Creativity and Game Mechanics: Press \( \text{X} \) to Attend This Talk

Dr. Christopher J. Hazard
Hazardous Software Inc.
To make new and valuable things and ideas
Big "C" Creativity
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Measuring A Person's Creativity

• Remote Associates:
  • Shoulder, Sore, Sweat
• Unusual uses, e.g., brick
• Insight problems (brain teasers)
• Self-assessment
• Name items that contain a component
Doing and Recognizing Creativity

- Recipe: relaxed brain state, extensive knowledge, divergent thinking (Heilman et al., Neurocase, 2003)
- Constraints
- Ah-ha! Moment
  - Appearances: "no self-respecting architect leaves the scaffolding in place after completing the building" - Carl Friedrich Gauss
The Fight for Creativity

• 3-fold contribution to success variance when compared to IQ (Plucker, Creativity Research J., 1999)

• Creativity falling since 1990's (K. Kim, Creativity Research J., 2011)

• Bias against creativity when faced with uncertainty (Mueller et al., Psych. Sci., 2011)

• Creatives take on risks, are non-conformists, and fight against traditional power structures (Staw; Ford & Gioia Eds, chap 37, Creative Action in Organizations, 1995)

• Most are "uncreativie", creativity is domain specific (Silvia et al., Psych of Aesth., Creat., and Arts, 2009)
Strategic Breadth (Experience, Knowledge)

Aesthetic Control (Form)

Strategic Depth (Intelligence, Search)

Real Life
Mutual Exclusion Between Mechanical and Social Reasoning
(Jack et al., Neuroimage, 2012)
"Falling Sand" Games

Powder Game (and 2) (DAN BALL)

Powder Toy
Game Mechanics Breadth, Experience, and Knowledge

Just Cause 2
Map scale

Typical Forgetting Curve for Newly Learned Information

Challenge

Flow Channel

Anxiety

Boredom

Skill

First Learned
Reviewed

Retention

Days

0 1 2 3 4 5 6 7

60% 70% 80% 90% 100%

Niel de la Rouviere, Stellenbosch University

"Flow" concept by Mihaly Csikszentmihalyi. Drawn by Senia Maymin.
Adaptive vs Choice vs Fixed Content

Crayon Physics Deluxe
Petri Purho
Learning vs Addiction

Bizo et al., 2001, Rats don't always respond faster for more food: The paradoxical incentive effect

← Remember this graph???
Accidental Variable Reinforcement: Good or Bad for Creativity?

Epstein & Skinner, 1982

Bizo & Sweeney, 2005, Use of an ESP Cover Story Facilitates Reinforcement Without Awareness
state of attribute \( x \in X \), given a set of observations \( I \) can be composed of the individual PDFs of each observation \( i \in I \), \( f_i \), as

\[
f_{a,i}(x) = \frac{\prod_{i \in I} f_i(x)}{\int_X \prod_{i \in I} f_i(y) dy}.
\]  

We say that an agent \( a \) computes its belief of variable \( x \) given the set of observations \( I \) as \( h_{a,I}(x) \), which is equal to \( f_{a,i}(x) \) only for an unbiased agent. Similarly, \( h_{a,i} \) represents agent \( a \)'s computed belief of the PDF of the attribute of observation \( i \). Each observation \( i \) has a target of observation, \( t_i \), a situation of observation, \( s_i \), comprising the tuple \((t_i, s_i)\). A target may be another agent or an object.

- **Confirmation Bias**: larger distance between prior belief and new observation \( j \) compared to \( k \) means diminished impact of observation \( j \):

\[
D_{KL}(f_{a,I \cup j} || f_{a,I}) > D_{KL}(f_{a,I \cup k} || f_{a,I})
\]

\( \land D_{KL}(h_{a,I \cup j} || h_{a,I}) < D_{KL}(h_{a,I \cup k} || h_{a,I}) \)  

(2)

- **Fundamental Attribution Error**: attribute observation to attributes of actor instead of situation (culturally influenced):

\[
f_{a,I\cup j} = f_{a,I\cup k} = f_{a,I\cup l}
\]

\( \land h_{a,I\cup j} \neq h_{a,I\cup k} = h_{a,I\cup l} \)

\( \land t_j = t_k \neq t_l \land s_j \neq s_k = s_l \)  

(3)

- **Bias Blind Spot**: don't know on biases, so can't correct for them even if they are known ("better than average")

\[
f_{a,I\cup j} \neq f_{a,I} \land h_{a,I\cup j} = h_{a,I} \land t_j = a
\]  

(4)

- **Anchoring Bias**: uneven weighting between observations - certain observations stand out more than others:

\[
D_{KL}(f_{a,I\cup j} || f_{a,I}) = D_{KL}(f_{a,I\cup k} || f_{a,I})
\]

\( \land D_{KL}(h_{a,I\cup j} || h_{a,I}) \neq D_{KL}(h_{a,I\cup k} || h_{a,I}) \)  

(5)

- **Representativeness Bias**: incorrect propagation of probability:

\[
h_{a,i}(x) \neq \frac{\prod_{i \in I} h_{a,i}(x)}{\int_X \prod_{i \in I} h_{a,i}(y) dy}
\]  

(6)

- **Projection Bias**: own shortcomings attributed to situation/others rather than self:

\[
D_{KL}(f_{a,I\cup j} || f_{a,I}) > D_{KL}(f_{a,I\cup k} || f_{a,I})
\]

\( \land D_{KL}(h_{a,I\cup j} || h_{a,I}) \neq D_{KL}(h_{a,I\cup k} || h_{a,I}) \)  

(7)
Intro to Computational Complexity

Deterministic finite automaton

\[
\begin{array}{c}
\text{Start} \\
S_0 \xrightarrow{1} S_1 \xrightarrow{0} S_2 \xrightarrow{1} \\
0 \xrightarrow{1} 0 \\
\text{Input: } 10101111101010101110101
\end{array}
\]

Nondeterministic finite automaton

\[
\begin{array}{c}
\text{Start} \\
S_0 \xrightarrow{1} S_1 \xrightarrow{0} S_2 \xrightarrow{0,1} \\
0 \xrightarrow{1} 0 \\
\end{array}
\]

\[P \text{ (polynomial time): max matching}\]

\[
\begin{array}{cccccccccccc}
5 & 7 & 7 & 1 & 0 & 5 & 1 & 7 & 0 & 0 & 2 & 3 & 0 & 8 \\
5 & 6 & 7 & 4 & 9 & 1 & 3 & 9 & 1 & 4 & 7 & 8 & 0 & 8 \\
\end{array}
\]

Fewest moves: NP-complete

\[
\begin{array}{cccccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 15 & 14 \\
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 15 & 14 \\
\end{array}
\]
NP-Hard

Specific Kinds of Pattern Matching (Graph Isomorphism, Knot untying)

2-Player Strategy Games

Tetris

Knapsack Problem

Shortest Path

Exploration

P ≠ NP

P = NP = NP-Complete

P = NP
"Reduction"
Introduction to "Reduction" in Computational Complexity

3SAT $\rightarrow$ graph 3-color
$(x \lor y \lor \neg z) \land (\neg x \lor \neg y \lor z)$

Focus on polynomial time reduction (P)

Turing Machine in Little Big Planet meunierc2008 on Youtube
Equivalencies Between Game Mechanics and Computational Problems

• "Same" problem:
  • Knapsack packing
  • Vertex cover (special units in tower defense, police stations in older versions of SimCity)
  • Hamiltonian path (various kinds of reconnaissance)

• "Same" problem
  • Go
  • Chess
  • Checkers
  • Model checking
Problem Decomposition & Importance of Constraints

Surprisal

- Self-information: information of outcome of random event
- Surprisal: \(-\log_2 P(x_i)\)
Measuring Difficulty by Non-Losing Decision Information Rate

No loss, no information

Average 1 bit of information

Average 0.5 bits of information

3 out of 6 paths lose

1.5 bits of total information to win

1.5 bits / 2 steps = 0.75 bits per step to win
Nash Equilibria
How We Make Rule Systems Now: Games

Scripting

```javascript
var distance;
var target : Transform;
var lookAtDistance = 15.0;
var attackRange = 10.0;
var moveSpeed = 5.0;
var damping = 6.0;

function Update ()
{
    distance = Vector3.Distance(target.position, transform.position);
    if(distance < lookAtDistance)
    {
        lookAt ();
    }
    if(distance < attackRange)
    {
        attack ();
    }
}

function lookAt ()
{
    var rotation = Quaternion.LookRotation(target.position - transform.position);
    transform.rotation = Quaternion.Slerp(transform.rotation, rotation, Time.deltaTime * damping);
}

function attack ()
{
    transform.Translate(Vector3.forward * moveSpeed * Time.deltaTime);
}
```

Unity Script

Machine Learning

Black & White
How We Make Rule Systems Now: Business

BPEL

<?xml version="1.0" encoding="UTF-8"?>
<process
 xmlns="http://schemas.xmlsoap.org/ws/2003/03/business-process/"
<!--Hello World - my first ever BPEL program -->
<import importType="http://schemas.xmlsoap.org/wsdl/
 location="../../test_bucket/service_libraries/tptp_EnginePrinterPort.wsdl"
 namespace="http://www.eclipse.org/tptp/choreography/2004/engine/Print" />

<partnerLinks>
   <partnerLink
      name="printService"
      partnerLinkType="print:printLink"
      partnerRole="printService"/>
</partnerLinks>

<variables>
   <variable
      name="hello_world"
      messageType="print:PrintMessage"/>
</variables>

<assign>
   <copy>
      <from><literal>Hello World</literal></from>
      <to>$hello_world.value</to>
   </copy>
</assign>

<invoke partnerLink="printService" operation="print" inputVariable="hello_world"/>
</process>
How We Make Rule Systems Now: Novice Programmers

Scratch

Alice
Enhancing Aesthetic Creativity: Procedural Content
Procedural Content Example

Koch Snowflake
More Advanced Procedural Content

Infinity (infinity-universe.com)

Spore
Emergent Behavior & Automated Creativity

Hazard et al., Complexity, 2005
Measuring Creativity of Something

• Desirability Index (geometric mean of conflicting metrics) in multicriteria optimization:
\[
\left( \prod_{i=1}^{n} a_i \right)^{1/n} = \sqrt[n]{a_1 a_2 a_3 \ldots a_n}
\]

• Relative Surprisal of solution, KL-Divergence:
\[
D_{KL}(P \| Q) = \sum_i P(i) \log \frac{P(i)}{Q(i)}
\]

• Complexity of solution (Information Entropy):
\[
- \sum_i P(i) \log P(i)
\]
Psychological Tricks

- **Blue** to sell (Bellizzi & Hite, 1992)
- **Red** to intimidate (Elliot et al., 2007)
- **Green** to be creative (Lichtenfeld et al., 2012)
- Make probability assessments when you're depressed, or ask your friends if they're sad (Korn et al., 2014)
Questions?