Automated Generation of Expert Systems Thinking Patterns using a Convolutional Neural Network

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15 Oct 2020

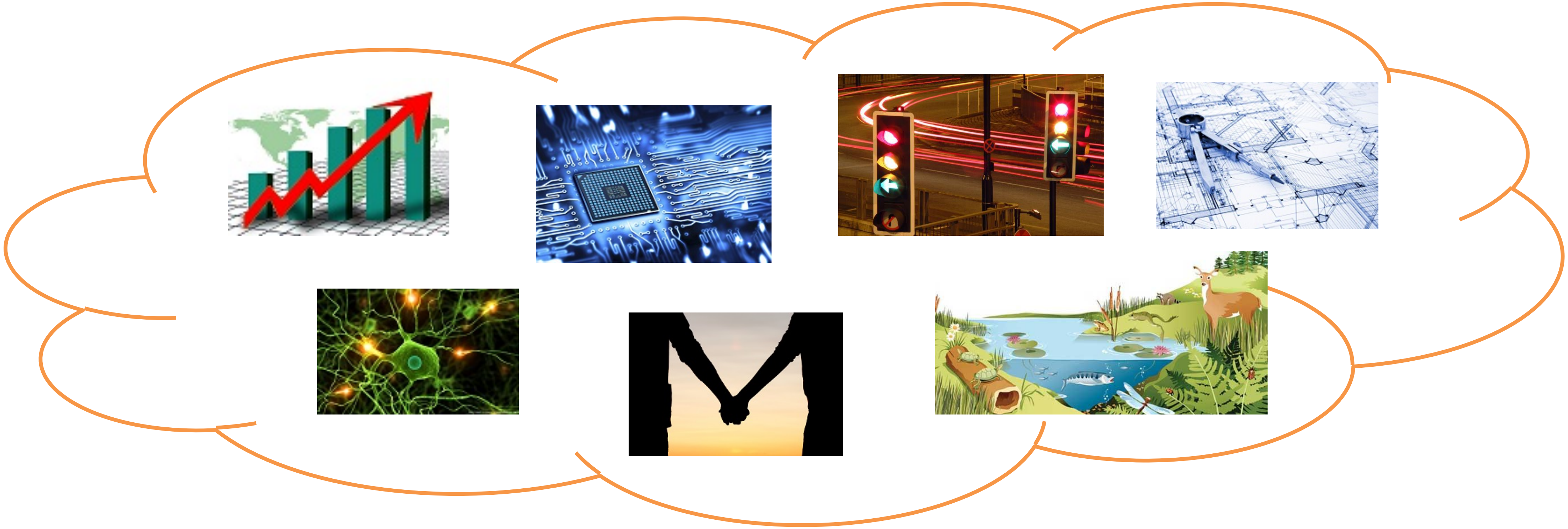
Overview

- Systems
- Systems Thinking Definition
- Systems Thinking Skills
- Assessment of Complex Skill Sets
- The Systems Thinking Game
- Systems Thinking Patterns
- Automated Assessment Scoring
- Limitations of State of the Art
- Use of Neural Network to Improve Scalability
- Neural Network to Generate Systems Thinking Patterns

Systems

What are “systems?”

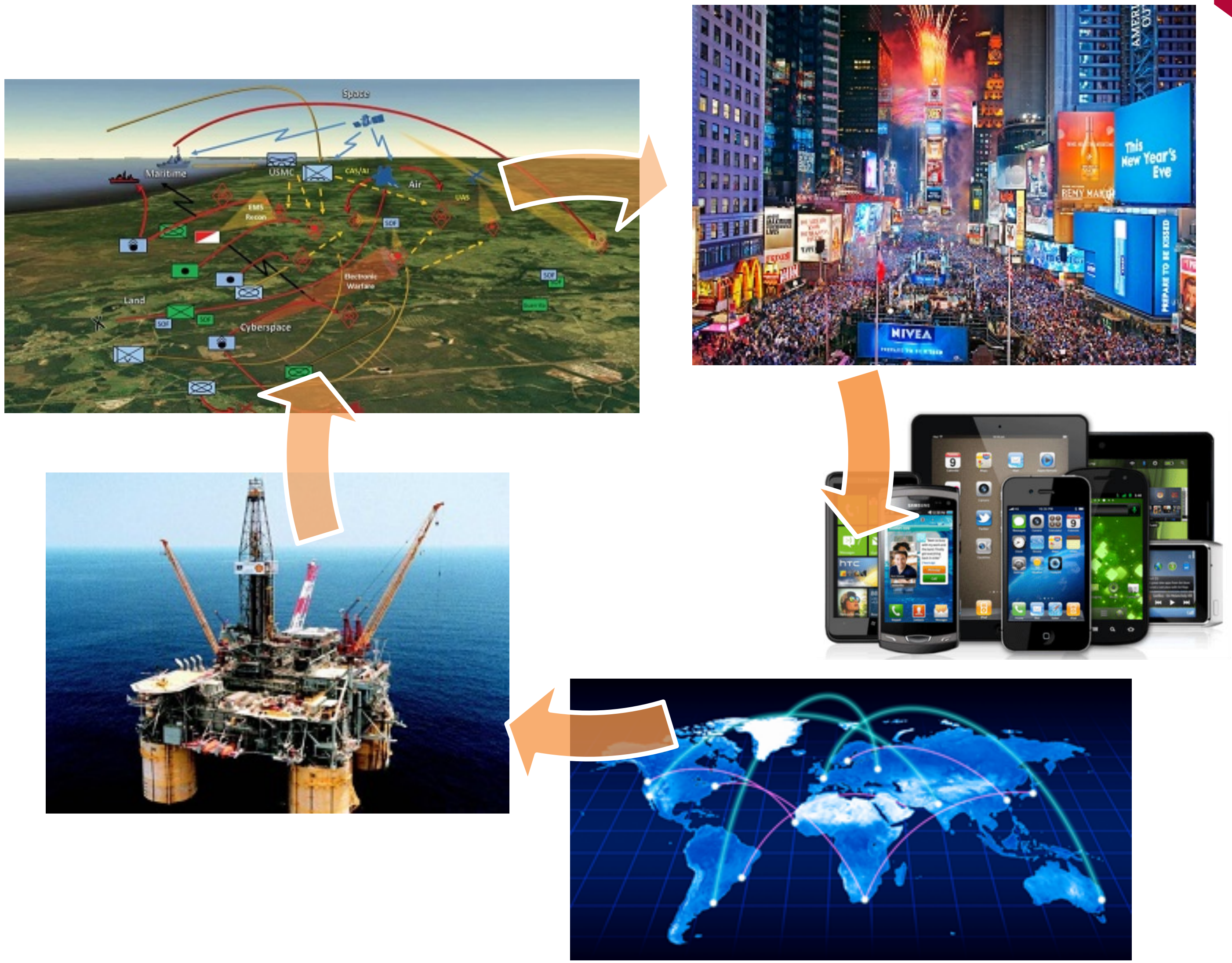
- Systems surround and encompass all aspects of life, from material to immaterial:



The Intersection of Systems

Results in emergent complexity

- The complexity of the human world, with all its systems, is increasing exponentially
- Nearly everyone is affected
- How do we cope with this complexity?



Systems Thinking

A tool to handle complexity

- ***A way to understand and predict complex systemic behavior***
- ***A system of skills for thinking about systems***
- ***Not intuitive (for most people)***

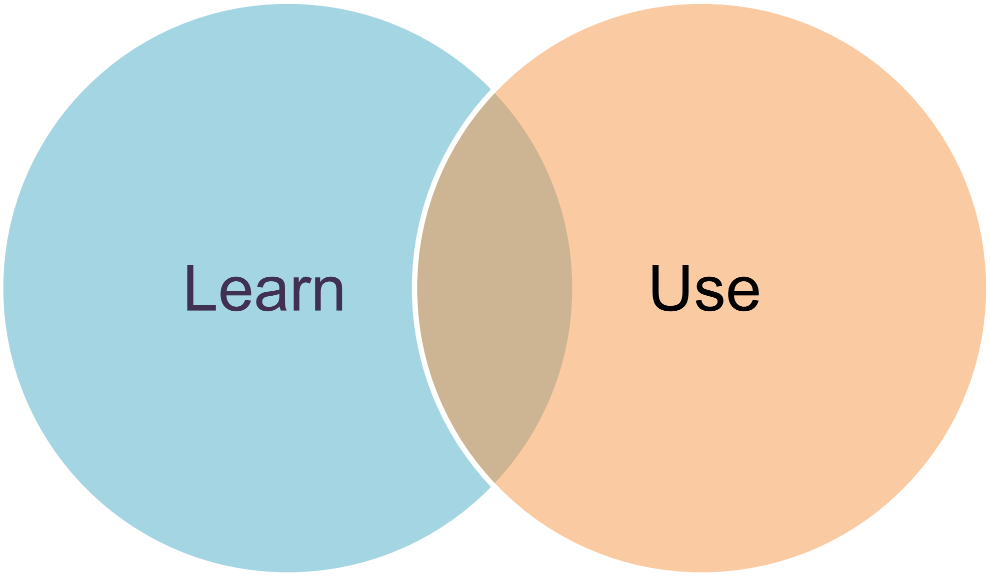
Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects.

These skills work together as a system.

Two Facets of Systems Thinking

Gaining Insight

Improving systemic insight into a particular system



Using Insight

Applying systemic insight to a particular system

Systems thinking involve the ability to gain insight into a system, and use that insight to change the system

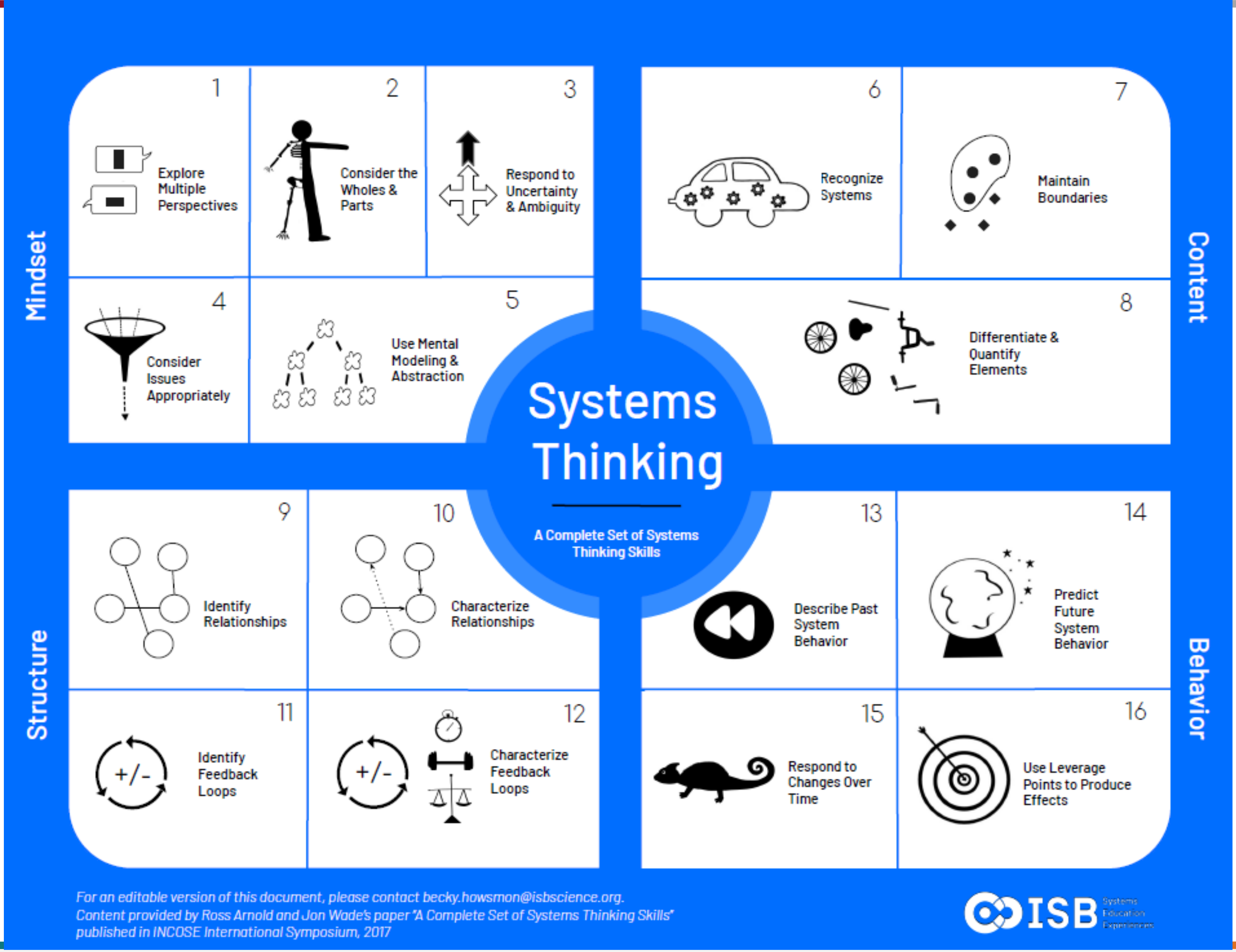
Systems Thinking Skill Domains

Mindset
How do we approach systems and systemic problems?

Content
What is the system, what's inside it, and what's outside it?

Structure
How is the content of the system organized?

Behavior
How do the organization, elements, their properties, and other factors interact to produce behavior? What can we do to change that behavior?


Mindset
1
Explore Multiple Perspectives
2
Consider the Wholes & Parts
3
Respond to Uncertainty & Ambiguity
4
Consider Issues Appropriately
5
Use Mental Modeling & Abstraction
Content
6
Recognize Systems
7
Maintain Boundaries
8
Differentiate & Quantify Elements
Systems Thinking
A Complete Set of Systems Thinking Skills
Structure
9
Identify Relationships
10
Characterize Relationships
11
Identify Feedback Loops
12
Characterize Feedback Loops
Behavior
13
Describe Past System Behavior
14
Predict Future System Behavior
15
Respond to Changes Over Time
16
Use Leverage Points to Produce Effects
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Content provided by Ross Arnold and Jon Wade's paper "A Complete Set of Systems Thinking Skills"
published in INCOSE International Symposium, 2017
ISB

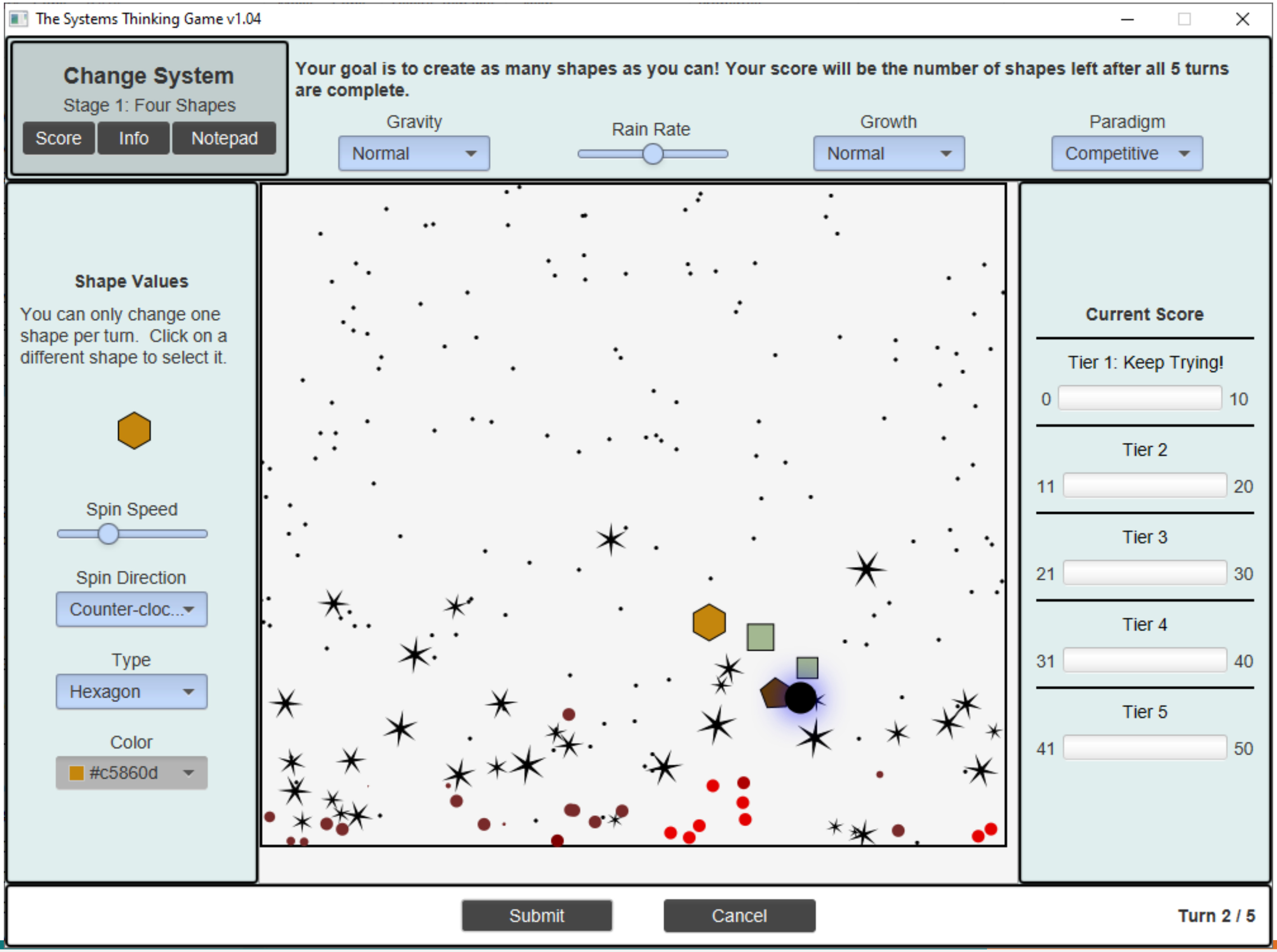
Assessment Methods

- How to assess performance in a complex skill set?
- Ongoing research problem

Method	Each Skill Tested	Multiple Levels	Automatic Evaluation	Holistic Evaluation	Real World Context	Pattern Matching
Specially designed computer simulation	✓	✓	✓	✓	✓	✓
Poker game		✓			✓	✓
Existing computer simulation/strategy game		✓			✓	✓
Written test		✓				
Concept maps		✓				✓
Systems Thinking Scale		✓				
Committee assessment rating	✓	✓		✓	✓	✓
Performing systems engineering		✓		✓	✓	✓

The Systems Thinking Game

- A novel method to evoke Systems Thinking skills
- Based on real-life systemic problems
- Contains classic embedded systems archetypes
- Built-in questions and decisions
- Built-in data collection



Assessment Rubric

Assessing and scoring the task

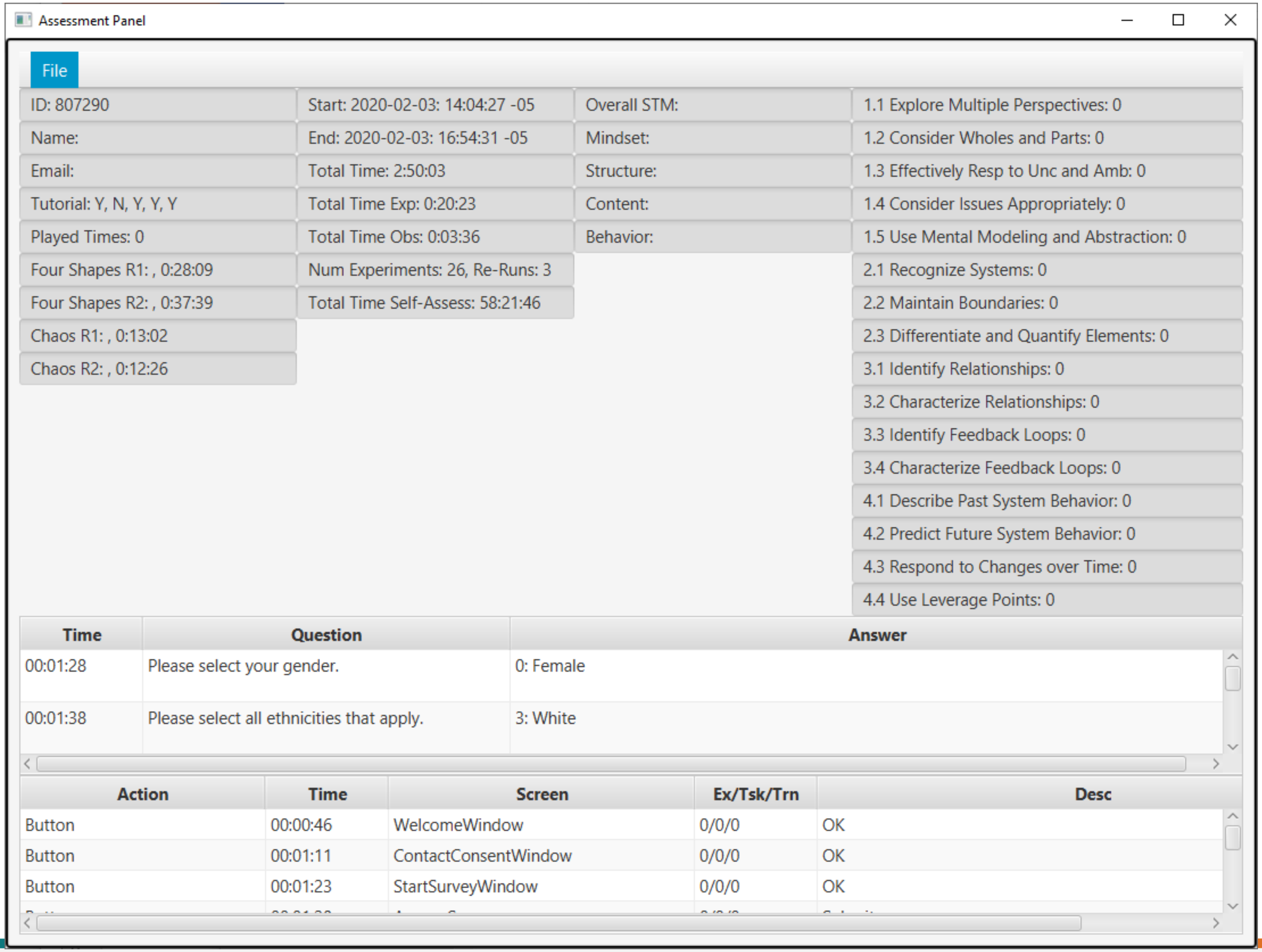
	1.2	1.4	2.2	2.3	3.1	3.2	3.3	3.4	4.4
dp1_rainAndGrowth_stg1()					1	1	1	1	1
dp1_rainAndGrowth_stg2()					1	1	1	1	1
dp2_stoppedSpikes_stg1()					1	1			
dp2_stoppedSpikes_stg2()					1	1			
dp3_ballSpikeRatio_stg1()					1	1	1	1	
dp3_ballSpikeRatio_stg2()					1	1	1	1	
dp5_scoreImproved_stg1()									
dp5_scoreImproved_stg2()									
dp7_clockwise()					1				
dp7_spinSpeedMaxWhileClockwise()						1			
dp8_paradigmCoop()					1				1
dp9_playAllFourShapes()		1							
dp10_playAllChaos()		1							
dp11_experiments()		1							
dp12_newExpChaos()		1							
dp13_changeAllExpVars()		1							
dp13_changeThreeExpVars()		1							
dp13_changeThreeOverallExpVars()		1							
dp13_changeThreeSpecificExpVars()		1							
dp13_changeAllExpVarsFirst()		1							
dp13_changeThreeExpVarsFirst()		1							
dp13_changeThreeOverallExpVarsFirst()		1							
dp13_changeThreeSpecificExpVarsFirst()		1							
dp14_orderGrowthVariable_stg1()									1
dp14_orderGrowthVariable_stg2()									1
dp14_orderParadigmVariable_stg2()									1
dp14_orderGravityWellLocationVariable_stg1()									1
dp14_orderGravityWellLocationVariable_stg2()									1
dp15_rateSpinDirOverType_stg1()									1
dp15_rateSpinDirOverType_stg2()									1
dp15_orderSpecificVariables_stg1()									1
dp15_orderSpecificVariables_stg2()									1
dp16_overallVarRating_stg1()									1
dp16_overallVarRating_stg2()									1

	1.2	1.4	2.2	2.3	3.1	3.2	3.3	3.4	4.4
Q16					1		1		
Q17				1					
Q18					1	1			
Q19							1	1	
Q20				1	1	1			
Q21					1	1			
Q22				1			1	1	
Q26							1		
Q27				1	1		1	1	
Q28-1				1	1				
Q28-2				1	1				
Q28-3				1	1				
Q28-4				1	1				
Q29				1					
Q30				1	1	1			
Q31-1			1		1				
Q31-2			1		1				
Q31-3			1		1				
Q31-4			1		1				
Q31-5			1		1				
Q32-1	1		1		1				
Q32-2	1		1		1				
Q32-3	1		1		1				

Automated Assessment

A novel method for Systems Thinking assessment

- Scoring is automated
  - Question Answers
  - Decision Points
  - Player Patterns
- Assessment Areas
  - Mindset (1/5)
  - Content (1/3)
  - Structure (4/4)
  - Behavior (1/4)



Limitations of Current Method

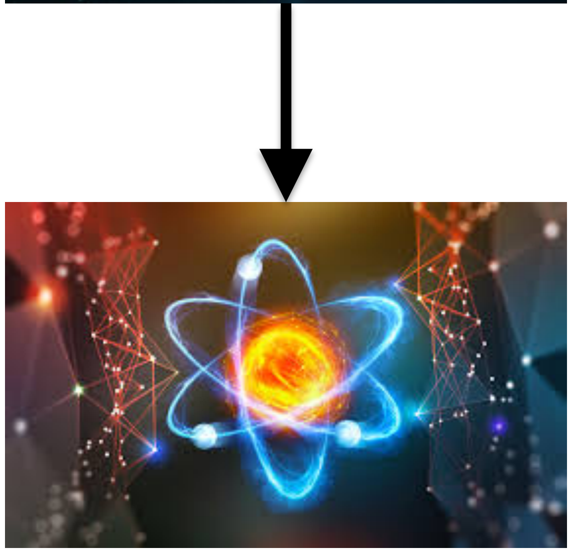
Method limited by necessity of human participants

- Scalability
  - Reached out to hundreds of participants
  - Only 20-30 completed the simulation
- Complexity of simulation
  - Takes too long; 1/3 of participants did not complete
  - Some did not “try their best”
- Generating new simulation physics
  - Replays cannot be compared between players because the system and tasks are the same
  - Game learning affects score

Neural Network to Generate Expert Patterns

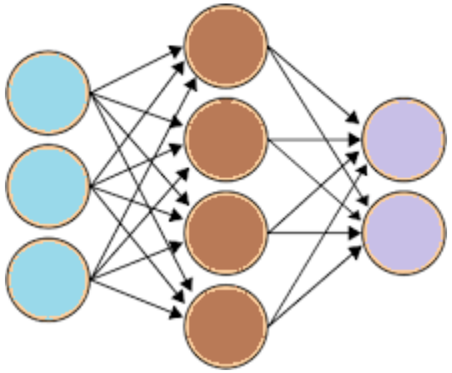
Intersection of AI and SE

- Imagine if the simulation physics varied/generated anew for each playthrough
  - Every replay requires a Systems Approach
  - Learning about the physics of the game would not help with replays
- Problem: How to generate expert patterns to compare results to?
- Solution 1: Consider using a neutral network to learn and play the simulation based on data generated from experts
- Solution 2: Use a genetic algorithm to find optimal ways to complete the game.
  - A human would need to review these to make sure they are things a person would reasonably do



Convolutional Neural Network

- CNNs often used for machine learning based on image and/or text
    - Patterns in data
- Translate the decision path of the game to text
- Use the text as training data for the CNN
- Other Neural Network methods may work as well

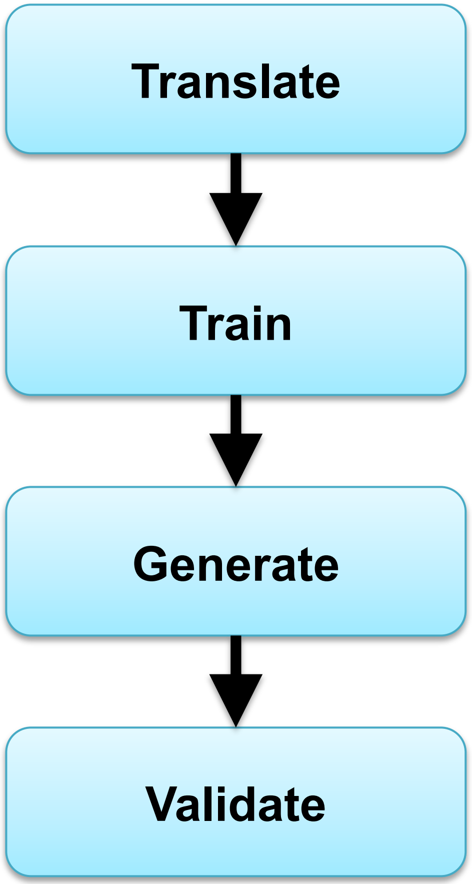


Suggestions?

Steps for Implementing CNN Approach

- Translate existing expert Systems Thinking simulation patterns from human players to text format
- Train CNN using this data
  - Issue – data volume is limited
- Present CNN with new, different variations of the simulation
  - Constants such as simulation physics could be altered, but general gameplay kept the same
- Automatically generate optimal solutions to the simulation tasks
- Validate the solutions through human investigation / rating

Through this method, a CNN could be used as a way to generate expert thinker patterns to which human player patterns could be compared and assessed.



Benefits of CNN Approach

- Highly scalable
  - Significantly reduce the number of human participants required
- Generate new simulation physics randomly
- Infinite different simulation tasks under a similar user interface
- New tests could investigate Systems Thinking ability independently from user interface or “game knowledge”
- Addresses many limitations of current approach

Issues with CNN Approach

Risks and roadblocks

1. **Data volume**
   - Currently we don't have a large number of responses to use as training data
2. NN selection
   - Which type machine learning strategy might be best?
3. Initially, results require human review
   - Subjective; will CNN-generated patterns actually reflect the use of good Systems Thinking skills?

May be a future activity due to data volume limitations; need to accumulate more data

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