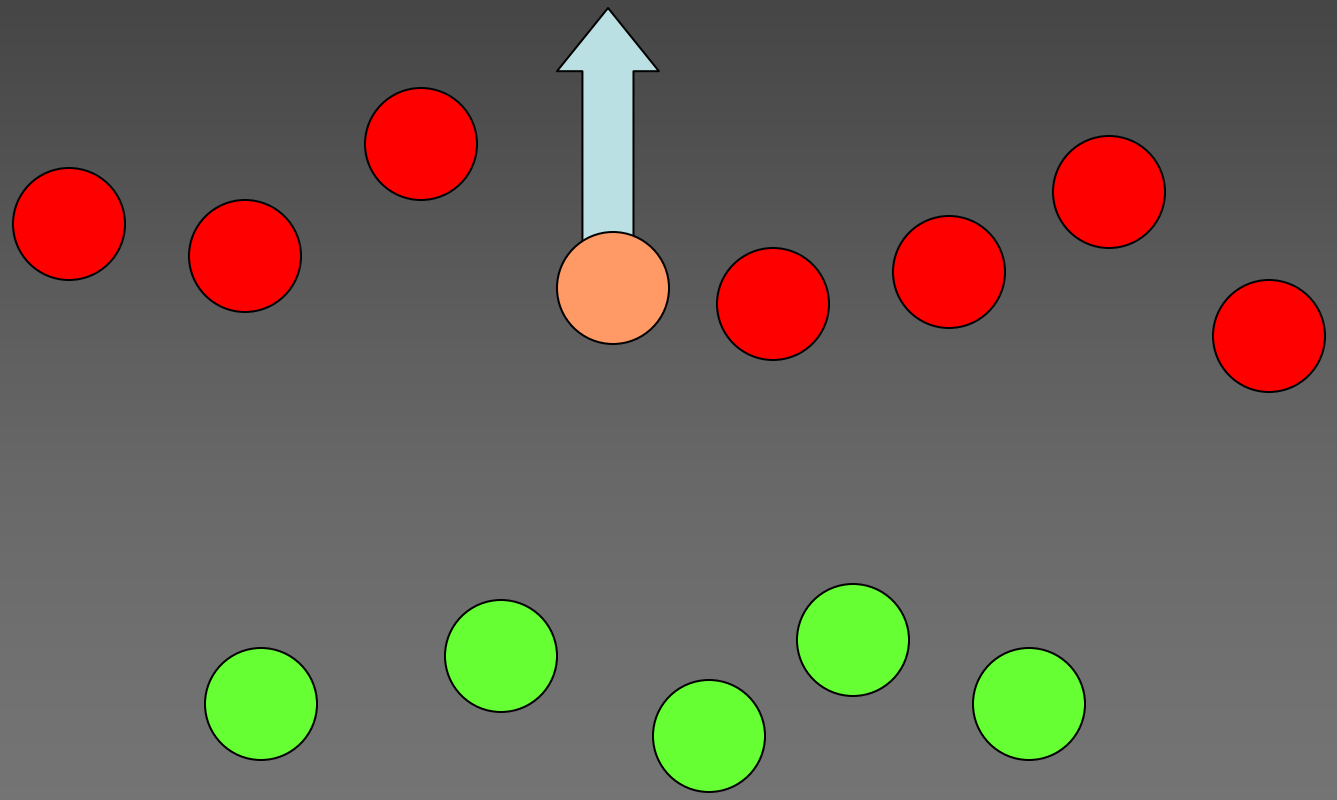
Know when to walk away…

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

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

$$PercentChance = 13\%$$

Know when to walk away…



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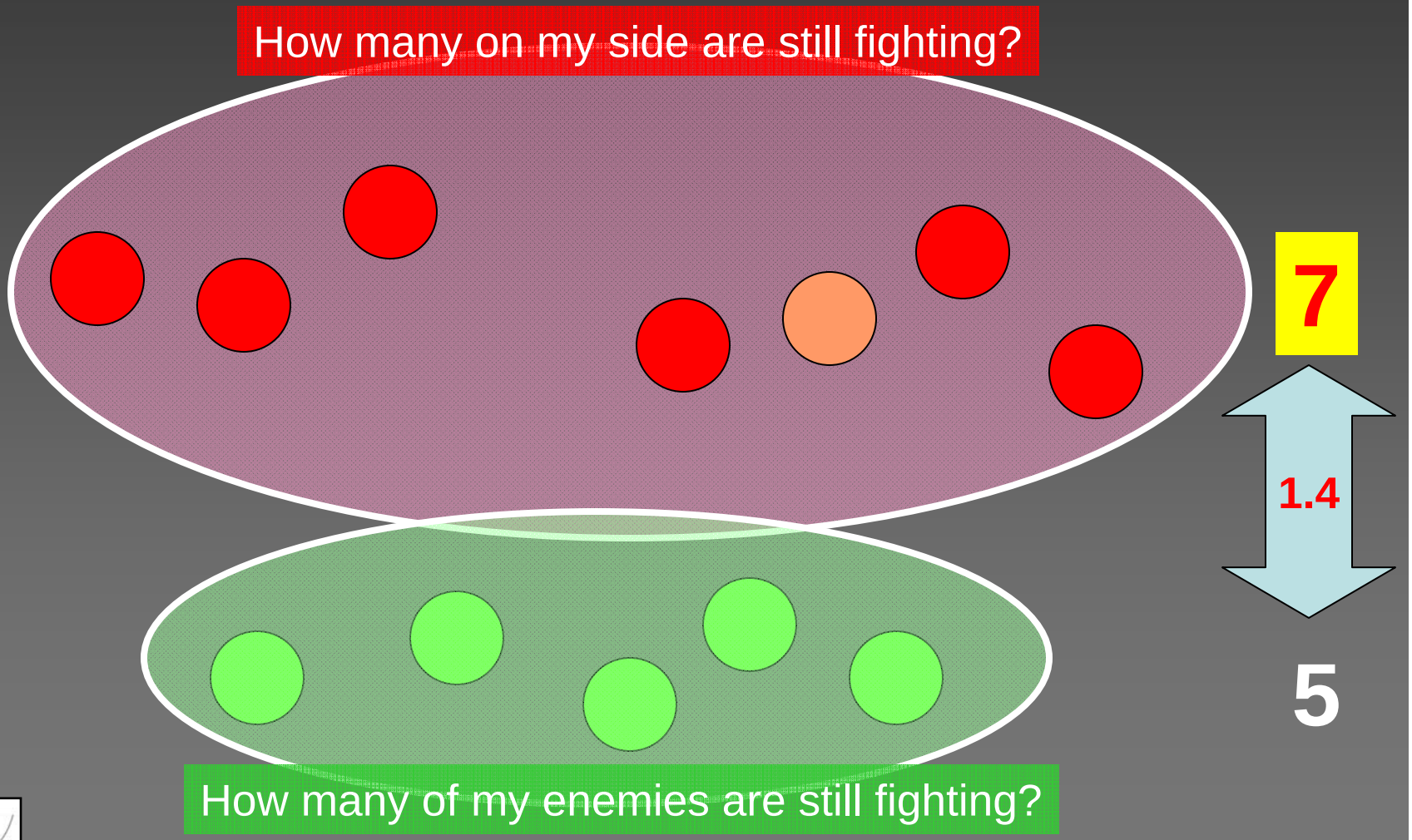


Know when to walk away…

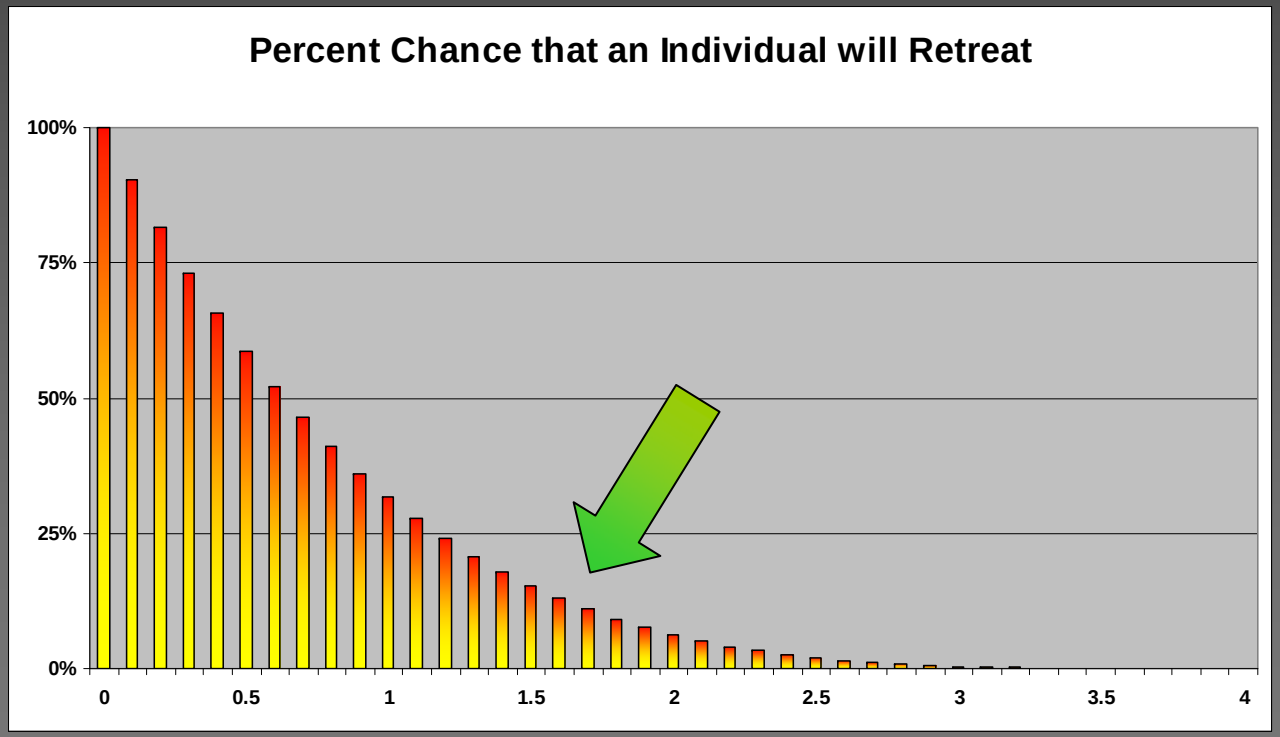
$$PercentChance = (4 - Ratio)^4 / (4^4)$$

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

$$PercentChance = 18\%$$

Know when to walk away…

$$PercentChance = (4 \times Ratio)^4 / (4^4)$$



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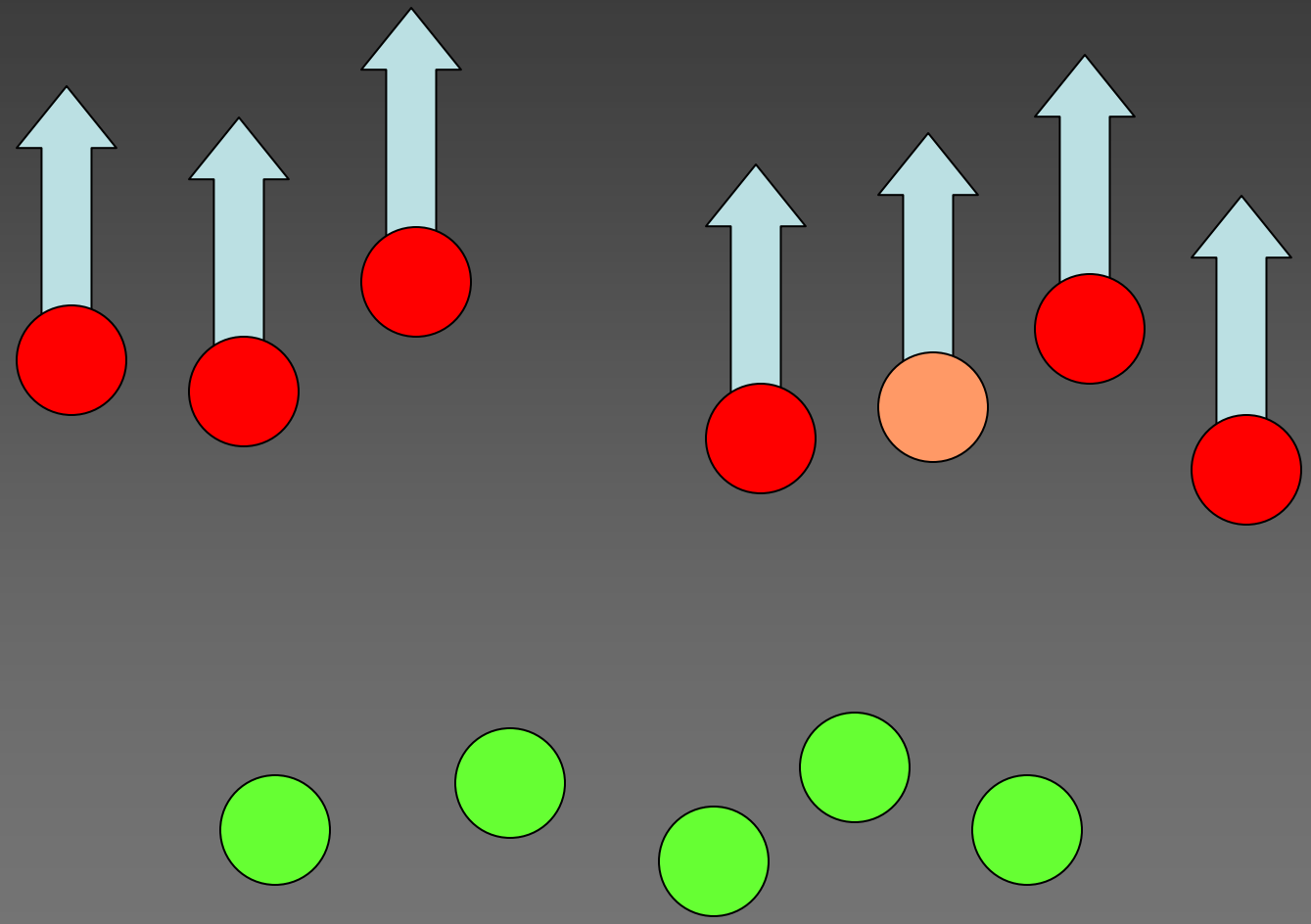
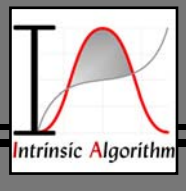


How Can We Express Differences?

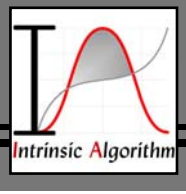
- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
- Allowing for more than one possible result



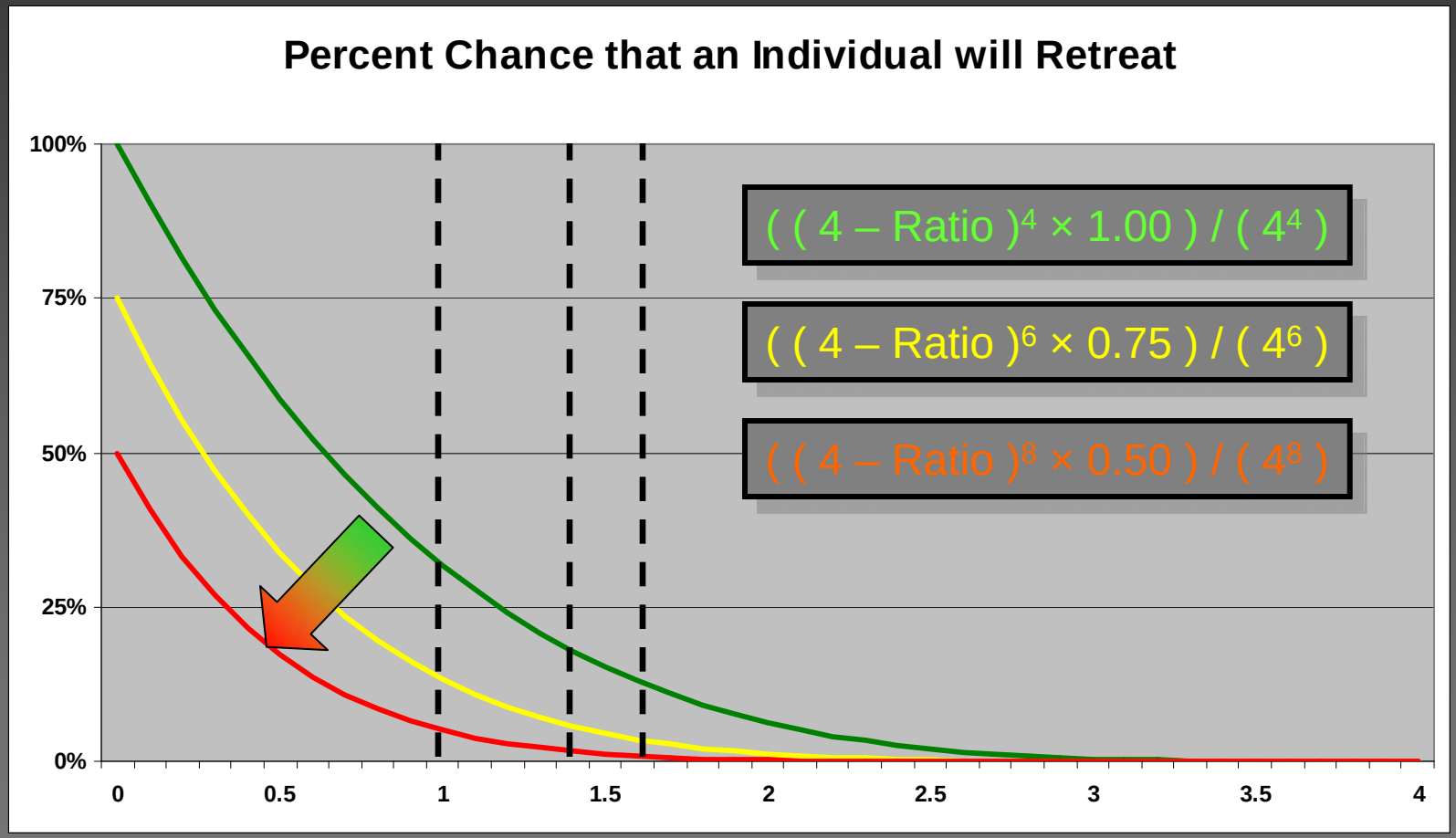
Know when to walk away…

$$PercentChance = \left(\left(MaxRatio - Ratio \right)^{k} \times MaxPct \right) / \left(MaxRatio^{k} \right)$$

	MaxPct	k
In Field	1.00	4
Near Base	0.75	6
In Base	0.50	8



Know when to walk away…



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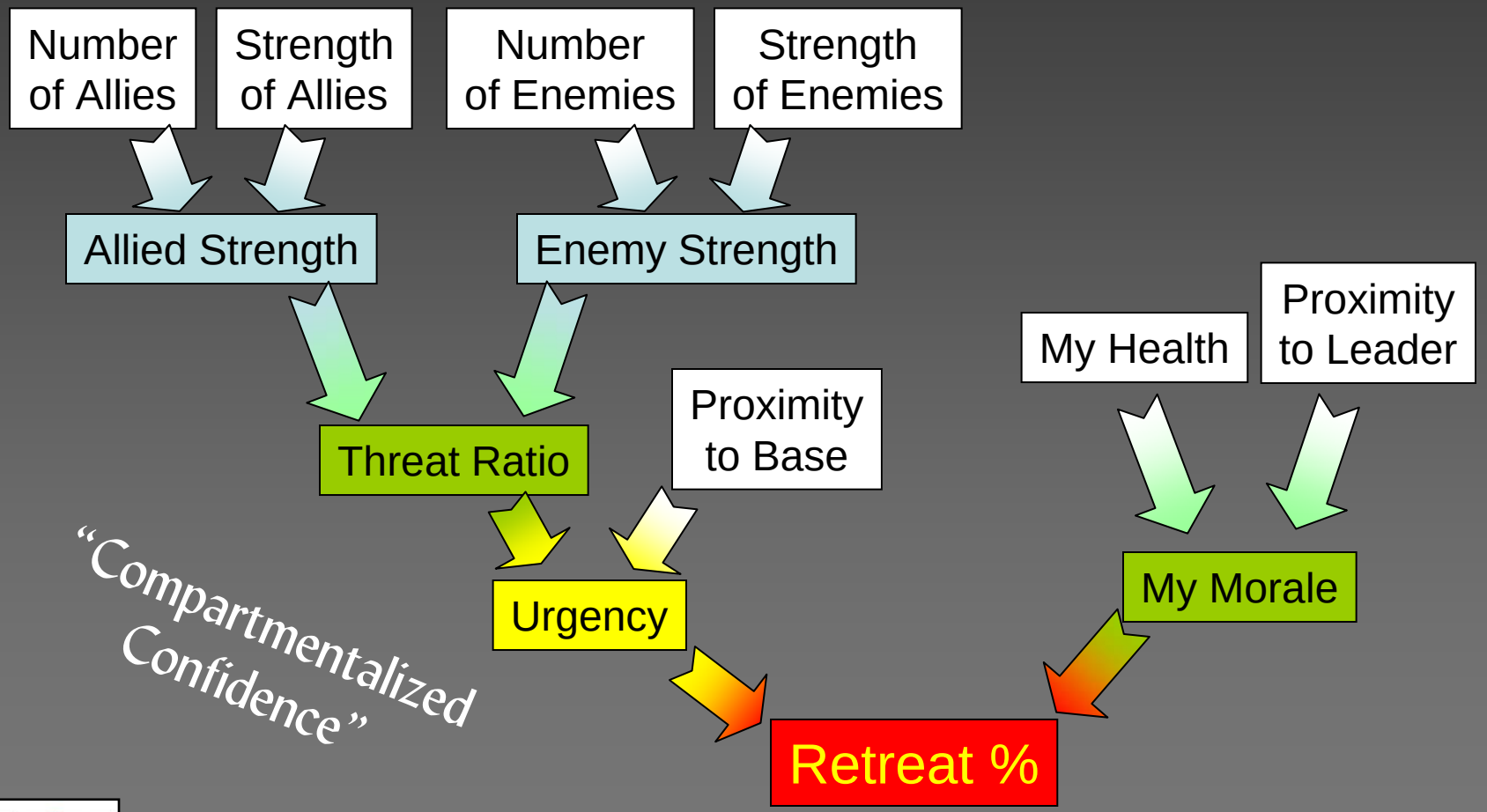
Know when to walk away…

- 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

Know when to walk away…



How does this look to the players?

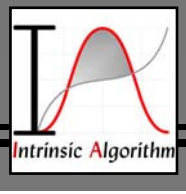
- Enemies aren't completely fearless
- They are slightly unpredictable
- They are still reasonable
- Curiosity: "Where is he going?"
- "If we show force, they might break and run."
- "If we back them up, they are more aggressive."
- We have to react to *their* reactions.

How Can We Express Differences?

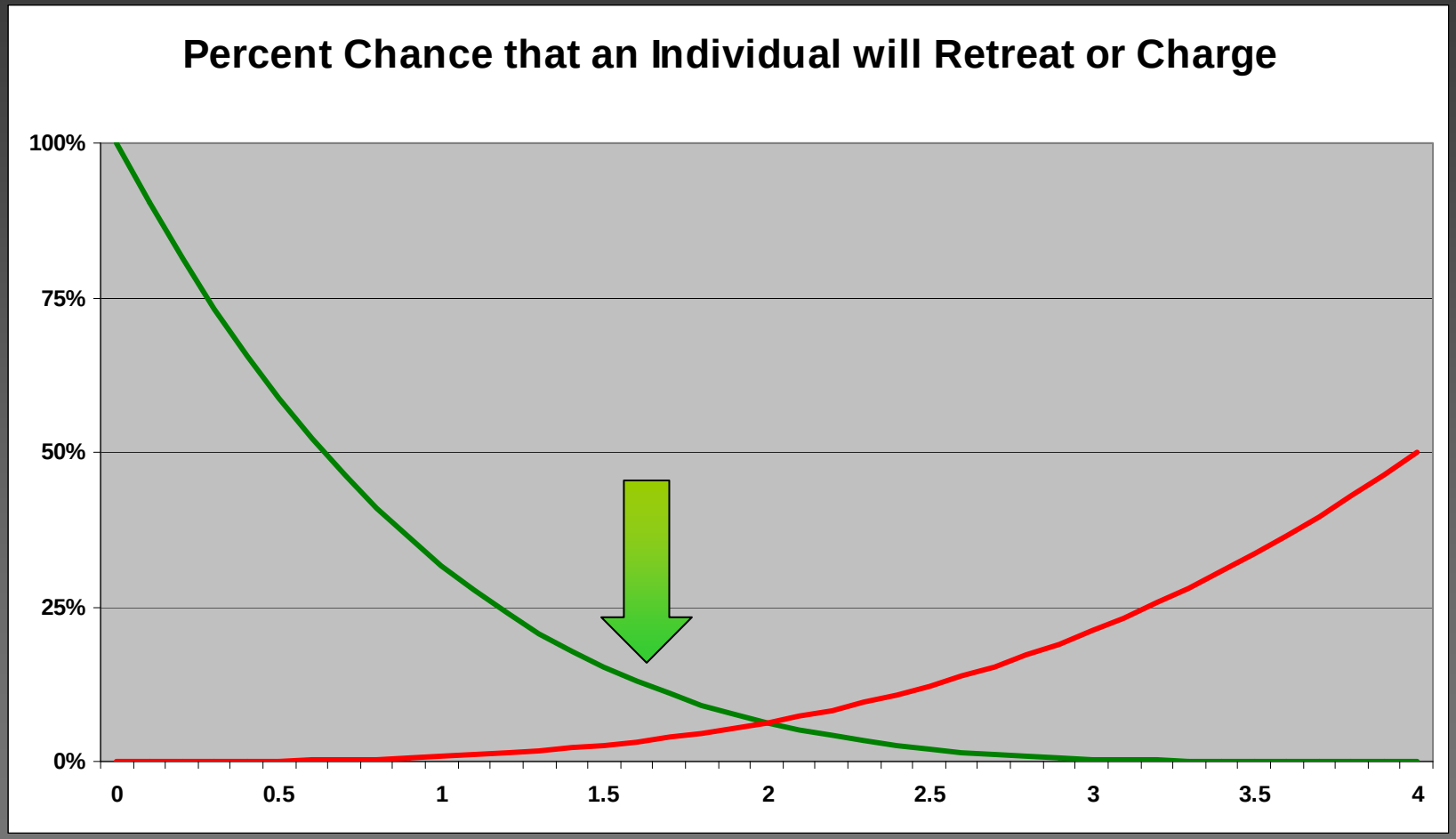
- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
- Allowing for more than one possible result

More than “Fight or Flight”

- Fight normally
- Flee
- Charge



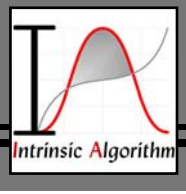
More than “Fight or Flight”



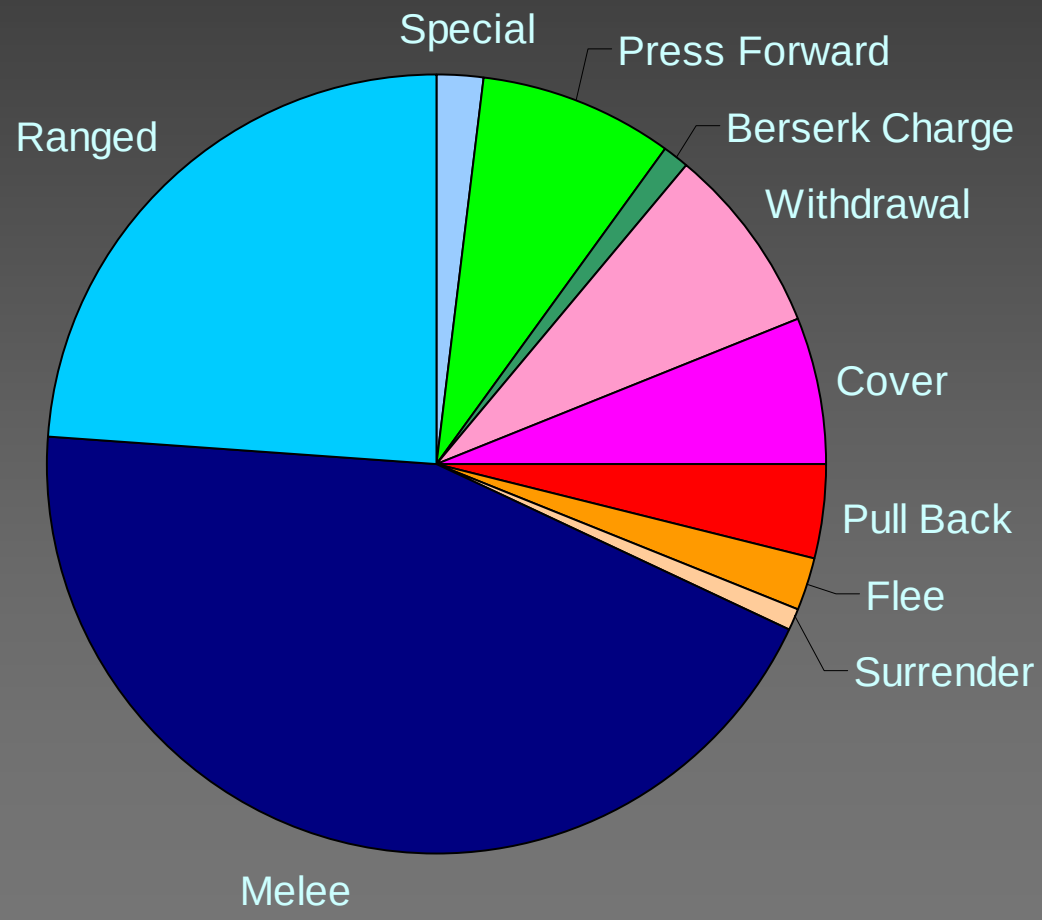
More than “Fight or Flight”

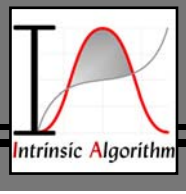
- Fight
  - Melee weapon
  - Ranged weapon
  - Special rare weapon
- Advance
  - Press forward
  - Berserker charge
- Retreat
  - Fighting withdrawal
  - Find Cover
  - Organized pull back
  - Flee in abject terror
  - Surrender

Too many individual curves!!



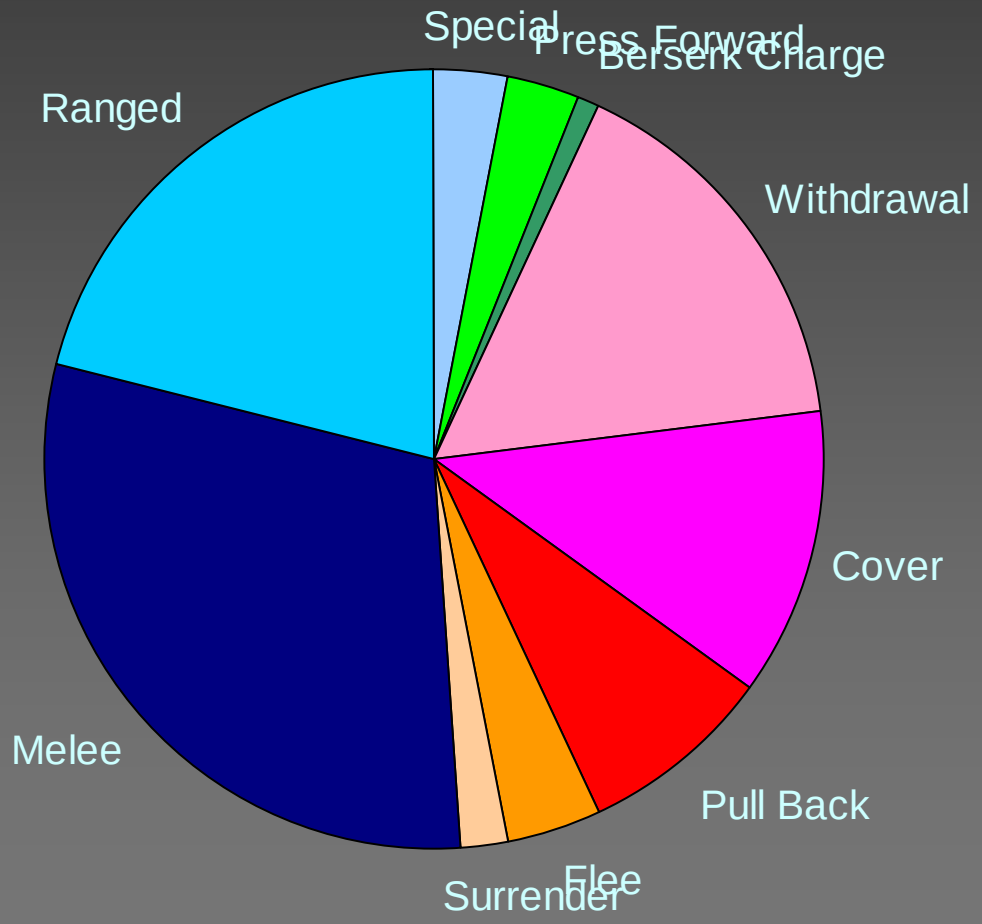
More than “Fight or Flight”

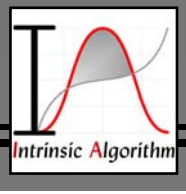




“Reducing the world to mathematical equations!”

More than “Fight or Flight”

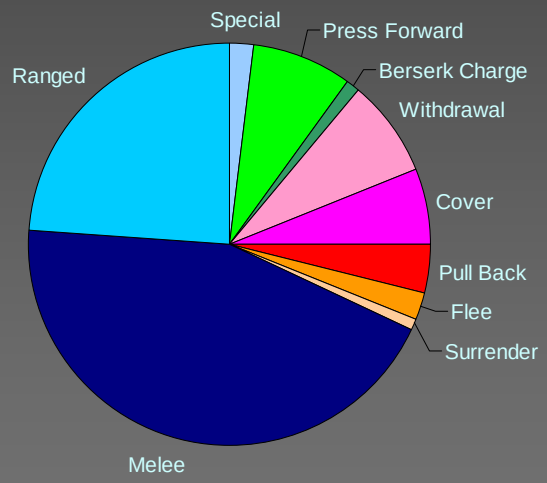




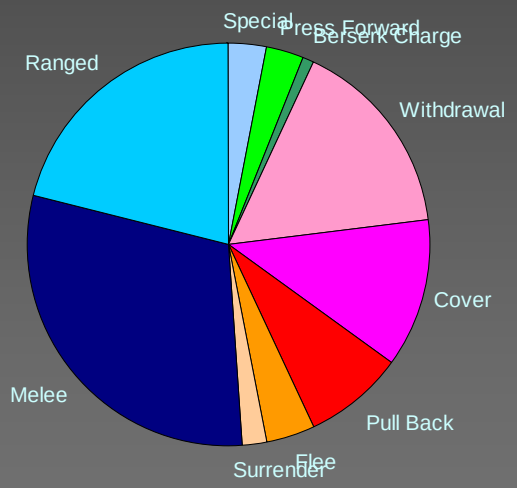
“Reducing the world to mathematical equations!”

More than “Fight or Flight”

“Normal”



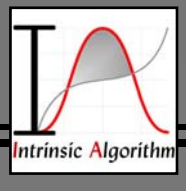
“Wounded”



How do we get to this point?

Selecting from Multiple Actions

- We can't run one check for each possible action
  - Too cumbersome
  - Each action is mathematically independent
- Structure to place all possible actions in play at the same time.
  - Auto-balancing
  - Expandable
  - Easy to select one action



Preferences = Differences






Ordinal Rankings

1

2

3

4

5

6

Measuring Information

- Identifying differences
  - Is ordinal enough?

    (i.e. $a < b < c$)
  - If more, then how much more?

    (e.g. $a = 2 \times b$)
- Normalization (e.g. 0..1)

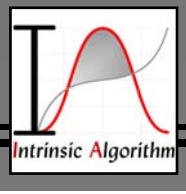
Normalizing Ratings

1.0 = "the best possible"

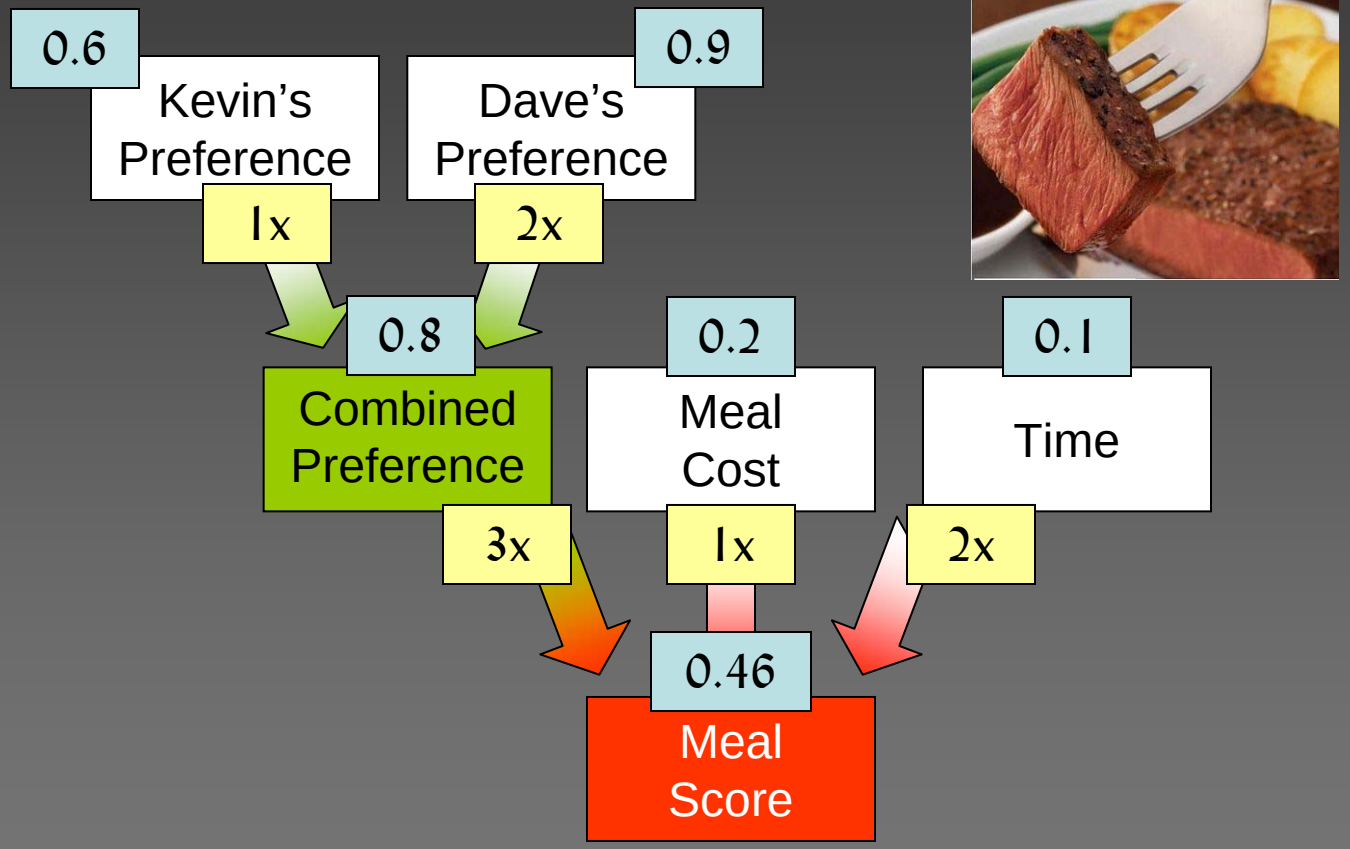
0.0 = "the worst possible"

You Can't Always Get What You Want

- Multiple Preferences
  - Mine
  - Kevin's
- Cost (Is Kevin paying?)
- Time (Do we still need to finish our slides?)



You Can't Always Get What You Want



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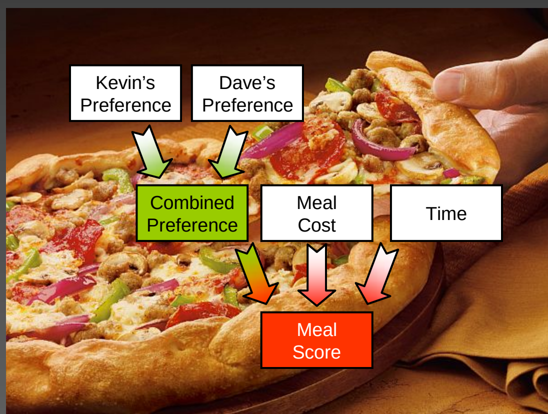
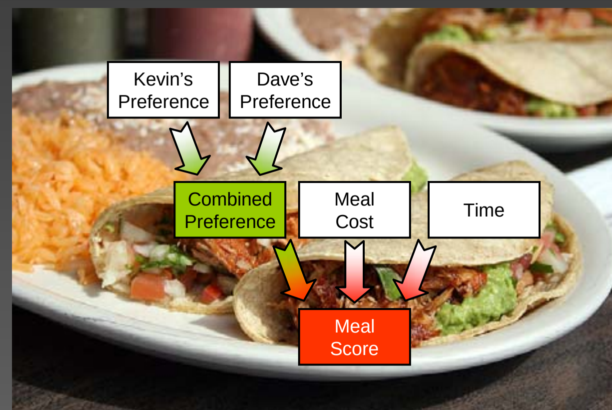
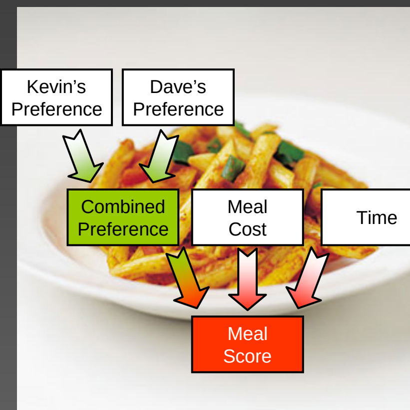
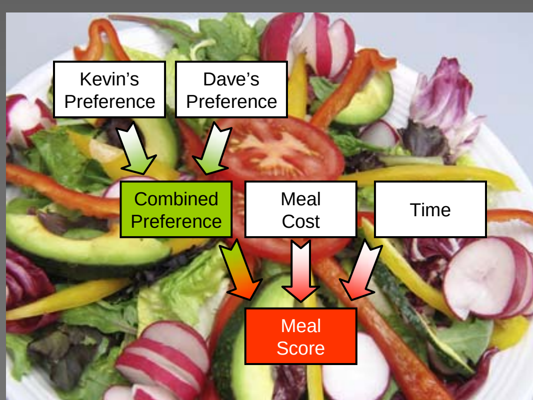
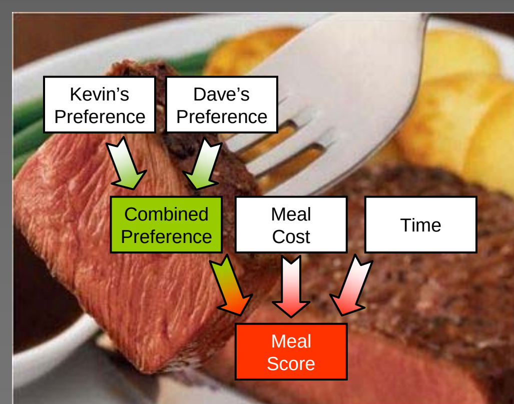
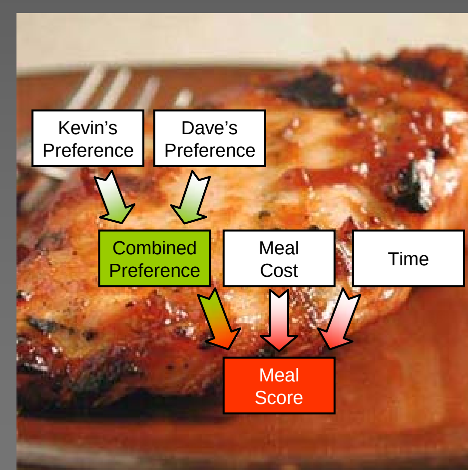












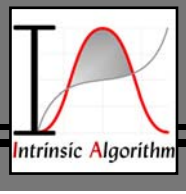
Intrinsic Algorithm

"Reducing the world to mathematical equations!"

AI GAME PROGRAMMERS GUILD

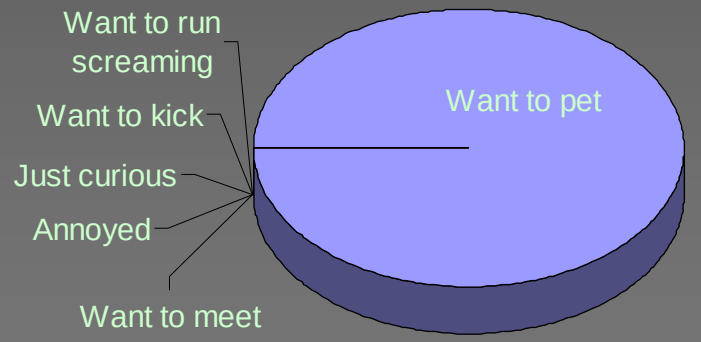
You Can't Always Get What You Want

Meal	Kevin	Dave	Pref.	Cost	Time	Score
Steak	0.6	0.9	0.80	0.2	0.1	0.47
Pizza	0.5	0.7	0.63	0.6	0.8	0.68
Chicken	0.7	0.6	0.63	0.4	0.3	0.48
Tacos	0.2	0.4	0.33	0.5	0.4	0.38
Salad	0.6	0.3	0.40	0.7	0.9	0.62
Pasta	0.8	0.1	0.33	0.8	0.8	0.57

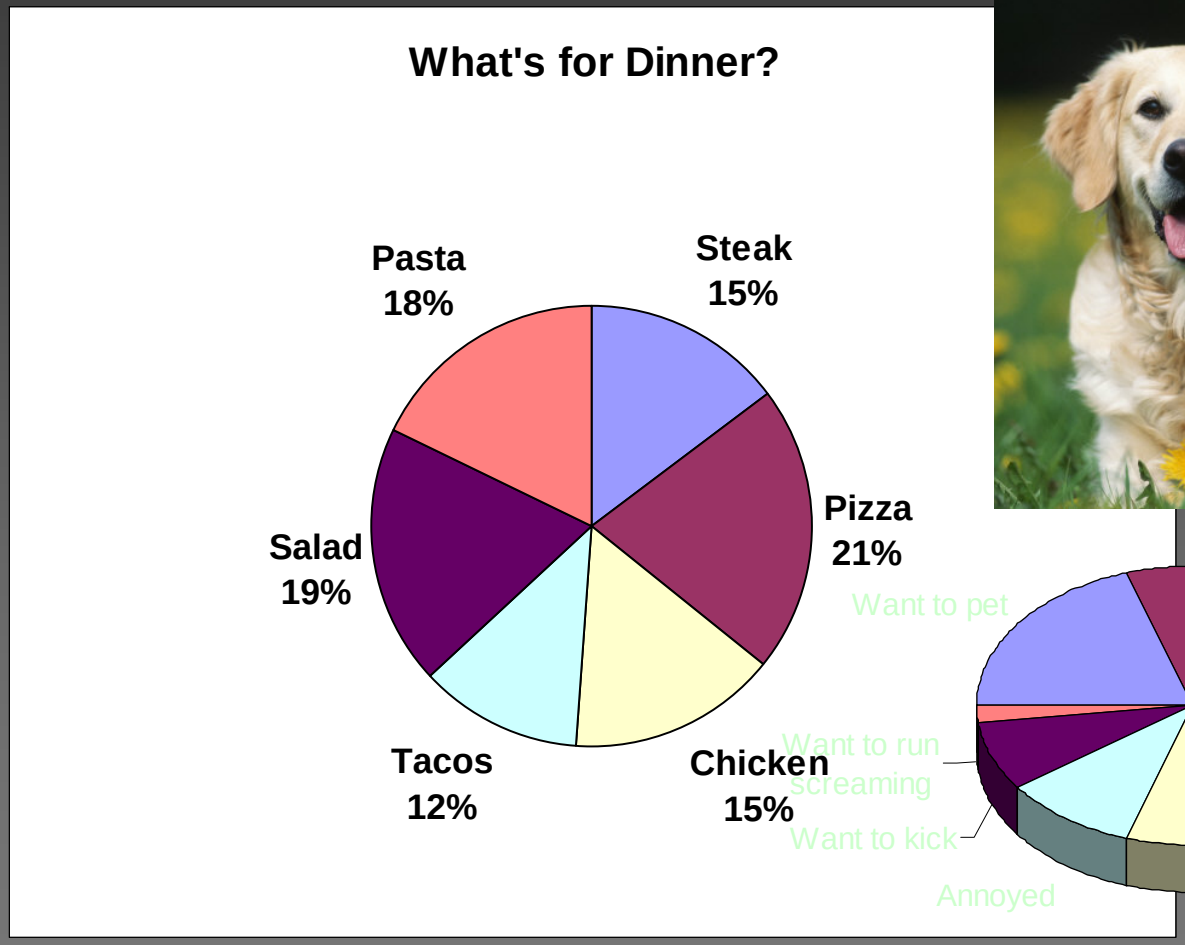


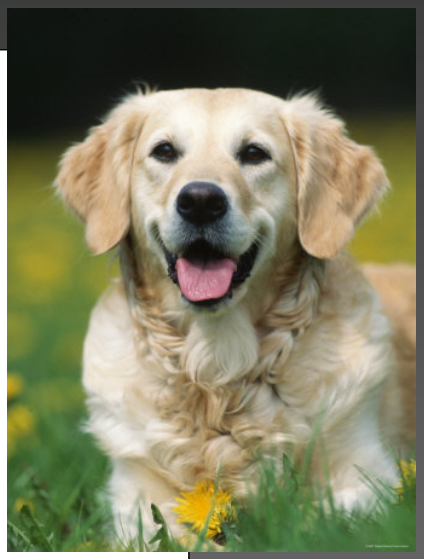
Selecting a Result

- Select Top Score
- Random from top *n* choices
  - E.g. “Pick evenly from top 3”
- Weighted random
  - All possible
  - Top *n*



Selecting a Result

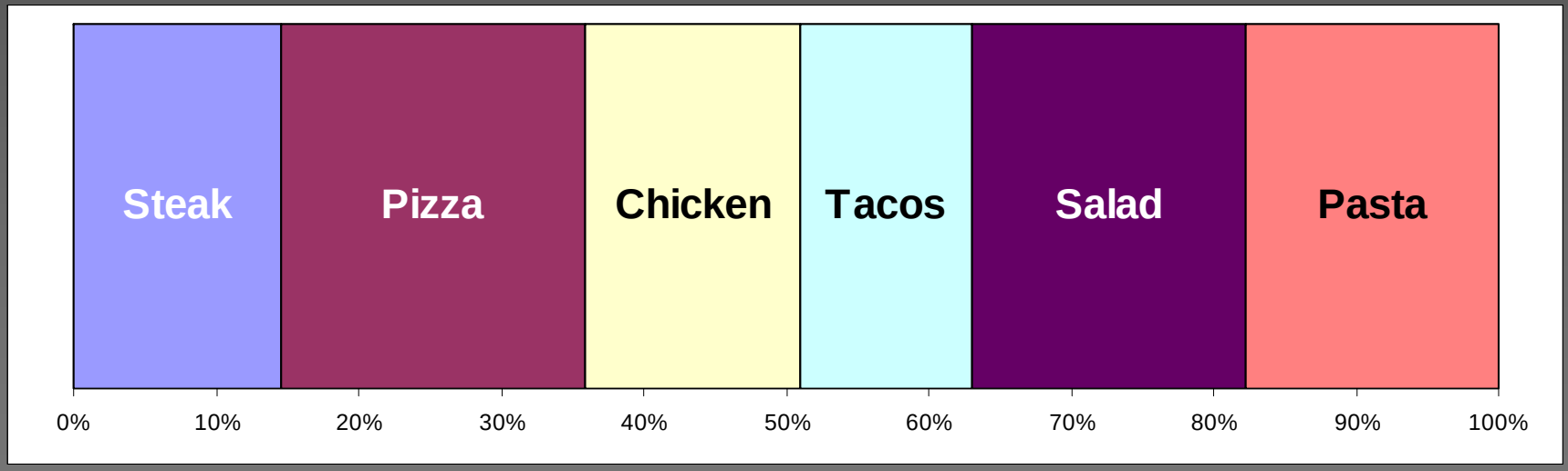




Weighted Random Selection

Generate a random number…

And let the bouncing ball choose.

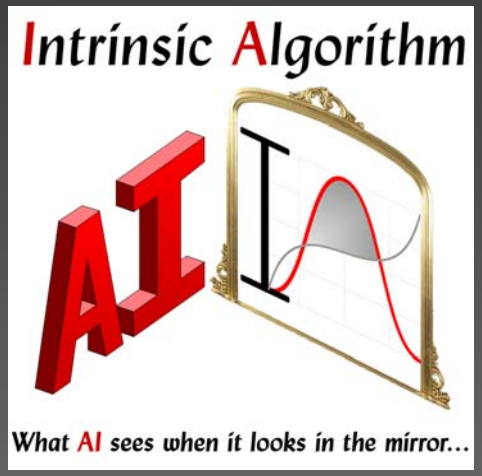


So what have we learned?

- People are different.
  - Different reactions to the same stimulus
  - Not random but reasonable
- Beyond just checking for information
  - What does that information mean to the decider?
  - How do different inputs relate to each other?
- Allow multiple reactions
  - Not just “the best” (Don’t *always* pet nice doggie.)
  - Base the possibility of a reaction on its merit

Dave Mark

Intrinsic Algorithm LLC



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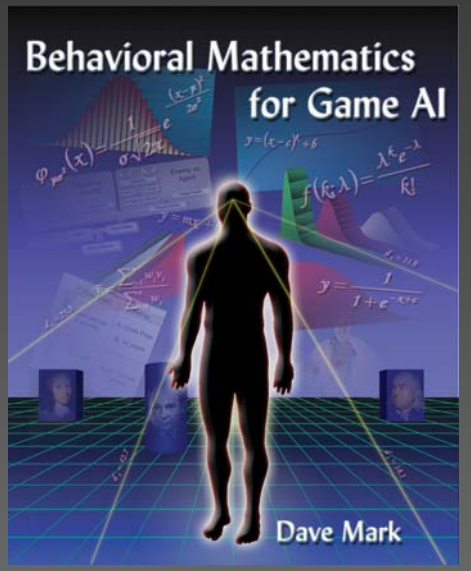

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"Reducing the world to mathematical equations!"

Kevin Dill

- Senior AI Engineer, R* New England
- Lecturer, Boston University
- Section Editor, AI Game Programming Wisdom 4

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AI GAME PROGRAMMERS GUILD

This Is A Tiger

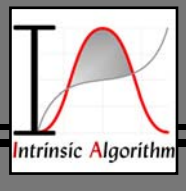
Tiger.mov

This Is A Tiger

- Constantly moving, constantly attending
- No looping or repetitive animations
- No straight lines or crisp turns
- Believable, organic, grounded in and reactive to the world around him
- *We won't be truly photorealistic until we achieve this*

The Big Picture

- Build strong cross-disciplinary teams
  - AI & animation
  - AI & sound
  - AI & dialog writers
  - Designers, QA, etc.
- Build capabilities from game to game
  - e.g. Natural Motion
- Retain (and develop) your core talent!!



Be An AI Artist

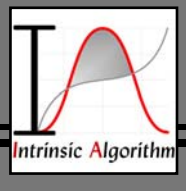
- Become an observer
  - How people move
  - How they interact
  - How they gesture
  - What they say
- Different situations
  - Halls & doorways
  - The mall
  - Parties & social groups
  - The boss's office
- Get lots of eyes on it
  - Your wife & friends
  - Your players
  - The animators
  - QA
- ***Crave criticism!!***

Behavioral Building Blocks

- Get core behaviors to work, build up
- Think about our tiger
  - Breathing
  - Fidgets: yawning, stretching, twitching, etc.
  - Attention
- Build those animation performances
- Build idles, movement behaviors
- Build play, eat, fight, sleep, work, …

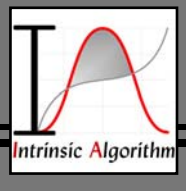
Believable, Organic

- Break the animation loop
- Multiple asynchronous animations
  - Separate out breathing, tail, etc.
  - Attention
- Random variance
  - Speed
  - Blend weights
  - Bone positions
  - Wiggle (Perlin noise)
- Blend procedural techniques & animation



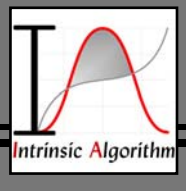
Grounded & Reactive

- Types of targets:
  - Neutral
  - Random
  - Object / entity
  - Event
- Types of attention
  - Ear twitch / cock head
  - Headlook
  - Behavior change
- Library of reactions
- What to do next?



No Straight Lines

- Path planner is just a general guide
- Do good smoothing, add a little wander
  - Use your terrain abstraction
- Or, flow fields to guide animation selection
- Support multiple locomotion modes
  - Walk, run, crawl, jump, climb, swim
  - Smooth, natural transitions
- Stop anywhere. Reach from anywhere.



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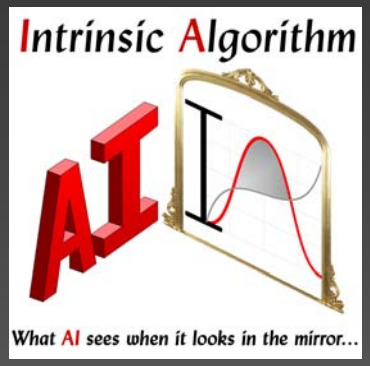

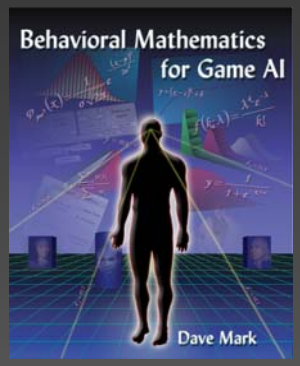

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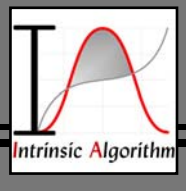

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