# The Intelligent Game Designer:
## Game Design as a New Domain for Automated Discovery

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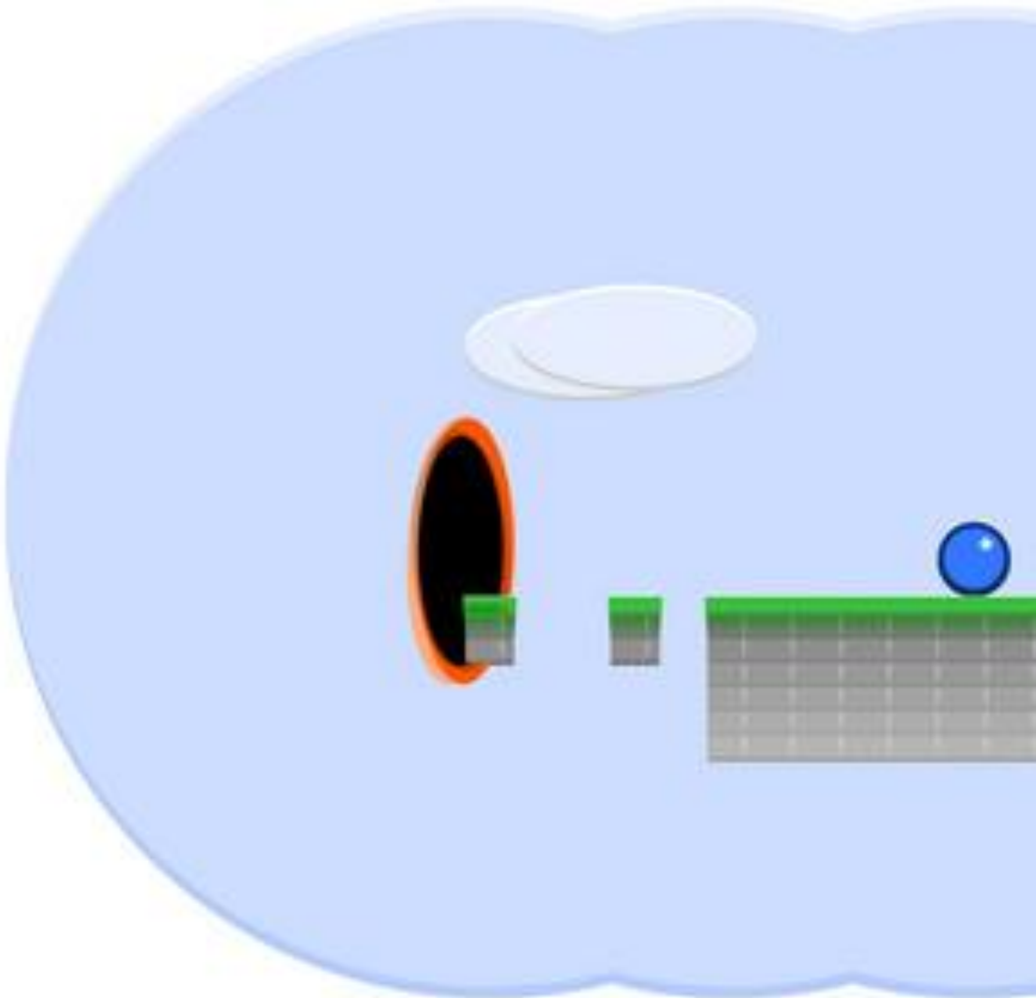
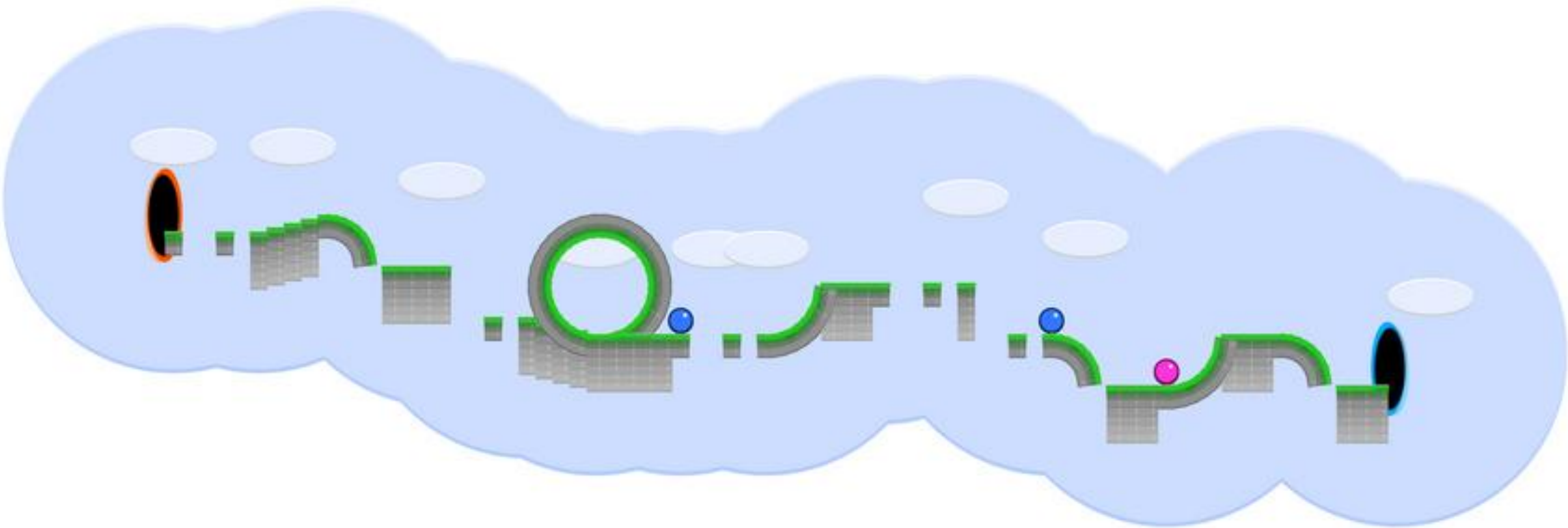
# PREFACE



# Preface

- Game design is clearly a **creative activity**.



- I claim a **machine** can do it.

# Preface

- Bruce Buchanan (in AAAI-2000 Presidential Address) says of existing creative systems…
  - *they do not accumulate **experience**, and thus, cannot reason about it;*
  - *they work within fixed frameworks including **fixed assumptions**, and criteria of success;*
  - *they lack the means to **transfer concepts and methods** from one domain to another.*

# Preface

- My "intelligent game designer" is all about turning **experience** into **communicable knowledge** (producing games along the way).

- But how?
  - *Operationalize* game design as an automatable scientific process.
  - *Re-conceptualize* creative design of expressive artifacts knowledge-seeking effort.

# Why is this realistic?

- Why me?
  - Game development
  - Generative art
- Why now?
  - Fresh tools
    - Abductive/Inductive logic learning
    - Automated debugging for logic programs
  - Fresh formalisms for games
    - Event-calculus
    - Recombinable mechanics

Context

Research Questions

Proposal Outline

# INTRODUCTION

# Perspectives in Game Design

- Experience sharing (informal knowledge, words)
  - Textbooks, forum posts, and technical talks
- Code Sharing (formal knowledge, code)
  - Procedural content generation, drama management, game engines, and miscellaneous middleware
- Nearly-automated Systems
  - Peer or design buddy?

# Perspectives in Learning / Creativity

- Statistical ML / Computational Intelligence
  - Structured data in, predictive model out
- Discovery systems
  - Data must be drawn out by experiment
  - Predictions should be consistent with rich, domain-specific, background knowledge
- Creative art systems
  - Artifacts are like exquisite experiments, results ignored
  - Leverage highly nuanced audience model, often fixed
- Domain-aware, creative discovery systems
  - Learning is the focus, artifact creation as side-effect

# Research Questions

- Function:
  - How does an **intelligent game designer** function?
- Implication:
  - What does such a system imply for the relationship between **discovery** and **expressive domains**?

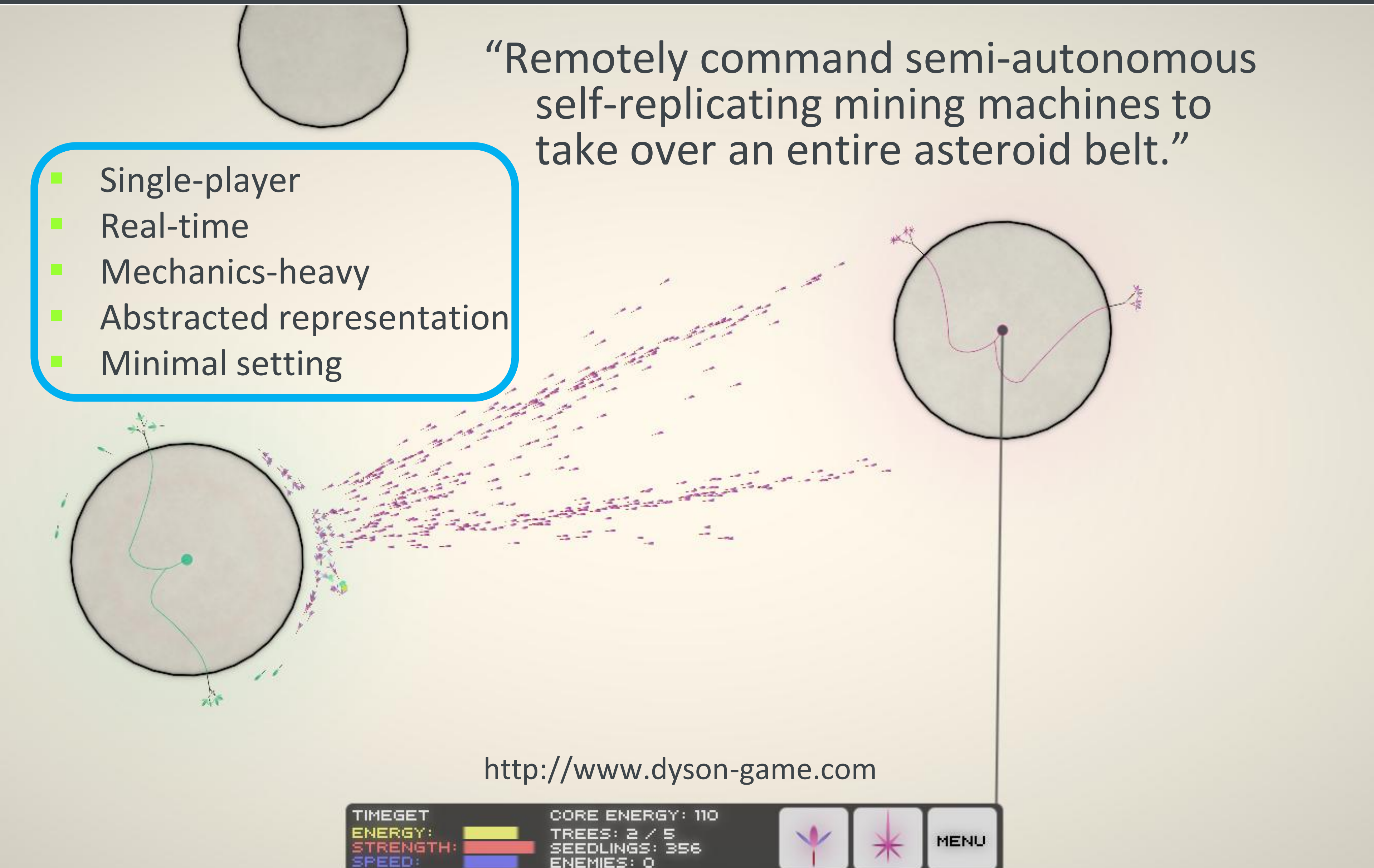
# Function: “games”

- Recognizable as “video games”
- Focusing assumptions:
  - Single-player
  - Real-time
  - Mechanics-heavy
  - Abstracted representation
  - Minimal setting

# Example “game”: *Dyson*

- Single-player
- Real-time
- Mechanics-heavy
- Abstracted representation
- Minimal setting

“Remotely command semi-autonomous self-replicating mining machines to take over an entire asteroid belt.”




http://www.dyson-game.com

# Function: “intelligent”

- Learning from experience
  - Knowledge production as a function of past design and discovery actions
  - Documentation as proof

# Function: “game design”

- Game design: **the informed construction of rules systems and supporting logic required to produce playable games**

- OK if playable games are a little rough, some human polish might be needed

# Implications: Game Design

- **What does _____ mean in game design?**
  - Discovery?
  - Conjecture?
  - Experiment (environments, observations, instruments)?
  - Verification?
  - Proof?

# Implications: Discovery

- **What does _____ mean in discovery?**
  - Prototyping and play testing?
  - Publishing a game?
  - Games vs. abstract state progression systems?
  - Expressive goals?
  - *Fun*?

# Research Questions Revisited

- Function:
  - How does an **intelligent game designer** function?
    - Need to build a system!
- Implication:
  - What does such a system *imply* for the relationship between **discovery** and **expressive domains**?
    - Need some theories to generalize!

# Outline

- Related work
  - Game design
  - Discovery and creativity systems
- Prior work
  - Interactive generative art
  - Logical games
  - Elementary discoveries in game design
- Proposed work
  - Theories
  - Systems
  - Experimental validation
  - Time line

Textbook game design

A call for structure

Game studies

Artificial intelligence

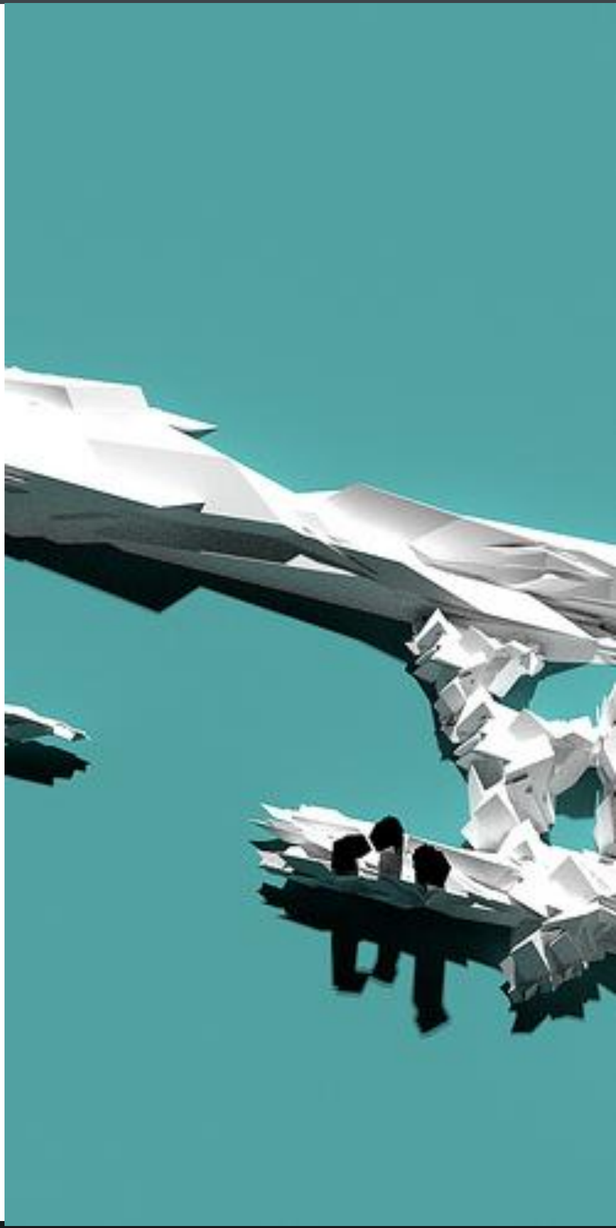
Models of discovery

Discovery systems

Computational creativity

Generative art

# RELATED WORK



# Textbook Game Design

**Artifacts**

- Design documents
- Prototypes
  - Paper
  - Computer-assisted
  - Computational
- Complete games

**Processes**

- Concept development
- Design
- Prototyping
- Play testing
  - Self-testing
  - Testing with friends
  - Testing with target audience
- Tuning
- Marketing

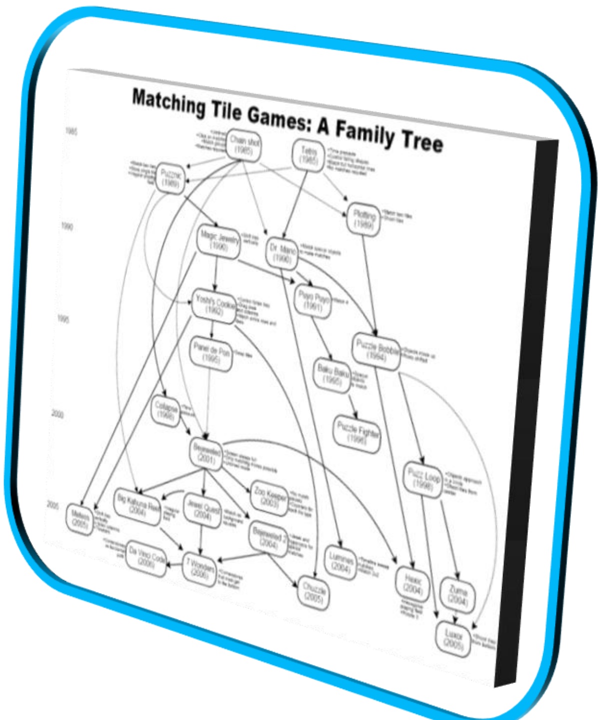
# A Call for Structure

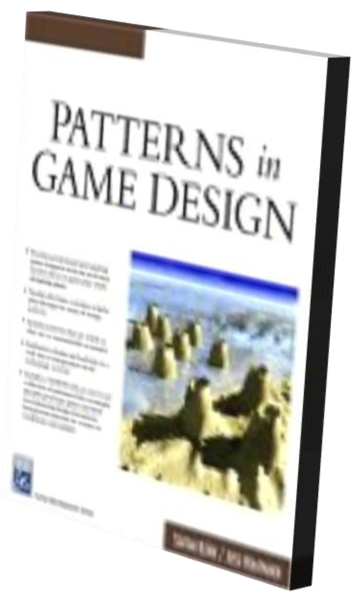
- *"Not enough is done to build on past* ***discoveries****, share* ***concepts*** *behind successes, and* ***apply lessons learned*** *from one domain or genre to another."* – Doug Church

- *Formal Abstract Design Tools* (Church 1999)
- *400 Project* (Barwood 2001)
- *The Case for Game Design Patterns* (Kreimeier 2002)

# Game Studies

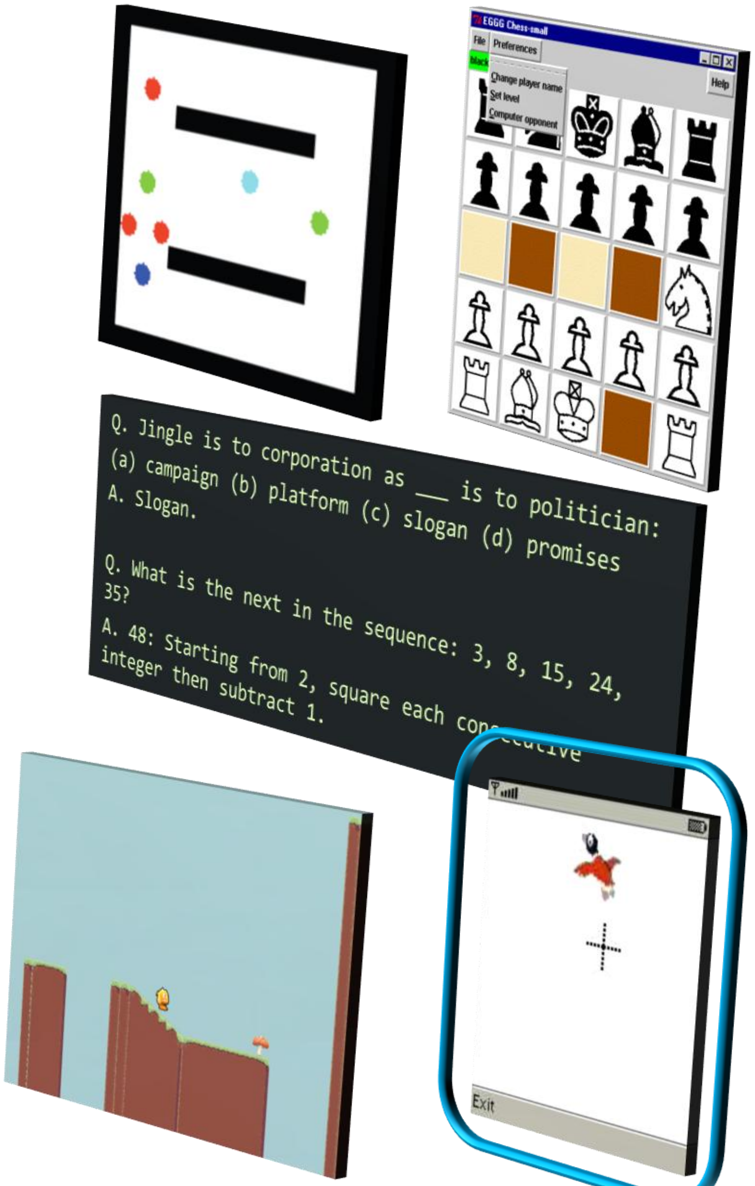
- *Swap Adjacent Games to Make Sets of Three* (Juul 2007)
- *Patterns in Game Design* (Bjork 2005)
- *Game Ontology Project* *(Zagal 2005)*




# AI: Game Generation

- *EGGG* (Orwant 2000)
- *Automated Puzzle Generation* (Colton 2002)
- *Towards Automated Game Design* (Nelson 2007)
- *An Experiment in Game Design* (Togelius 2008)
- *Rhythm-Based Level Generation for 2D Platformers* (Smith 2009)



# AI: General Game Playing

- GGP: getting machines to play **arbitrary games** well given only the rules and a little bit of time to practice (evolved from AI chess)
- Game Description Language (Love 2006) describes games as state transition systems in datalog.

# AI: Game Design Assistance

- Parallel research by Mark J. Nelson at EIS
- Goal: *create a game-design assistant that helps designers prototype their rule systems*

- Gist:
  - Let the machine comment on formal issues
    - Reachability, exploits, indirect constraints
  - Let human players comment on soft issues
    - Engagement, fun, hesitation

# Personal Game Design Experience

*Drive-by CTF*

*AjaxWar*

*Katamari Damacy Text Adventure*

*the.cubing.game*

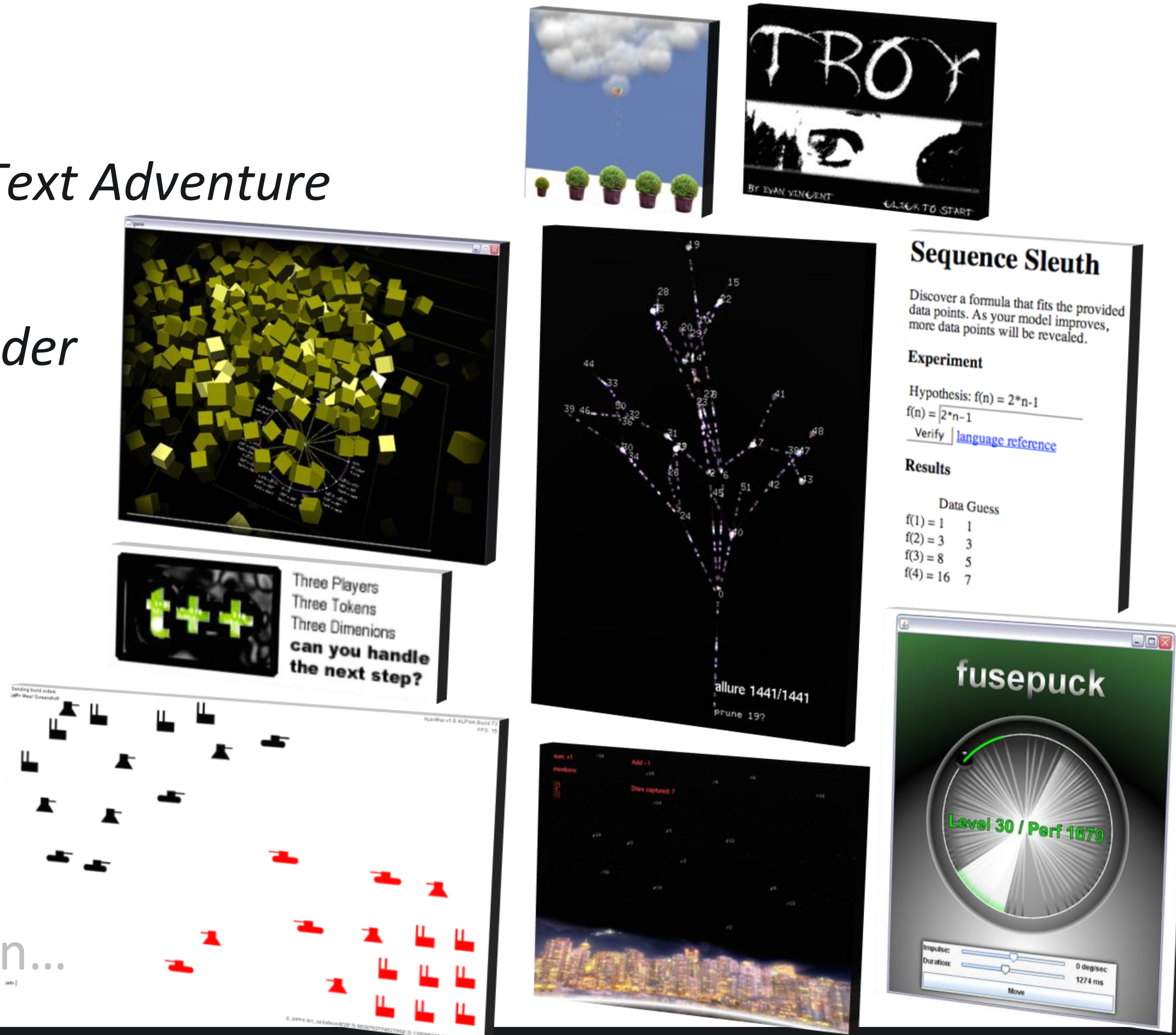
*the.discrete.gardender*

*Sequence Sleuth*

*Troy*

*fusepuck*

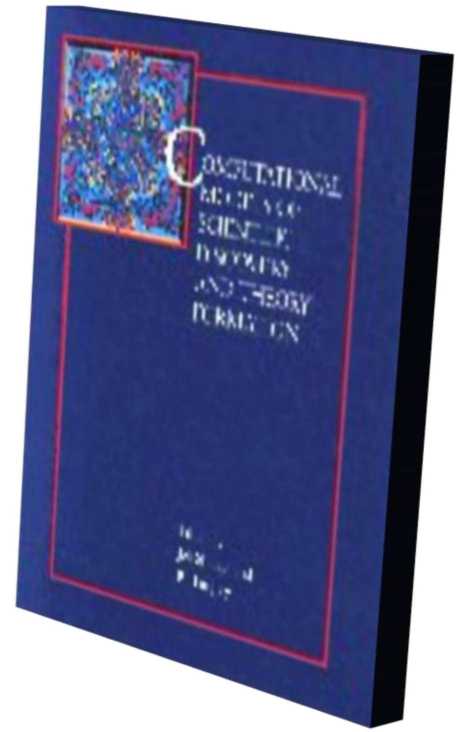
*T++*




others I've forgotten...

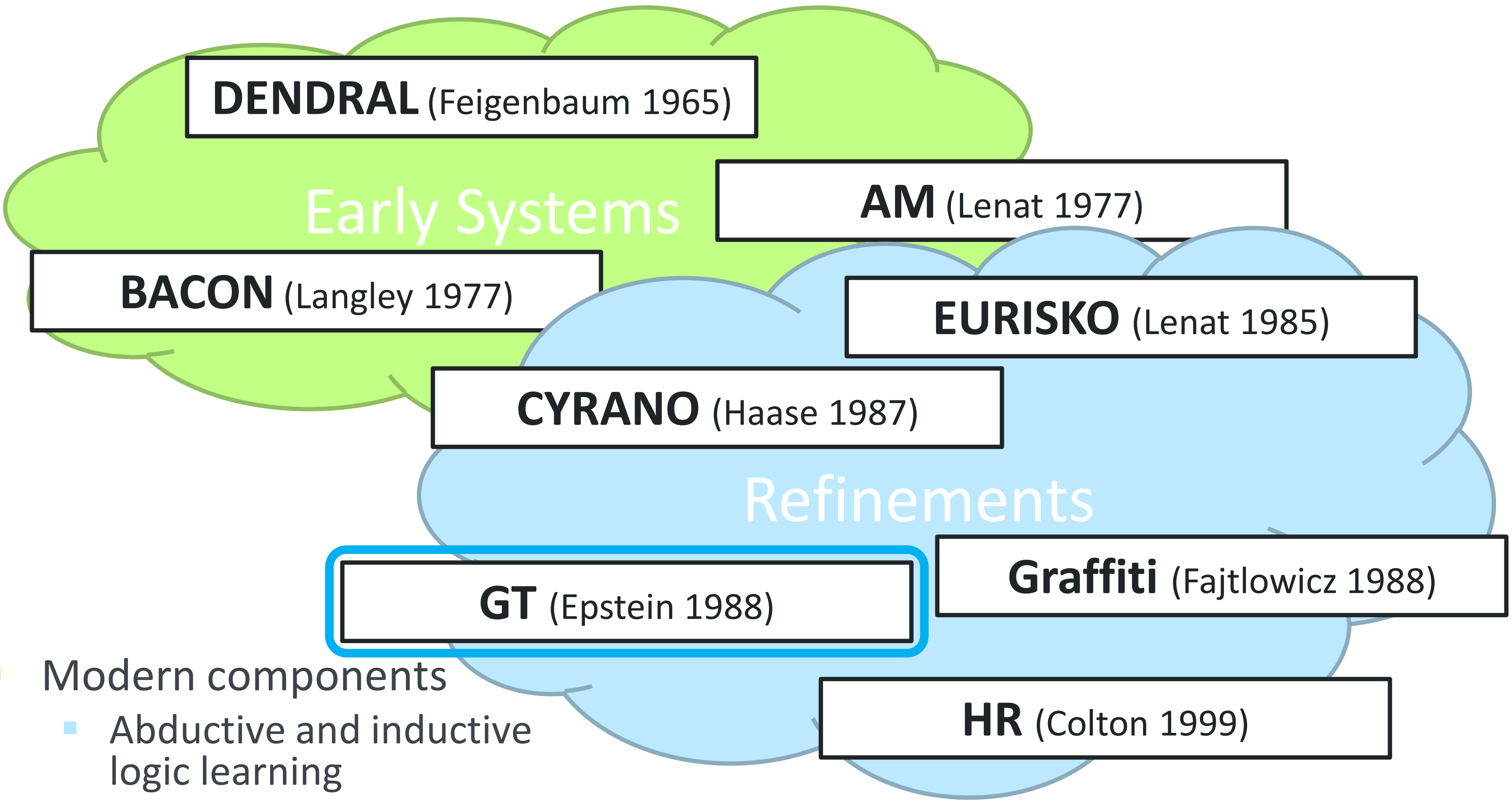
# Models of Discovery

- Two common domains:
  - Natural science
    - physics, chemistry, genomics, virology
  - Mathematics
    - graph theory, number theory
- Two common goals:
  - Explain historic discoveries
  - Produce new knowledge



- Unifying vocabulary for discovery:
  (Shrager and Langley 1990)
  - **Knowledge structures**
  - **Processes**

# Discovery Systems




- Modern components
  - Abductive and inductive logic learning
  - Inductive process modeling
  - Statistical-relational learning

# Computational Creativity

**Theoretical Models**

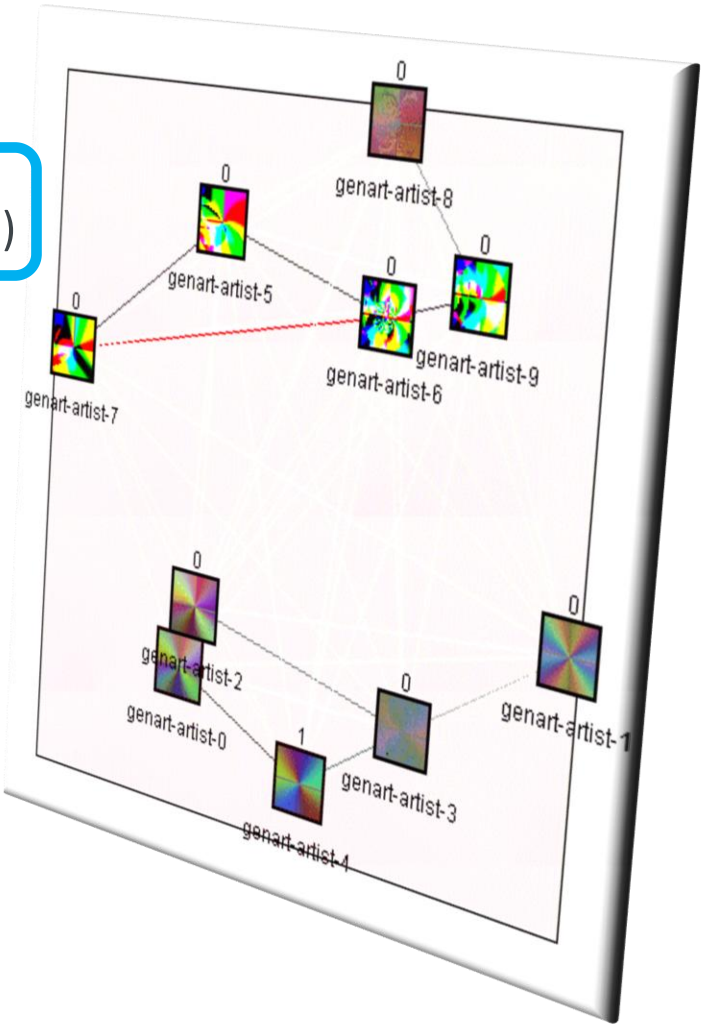
- Conceptual spaces (Boden)
- Domain, individual, field, interaction (DIFI) (Feldman)
- Curiosity (Saunders)
- Perceptual Creativity (Colton)
- …

**Aspects**

- Artifacts
- Processes
- Expectation
- Emotion
- Socialization
- Novelty and value
- Generate and test loop
- …

# Creative Art Systems

- AARON (Cohen)
- NEvAr (Machado)
- Digital Clockwork Muse (Saunders)
- EMI (Cope)
- MINSTREL (Turner)
- The Painting Fool (Colton)



# Recap of Related Work

- Game Design
  - Textbook + Call for more structure
  - Game studies + AI
- Discovery and Creativity
  - Models of Discovery + Systems
  - Computational Creativity + Systems

*Tableau Machine*

Logical game design

Game generation

Elementary discovery in game design

# PRIOR WORK

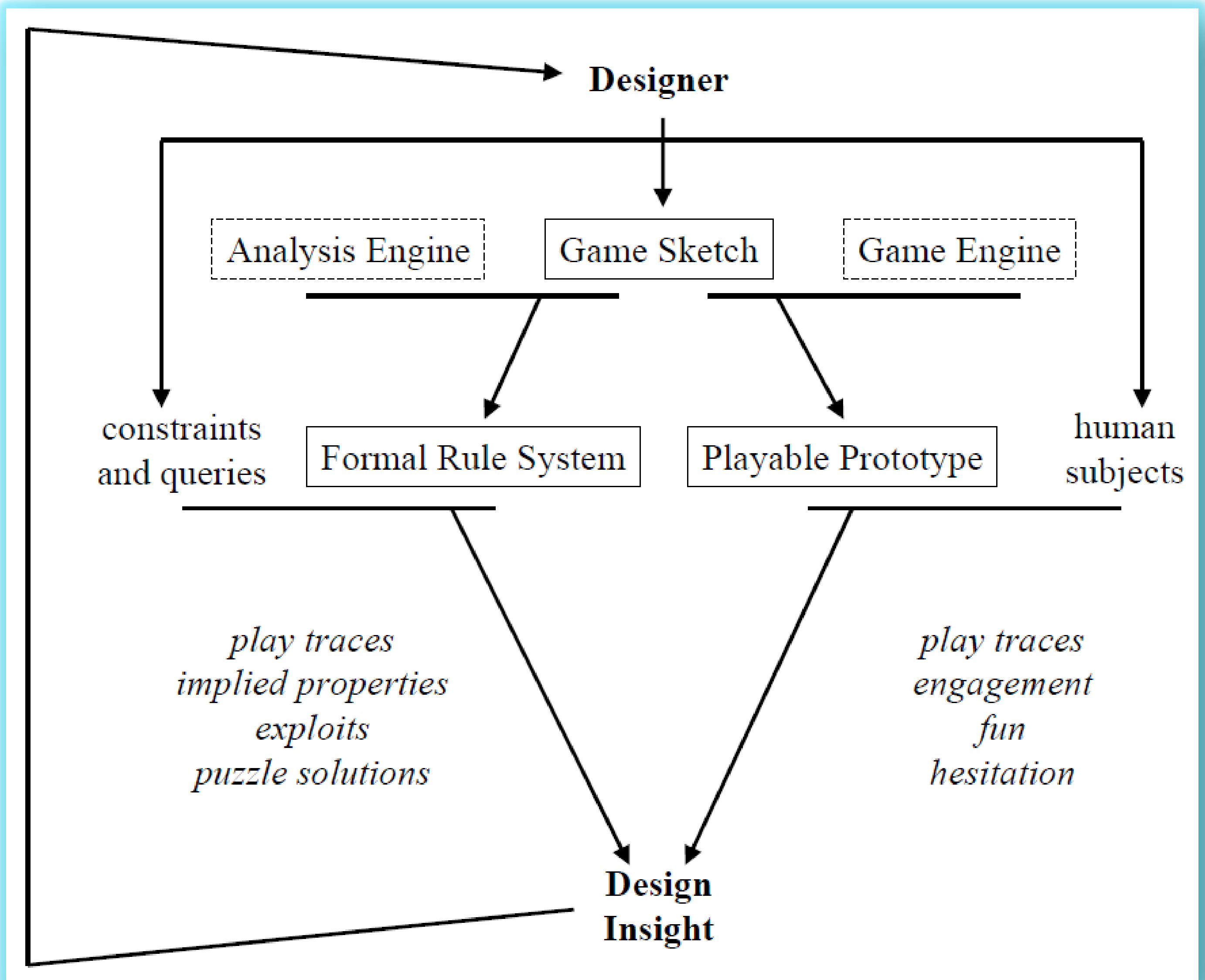
# Tableau Machine

- Experience formalizing an expressive domain

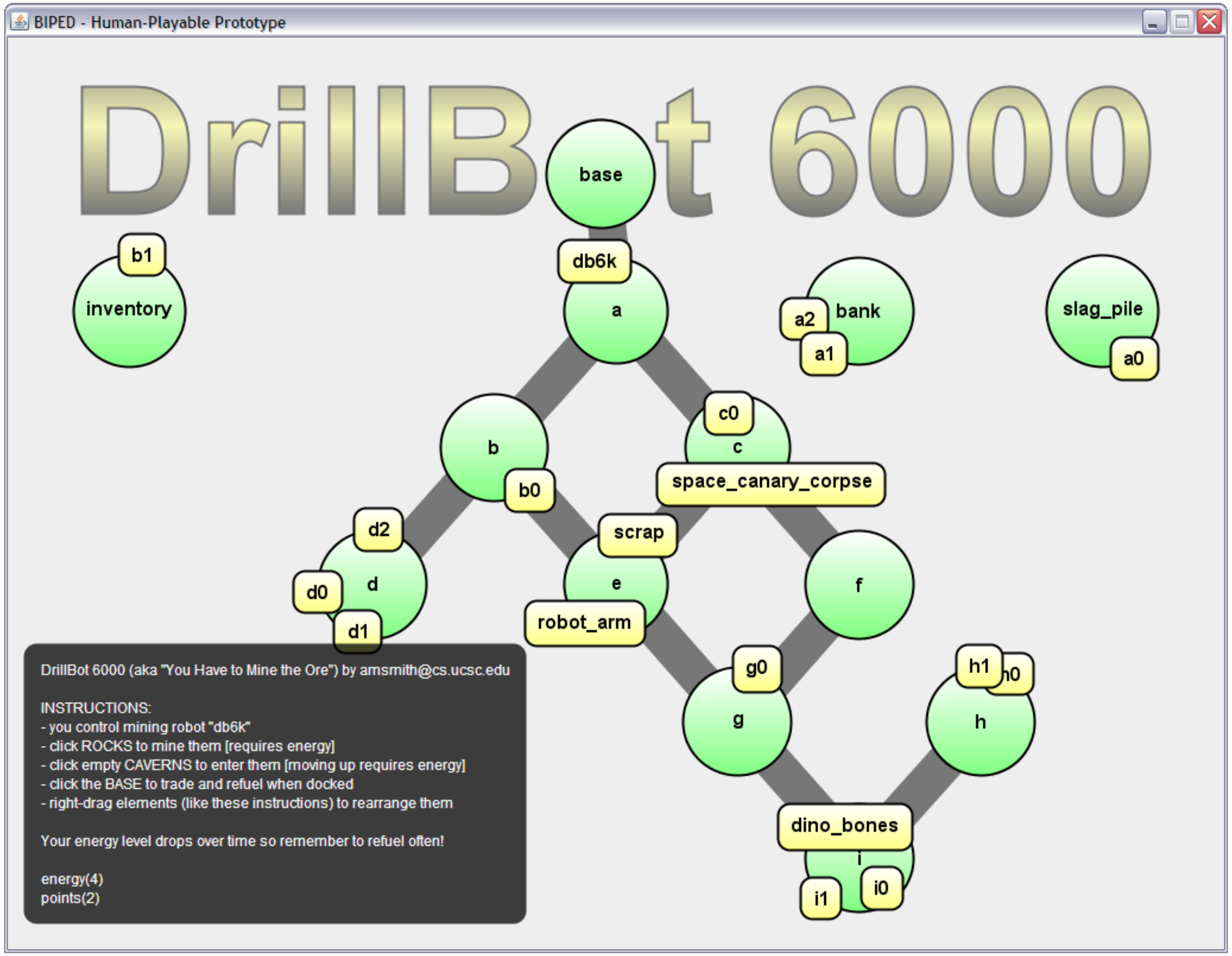
- Generate-and-test
  - Design grammars
  - Image analysis

- Learn long-term patterns in sensor data to stay relevant

# BIPED: Computational support for play testing game sketches



# Example Game: *DrillBot 6000*




```
happens(mine(a1),0).
happens(drain,1).
happens(drain,2).
happens(trade,3).
happens(mine(a2),4).
happens(mine(a0),5).
happens(down_to(a),6).
happens(mine(corpse),7).
happens(mine(c0),8).
happens(down_to(c),9).
happens(down_to(f),10).
happens(up_to(c),11).
happens(up_to(a),12).
happens(down_to(c),13).
happens(down_to(f),14).
```

# Logical Game Programming

- Movement mechanic from *DrillBot 6000*

```
pos(base). pos(a). pos(b). pos(c). …

game_state(position(P)) :- pos(P).

game_event(up_up(P)) :- pos(P).
game_event(down_do(P)) :- pos(P).

initiates(down_to(P),position(P)) :- pos(P).
terminates(down_to(_),position(Prev)) :-
     holds(position(Prev)).

initially(position(base)).
```

# Logical User-Interface Programming

- UI bindings in *DrillBot 6000*

```
ui_title('DrillBot 6000').

ui_space(P) :- pos(P).
ui_space(inventory).

ui_token(db6k).
ui_location(db6k,P) :- holds(position(P)).

ui_triggers(ui_click_space(P),down_to(P)).
ui_triggers(ui_click_space(base),refuel).
```

# Capabilities

- Syntactic properties
  - Design validation
- Semantic properties
  - Trace harvesting
  - Rule set debugging
  - Win-ability verification
  - Reachability analysis
  - Uniqueness verification of puzzle solutions
  - Testing a game before you ever make a UI
- Induction on semantics
  - Player-model construction

# Game Generation

- BIPED-tech is great for **testing** game ideas, but who **generates** them in the first place?
  - Need a “design grammar” for games

- Propositional game generator experiment
  - Generation of rule systems is feasible.
  - Needs higher-level building blocks:
    - Multi-clause rules
    - Multi-rule mechanics
    - Higher-level mechanics

# Elementary Discovery in Game Design

## "Movement between underground caverns" in *Drillbot 6000*

```
% positions (caverns)
pos(base).
pos(a).
pos(b).
pos(c).
% links (drillable routes)
link(base,a).
link(a,b).
link(a,c).
% event preconditions
possible(down_to(Dst)) :-
   holds(position(Src)),
   link(Dst,Src).
…
```

## A general "network navigation" design pattern at the code level

- Setting: predicate **`room(R)`**
- State: **`location(R)`** such that **`room(R)`**
- Setting: **`doorway(R1,R2)`** such that **`room(R1)`** and **`room(R2)`**.
- Event: **`move_to(R)`** is possible only if **`room(R)`** and you **`location`** adjacent room, as judged by **`doorway`**
- …

# Recap of Prior Work

- *Tableau Machine*
- Logical game design
- Game generation
- Elementary discovery in game design

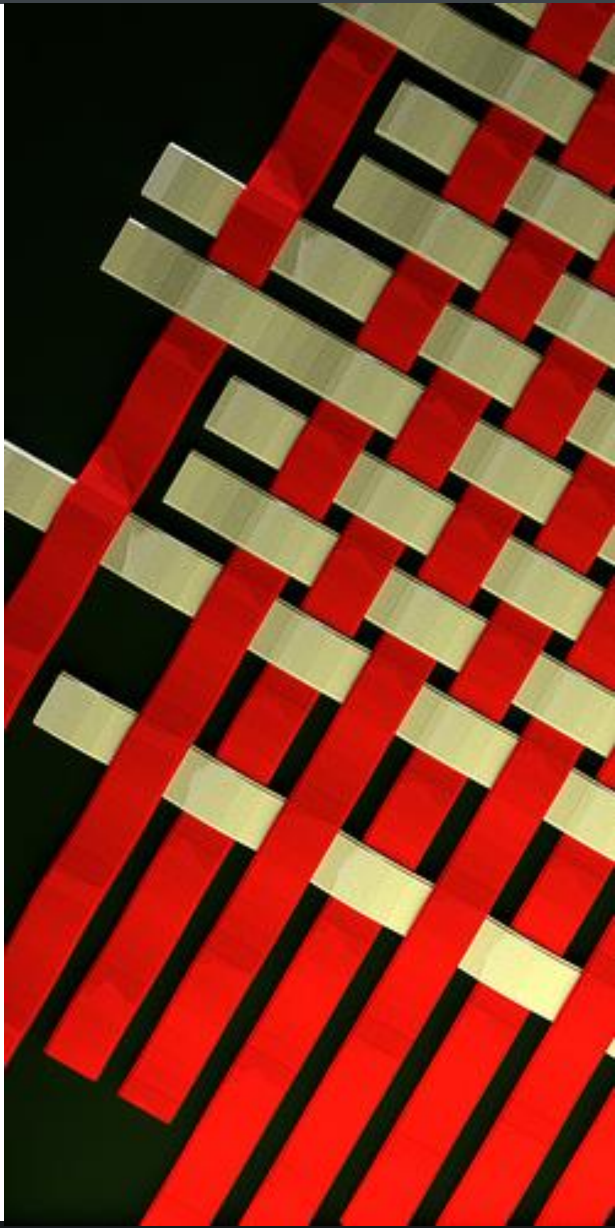
New Theories

System Architecture

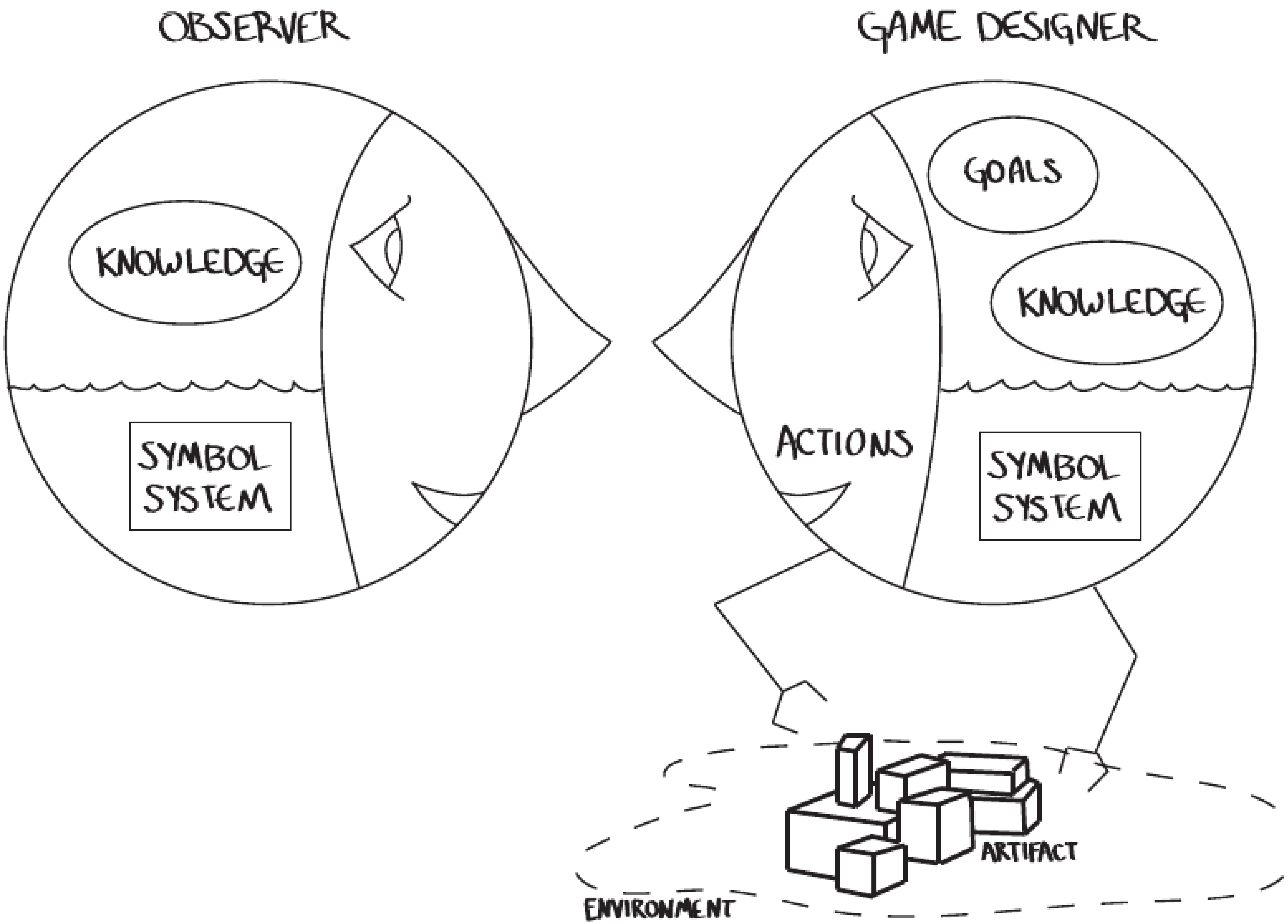
Experimental Validation

Timeline

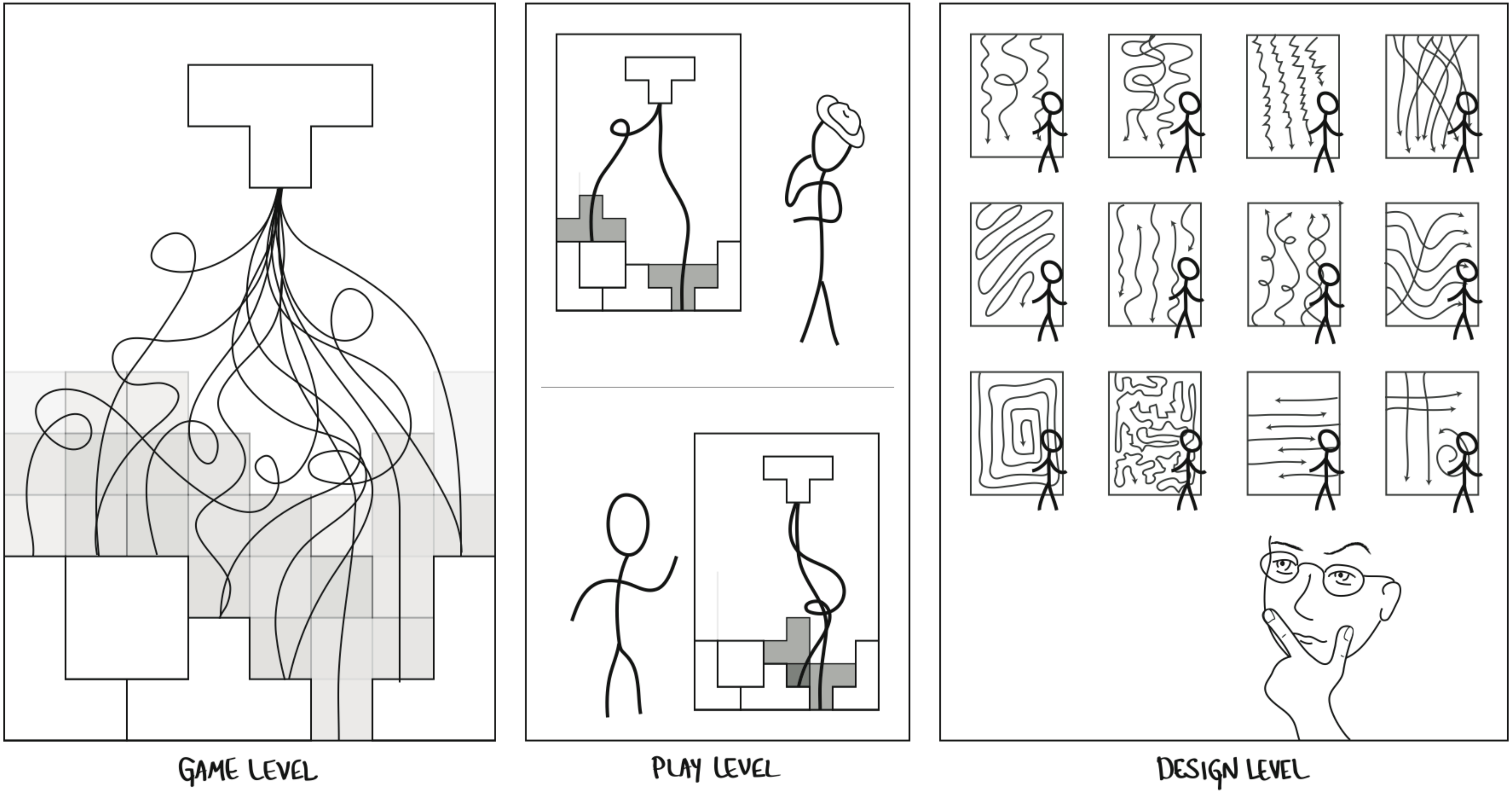
# PROPOSED WORK



# Reviewing the Knowledge Level

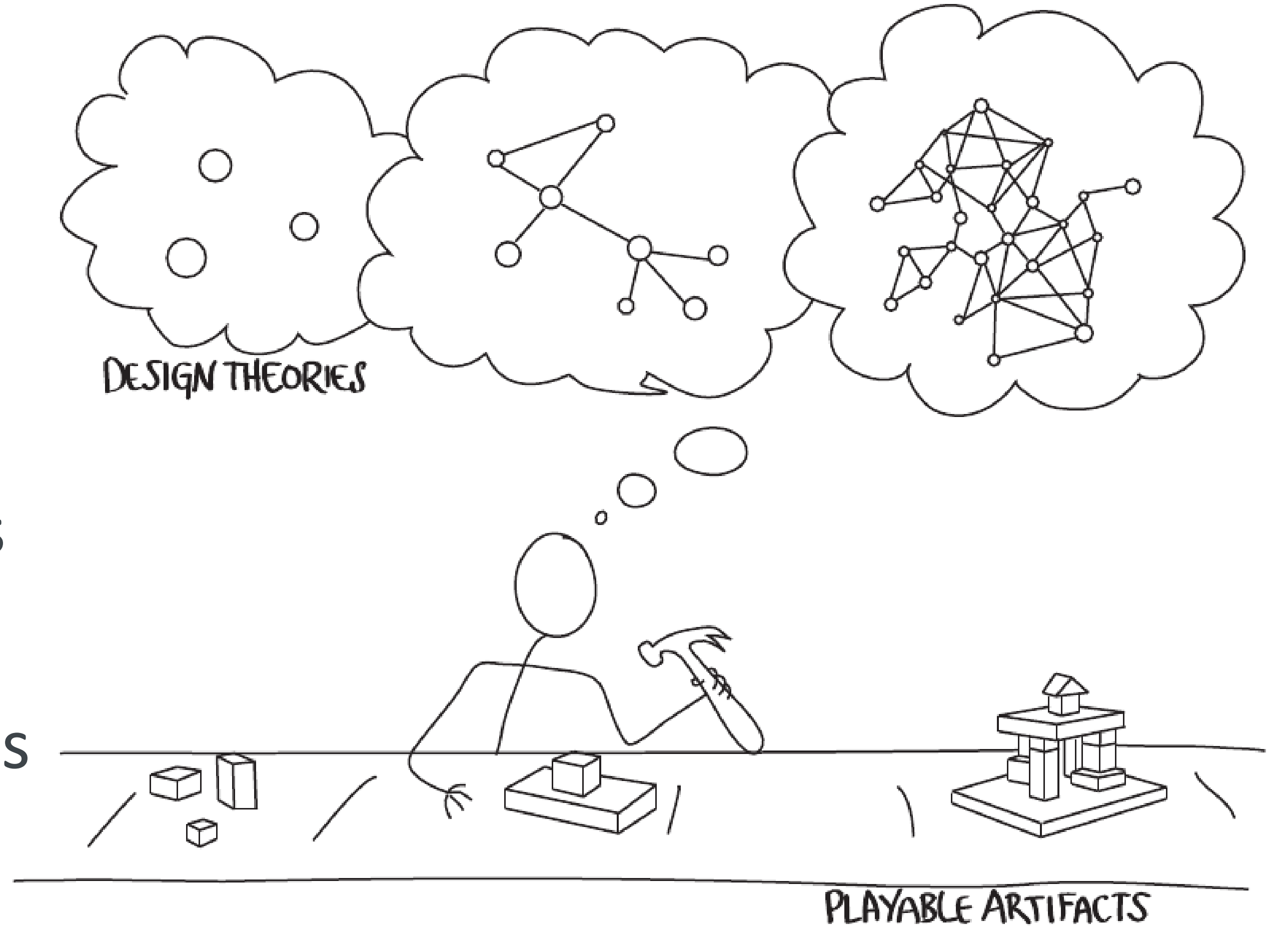


# A Game Design Meta-Theory



# A Knowledge-Level Account of Game Design

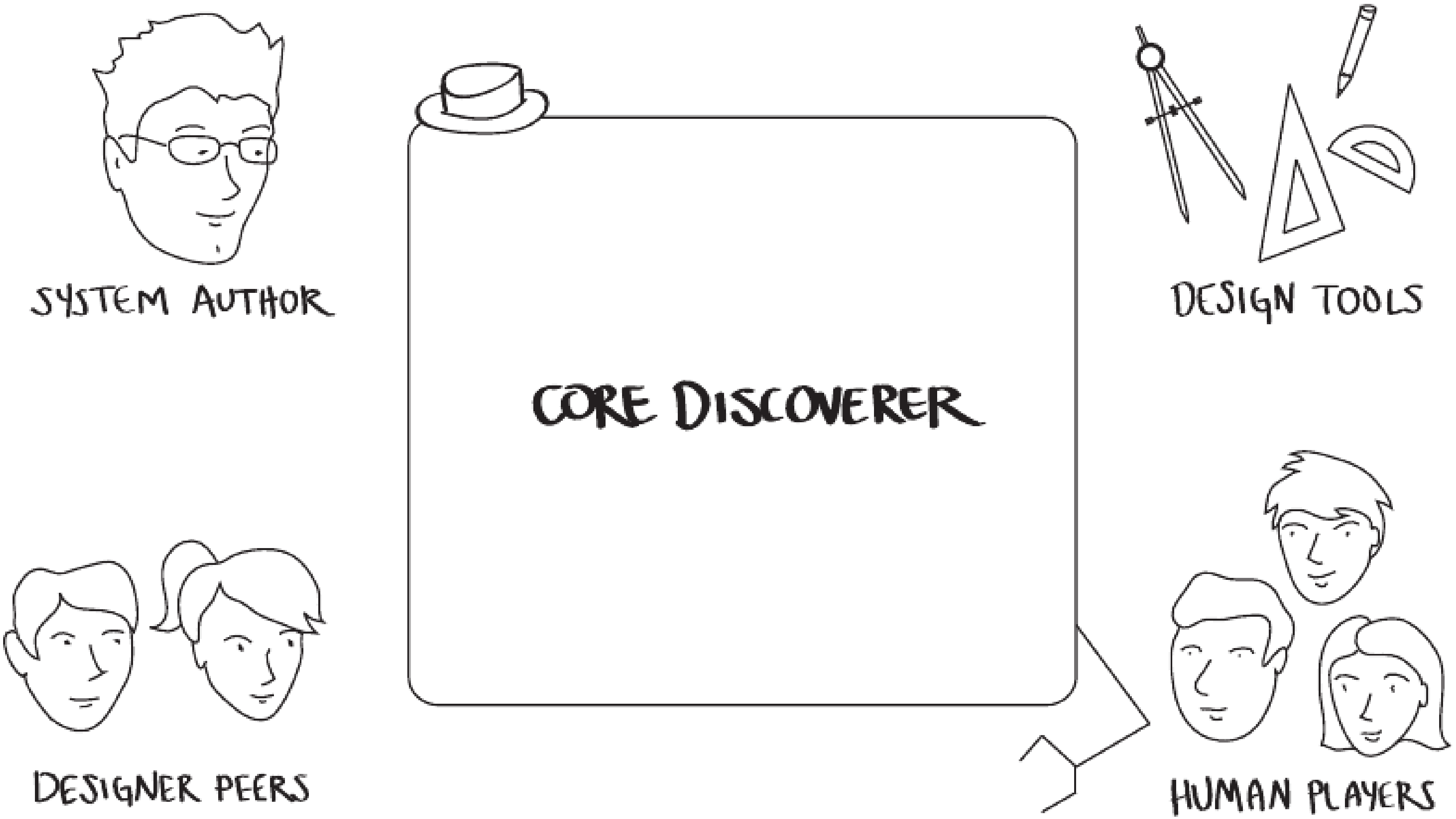
- Agents
  - Designers!
- Actions
  - Game actions
  - Play actions
  - Design actions
- Goals
  - **Discovery of design-level knowledge**



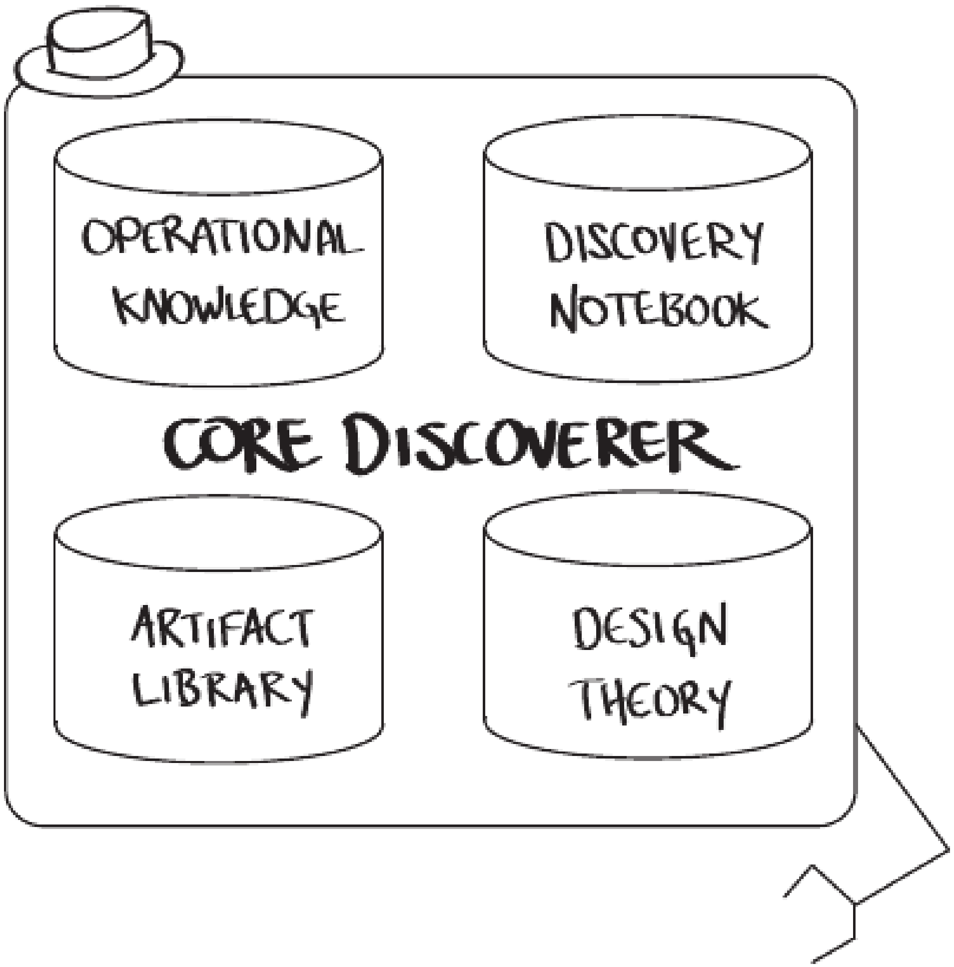
# Reflexive Creativity

- My conjecture on creativity:
  - Creativity is the **rational pursuit of curiosity** that results in a surprise.
- Mash up some theories:
  - If game designer aim to discover…
  - And discovery is way to satisfy curiosity…
  - **Maybe creative game designers make games to help them discover!**

# System Overview: Exterior



# System Overview: Interior



# Symbol-level Implementation

- Implement as  a production system
  - Facts, rules, and a rule engine/executive

- Operational knowledge:
  - Fixed rule set
- Design theory:
  - Mutable rule set, Mutable fact-base
- Artifact library:
  - Append-only fact-base
- Discovery Notebook
  - Mutable fact-base

# Operational Knowledge

- Remember those scientific **knowledge structures** and scientific **processes**? I've translated them to game design.

- Layered mapping:
  - Scientific knowledge structures and processes
  - Game design knowledge structures and processes
  - Data structures and operations
  - Production rules and facts

# Artifact Library

```
% entry for an generated sequel to DrillBot 6000
game(db6k_mk2, [
   construction(expand_map(drillbot6000)),
   rules({BIPED-compatible rule set}),
   design_annotations(expand_map_seed(12391))]).

% a player model
player(energy_hog, [
   construction({prodution rule used to produce this player}),
   rules({internal state, predicate transformers, BIPED-compatible play-hook clauses}),
   design_annotations({…})]).

% entry for an instance of play
play_instance(pairing23423,[
   game(db6k_mk2),
   player(energy_hog),
   pairing_rules({choices the system had to make to glue the player to the game}).
```

# Design Theory

- What-is knowledge
  - Design patterns (named and detailed game and play structural elements)
    - Recall the "network navigation" pattern
  - Trace predictors
    - "If the game contains pattern X, then Y should be found in the trace"
- How-to knowledge
  - *When-to-always* and *when-to-never* perform certain design actions under certain conditions

# Raw Design Theory Examples

```
% a movement mechanic
mechanic(movement_between_rooms(R,D),[
   dungeon_map(R,D),
   game_state(at(agent/1,R)),
   game_event(moves_to(agent/1,R)),
   {trigger logic}
]).

% player's view of the game state as a player character
player_construct(pc_avatar(PcPred),[
   binder(pc_avatar(PcPred)),
   pc_avatar(Pc),
   pp_mapper(in(Pc,X),out(X))]).

% trace property predictor
trace_implication(happens(victory,T2),happens(boss_kill,T1)) :-
   T2 <= T1, mechanic(boss_kill_victory).

% how-to
designers_never(game_apply(expand_map),game_apply(expand_map)).
```

# Discovery Notebook

- Starts empty
- Contains
  - Outstanding experiments
  - Expectations
  - Agenda
  - …
- General working memory
- Usage dictated by operational knowledge

# Actions:

- Design actions:
  - *Manipulate* game, player, and play instance models
  - *Solicit* a game or play trace from an automated tool or a human player
- Discovery actions:
  - *Propose* new game, player, and play instance structural elements or production constraints
  - *Look* for examples of new patterns in old artifacts
  - *Verify* (prove?) trace predictors

# Design Tools

- Design validator
- Gameness-check
- Trace-finder
- Human player trace harvester
- Logical debugger
- Misc. statistical-relational learning tools

- Potential add-ons from Mark's research:
  - Alternate trace-finding back-ends
  - Query suggester and answerer
  - Rule visualizer

# Experimental Validation – Q1

## How does an intelligent game designer function?

- "games" – Ask some players if the machine-designed games felt like real games
  - Do the players think the games feel *real*?
- "intelligent" – Ask some expert designers to perform some discovery, and record the result (using same tools).
  - Does my system *rediscover* it?
  - Did my system discover something *beyond* it?
- "game design" – Ask some expert designers to design some games and record the result (using same tools).
  - Does the designer think the games feel *real*?
  - Does the system produce the *same* kind of games?

# Experimental Validation – Q2

**What does such a system imply for the relationship between discovery and expressive domains?**

- Test the theory by testing the systems designed according to it.
  - Toggle various elements of the architecture to see what is really to blame for the interesting behavior
- Need implications in-hand to propose concrete experiments

# Time Line

- Year one: **focus on stretching game design into a science-like practice, automation comes at the very end**
  - Summer 2009: play with more **manual discovery**
  - Fall 2009: implement scientific **knowledge structures**
  - Winter 2010: implement the scientific **processes**
  - Spring 2010: integrate the system, **close the loop**
- Year two+: **focus on architectural experimentation, system evolution, and generalizing to my theoretical contributions**
  - Summer 2010: plan the dissertation
  - Fall 2010: perform the experiments
  - Winter 2011: synchronize experimental results with plan
  - Spring 2011: dissertation writing
  - Summer 2011: final polish and defense

# Recap of Proposed Work

- Improve upon some new theories
- Implement system according to proposed architecture
- Validate my intelligent game designer in experiments
- Generalize from working system to more general theories

Revisiting Buchanan’s criticisms

# EPILOGUE

# Epilogue

- Bruce Buchanan (in AAAI-2000 Presidential Address) says of existing creative systems…
  - *(1) they do not accumulate* ***experience****, and thus, cannot reason about it;*
  - *(2) they work within fixed frameworks including* ***fixed assumptions****, and criteria of success;*
  - *and (3) they lack the means to* ***transfer concepts and methods*** *from one domain to another.*

Thesis proposal: PROPOSED

# THANKS

# Detailed First Year Plan

- Summer 2009
  - Flesh out first system architecture (mostly complete)
  - Perform manual discovery with the raw tools and representations (already started)
    - Produce example outputs
    - Document the manual process
- Fall 2009
  - Implement knowledge structures
    - Games, player, play instances, trace predictors
    - Structural elements (setting constructs, mechanics, player predicate transformers)
  - Perform manual discovery with richer representations
- Winter 2010
  - Implement processes
    - Drivers/scripts for external tools
    - Action sequences ("get a trace, then induce a player model")
    - Heuristic processes selection ("try verifying a trace prediction")
  - Perform manual discovery using large-scale processes as the individual move
- Spring 2010:
  - Write up preliminary view of game design as a scientific domain (with structures and processes in-hand)
  - Plan expert and player evaluations
  - Create minimal closed-loop system
    - Theory goes in, improved theory comes out; also, games were produced
  - Improve system by building larger scale processes

# Detailed Second Year Plan

- Summer 2010
  - Write up initial results and architecture of integrated system
  - Perform final literature review
    - Game design, discovery, and generation in expressive domains
    - Digital media (and other fields outside my own) for reference on expressive artifacts
  - Formulate initial implications between discovery and expressive domains
  - Design experiments to test implications
  - Produced detailed dissertation outline
- Fall 2010
  - Carry out experiments
- Winter 2011
  - Reconcile experimental results with theory, adjust claims
  - Start dissertation writing
- Spring 2011
  - Dissertation writing
  - Clarifying experiments
- Summer 2011
  - Final polish and defense