



Michael Cerny Green

Automated Video Game Tutorial Generation

Committee Members

- Professor Julian Togelius, NYU
- Professor Gillian Smith, WPI
- Professor Andy Nealen, USC
- Professor Michael Mateas, UCSC

Thesis Statement



“We can automatically generate tutorials and tutorial levels for video games using mechanics and play personas.”

What is a Tutorial?



1. PRECAUTIONS

- 1) This is a high precision game. It should not be stored in places that are very hot or cold. Never hit or drop it. Do not take it apart.
- 2) Avoid touching the connectors, do not get them wet or dirty. Doing so may damage the game.
- 3) Do not clean with benzene, paint thinner, alcohol or other such solvents.

Note: In the interest of product improvement, Nintendo Entertainment System specifications and design are subject to change without prior notice.

This game has been programmed to take advantage of the full screen. Some older model T.V.'s have rounded screens and may block out a portion of the image.

2. NAMES OF CONTROLLER PARTS AND OPERATING INSTRUCTIONS

Controller 1/ Controller 2 *Controller 1 — for 1 player game
*Controller 2 — for second player in 2 player game

+Control Pad moves Mario (Luigi):

Control Pad B button A button START button SELECT button

Walk to the right. (Push button B at the same time to run.) Crouch. (Super Mario only.) Walk to the left. (Push button B at the same time to run.)

???

SUPER MARIO BROS.

A button
Jump Mario (Luigi) jumps higher if you hold the button down longer.
&
Swim When you're in the water, each press of this button makes you bob up.
"Don't get too lazy about swimming or you'll get pulled under by the whirlpool at the bottom of the screen."

B button
Accelerate ... Press this button to speed up, then jump and you can go all the higher.
&
Fireballs..... After you pick up the fire flower, you can use this button to throw fireballs.

SELECT button

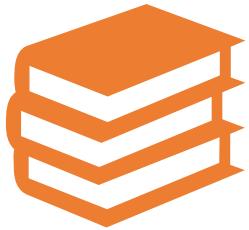
Use this button to move the mushroom mark to the game you wish to play.



Game Mechanic (n.):

Any event in the game that involves game entities and changes the game's state.

Types of Tutorials



Instructions



Demonstrations



Interactive
Experiences

ADVISOR

Your Excellency, I feel it is time to build some Neighborhoods for our growing populous. We should build these on our most beautiful lands - near natural wonders, or perhaps by the Coast.

OK

Tell me more



Instructions

- Text-based
- Advice/explanation

Demonstrations

- NPC in control
- Visualize player actions

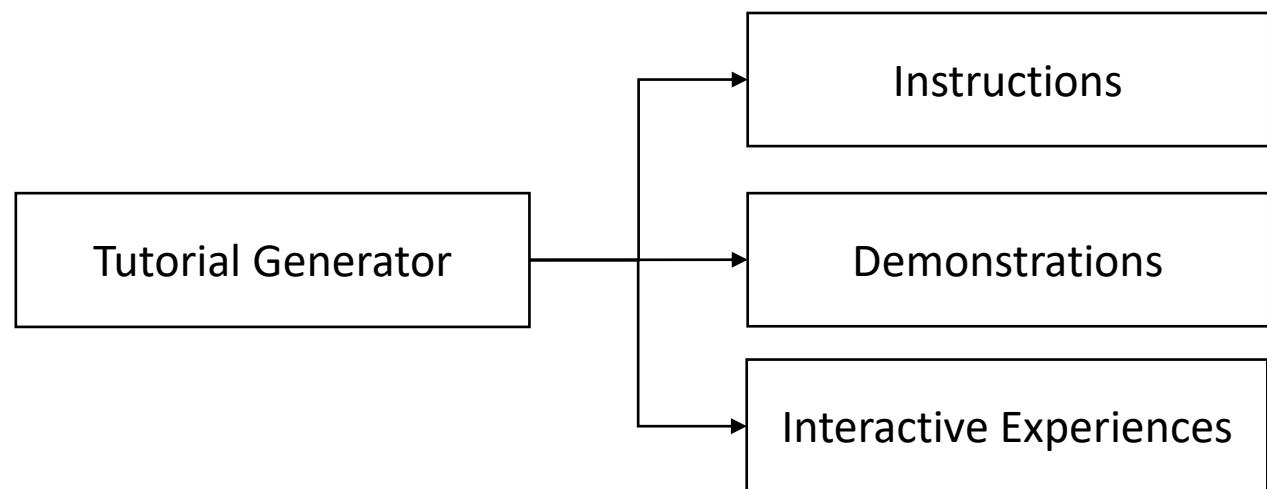


Interactive Experiences

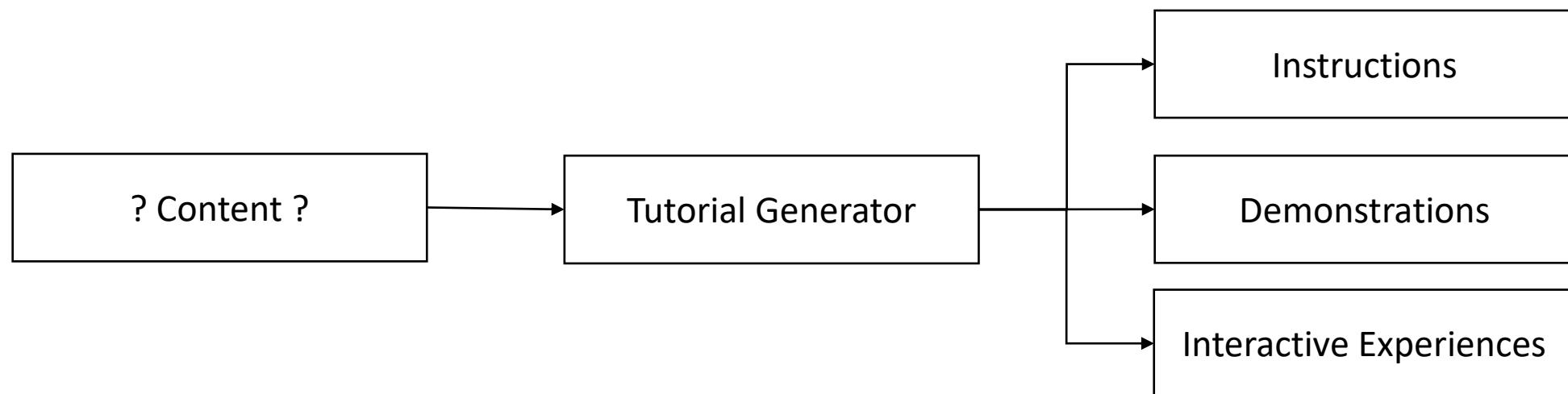
- Levels/Challenges
- Teach a skill
- Allow practice opportunities



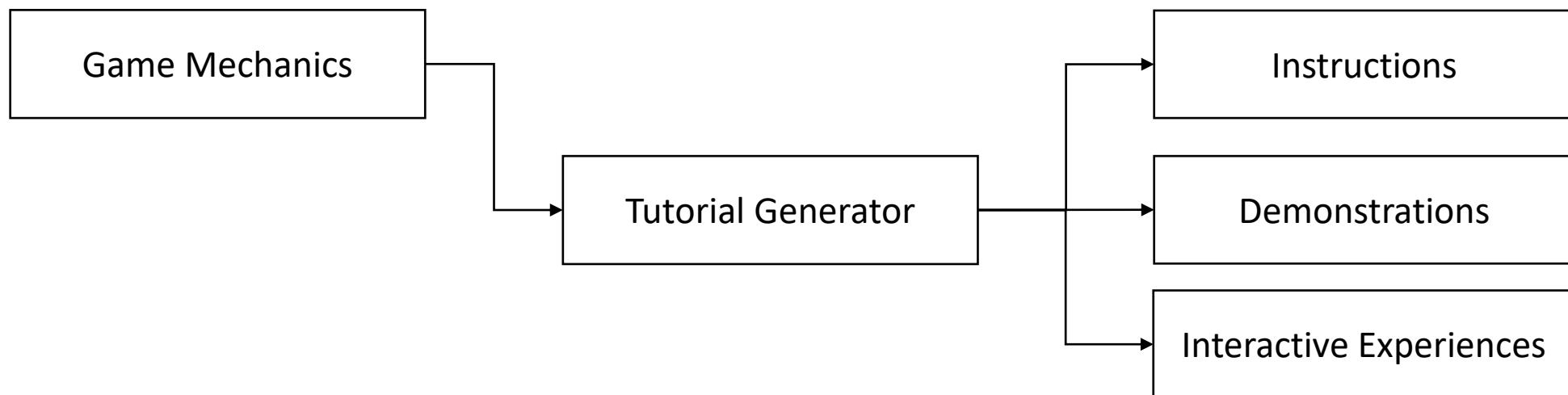
Tutorial Generation



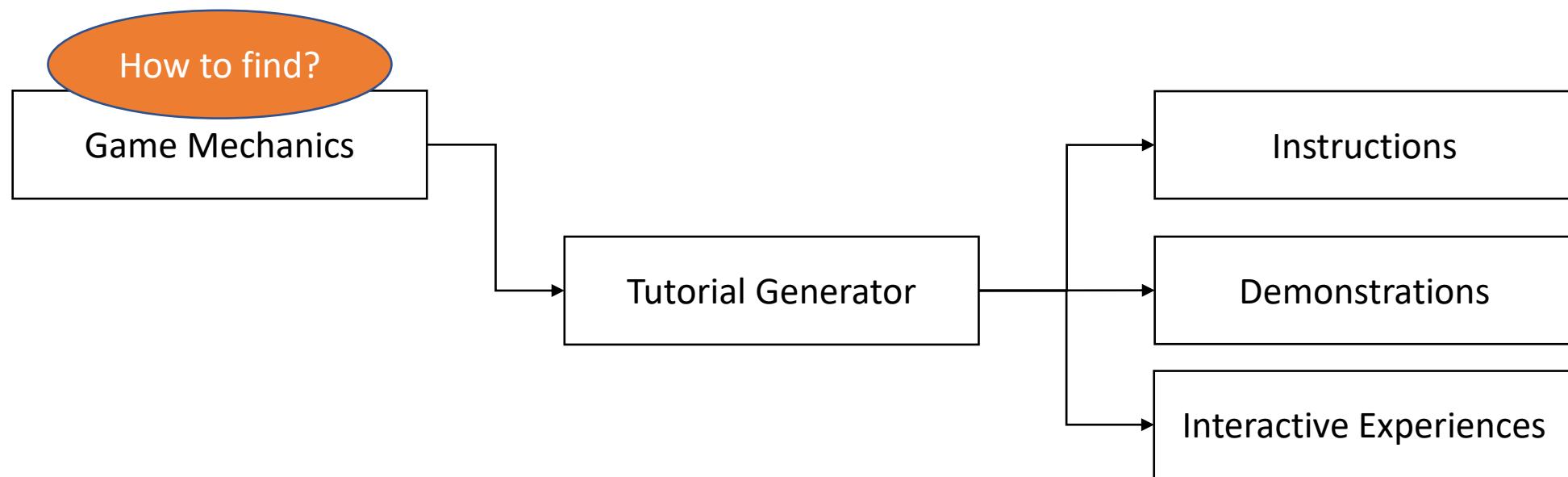
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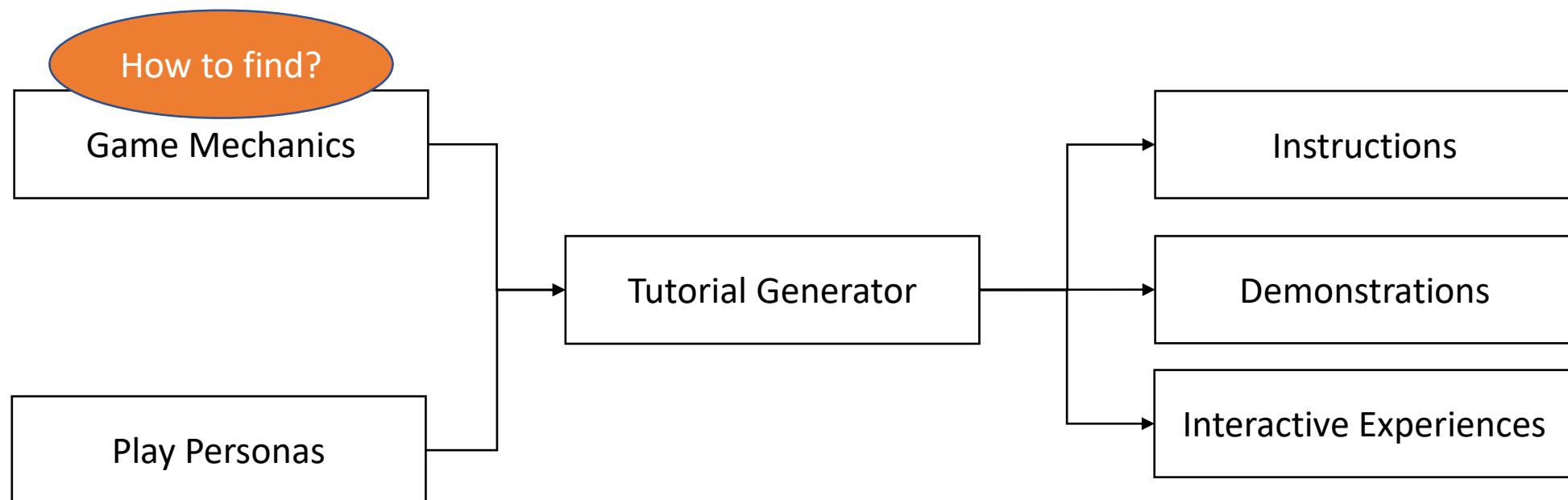
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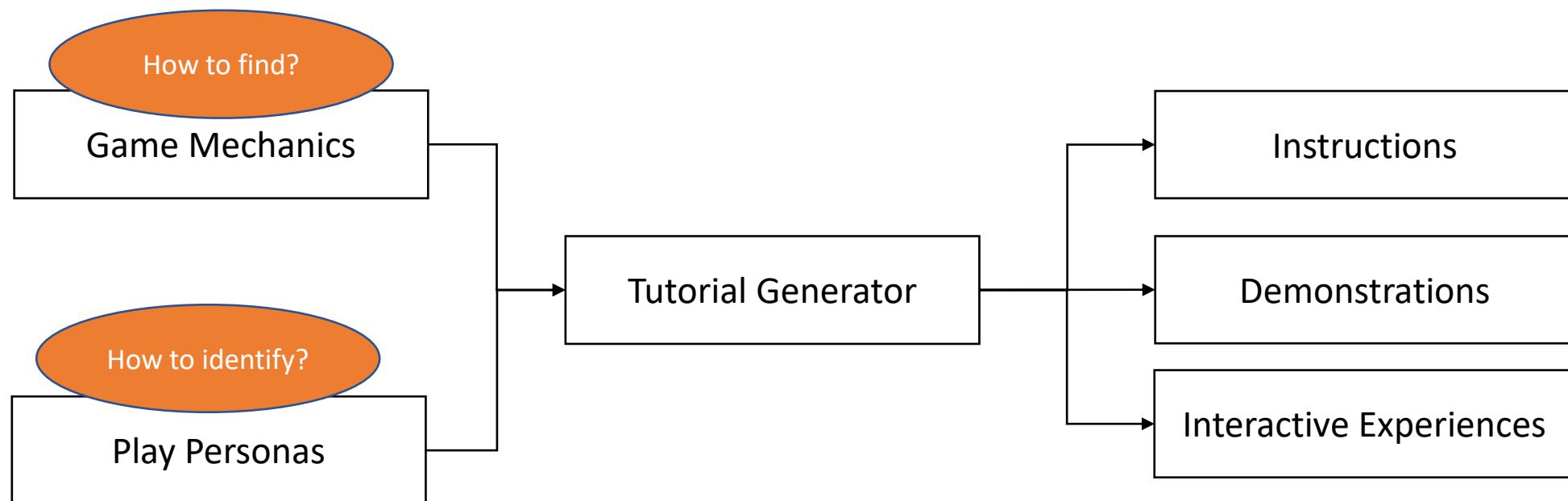
Tutorial Generation



Tutorial Generation



Tutorial Generation



Thesis Contributions



Mechanic Graphs & Critical Mechanic Discovery

A theory of Game Mechanic Alignment

A System for Tutorial Card Generation

Techniques for Tutorial Level Generation using
Mechanics and Procedural Personas

Play Persona Classification

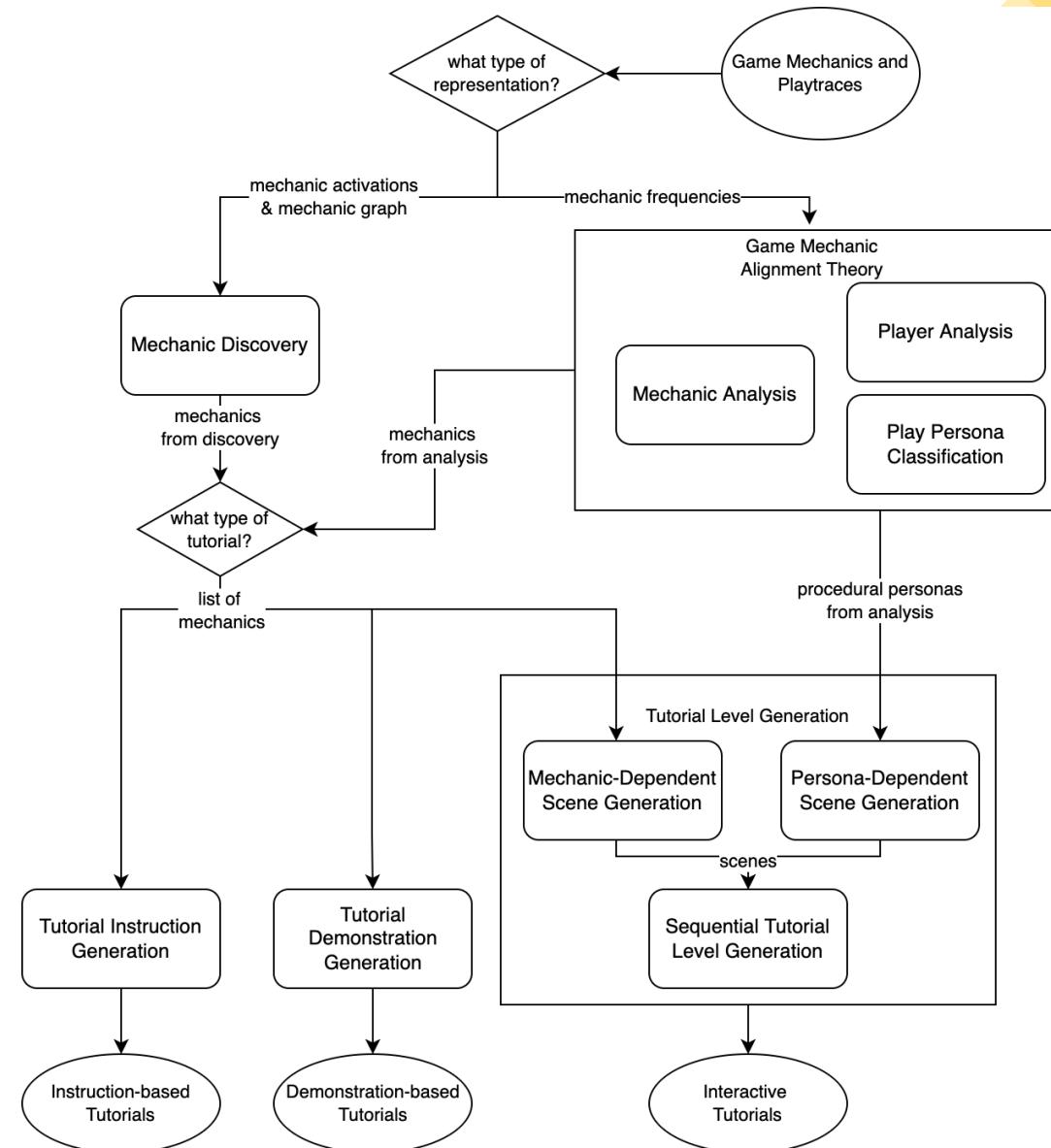
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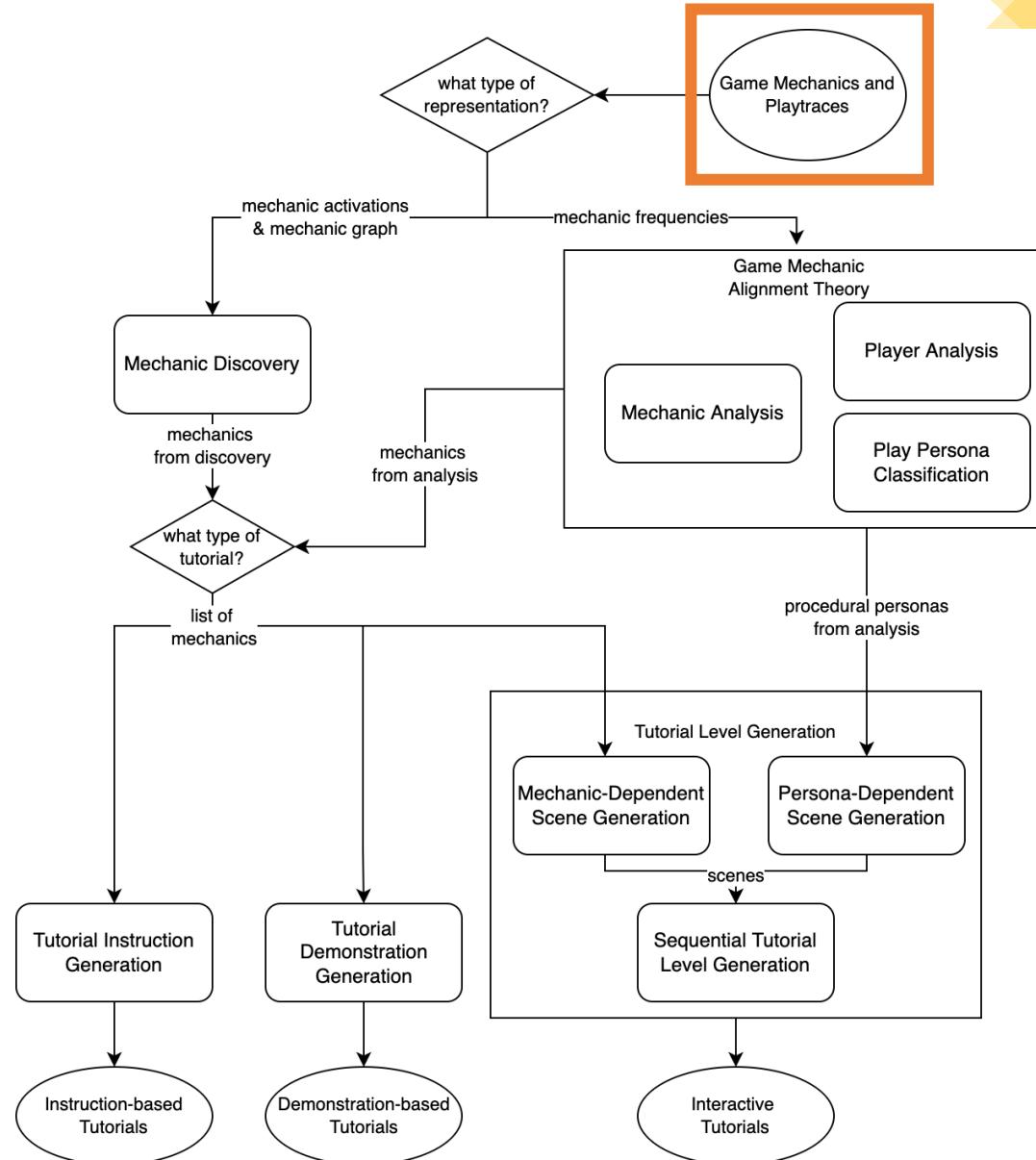
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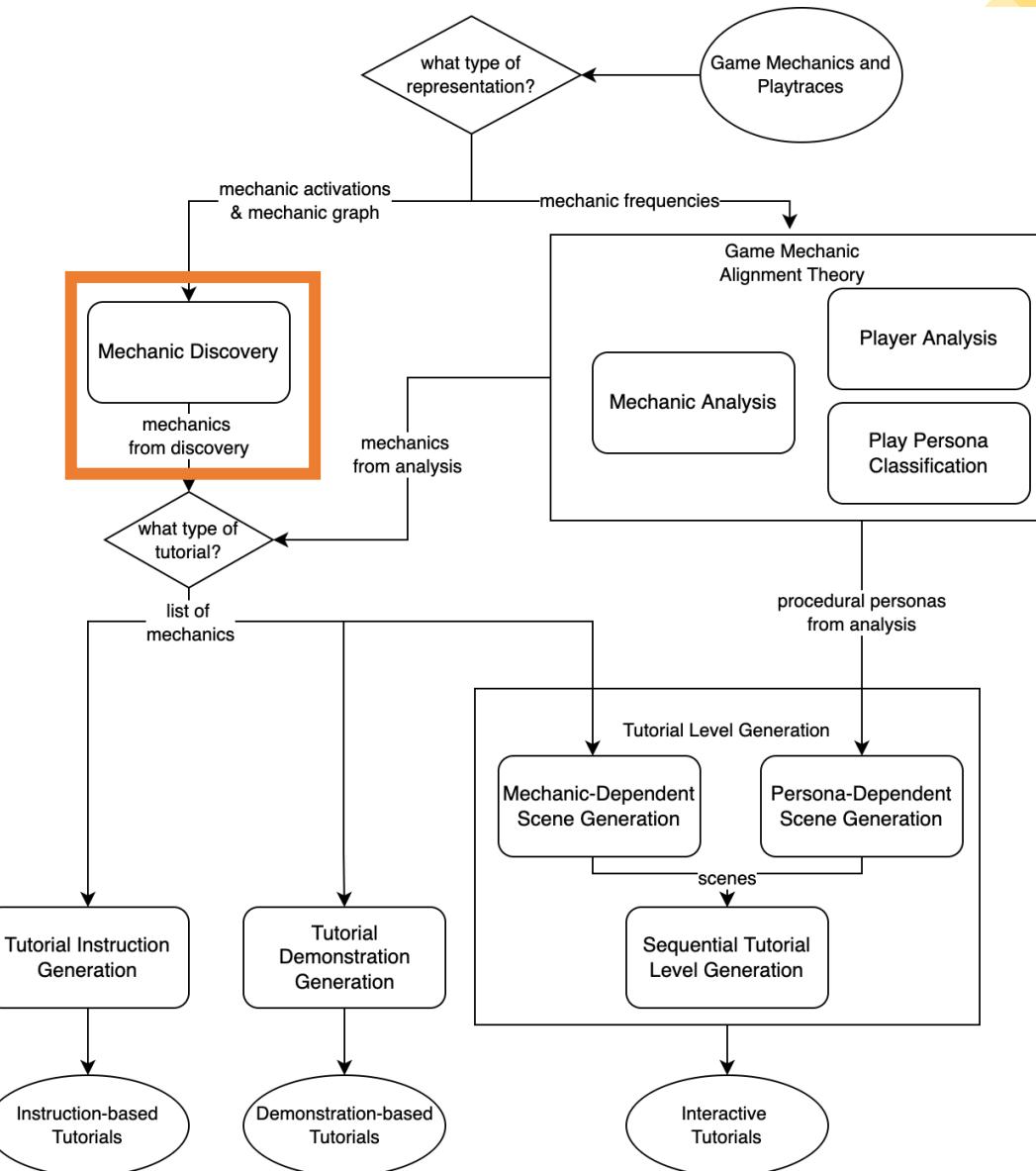
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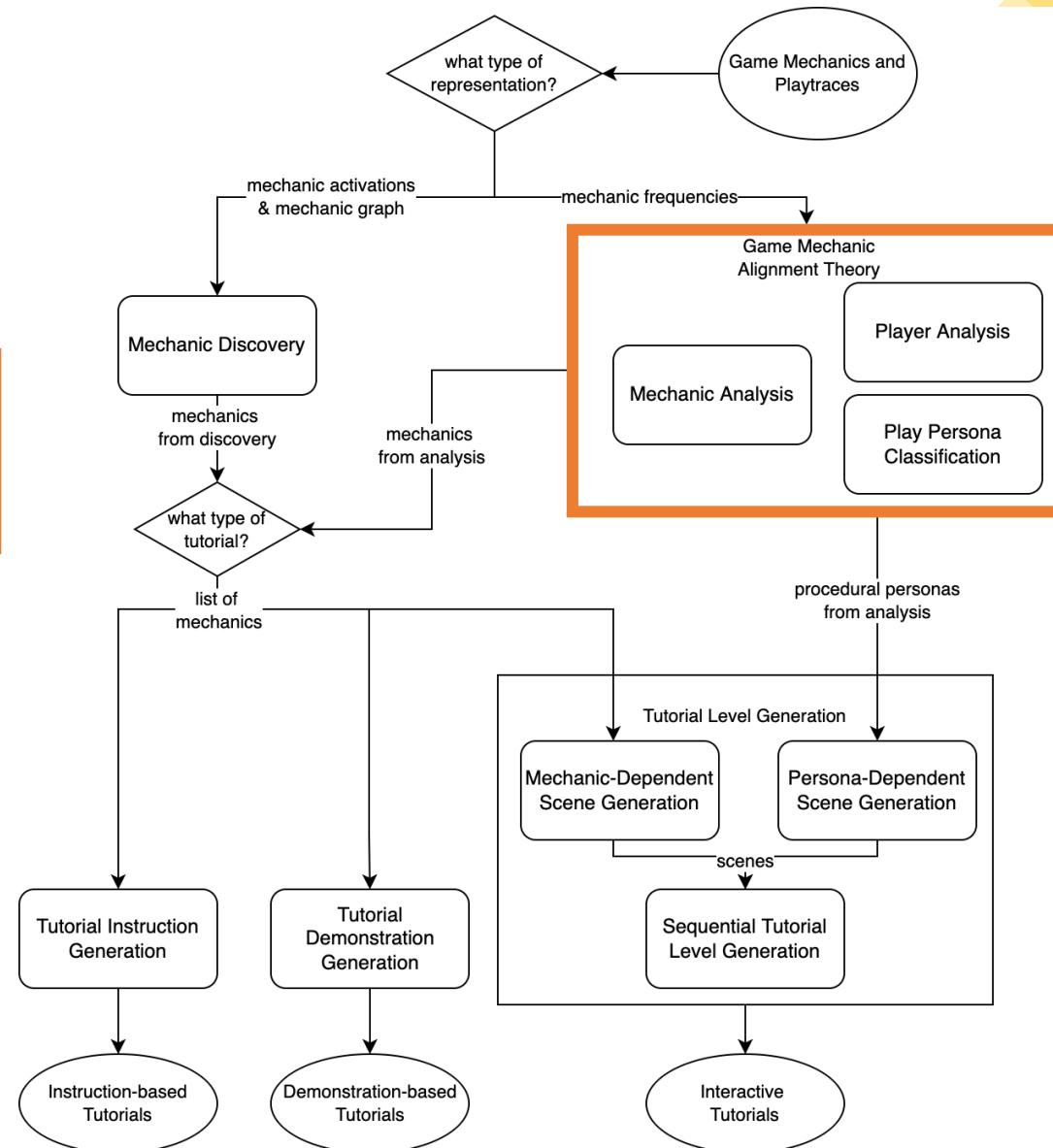
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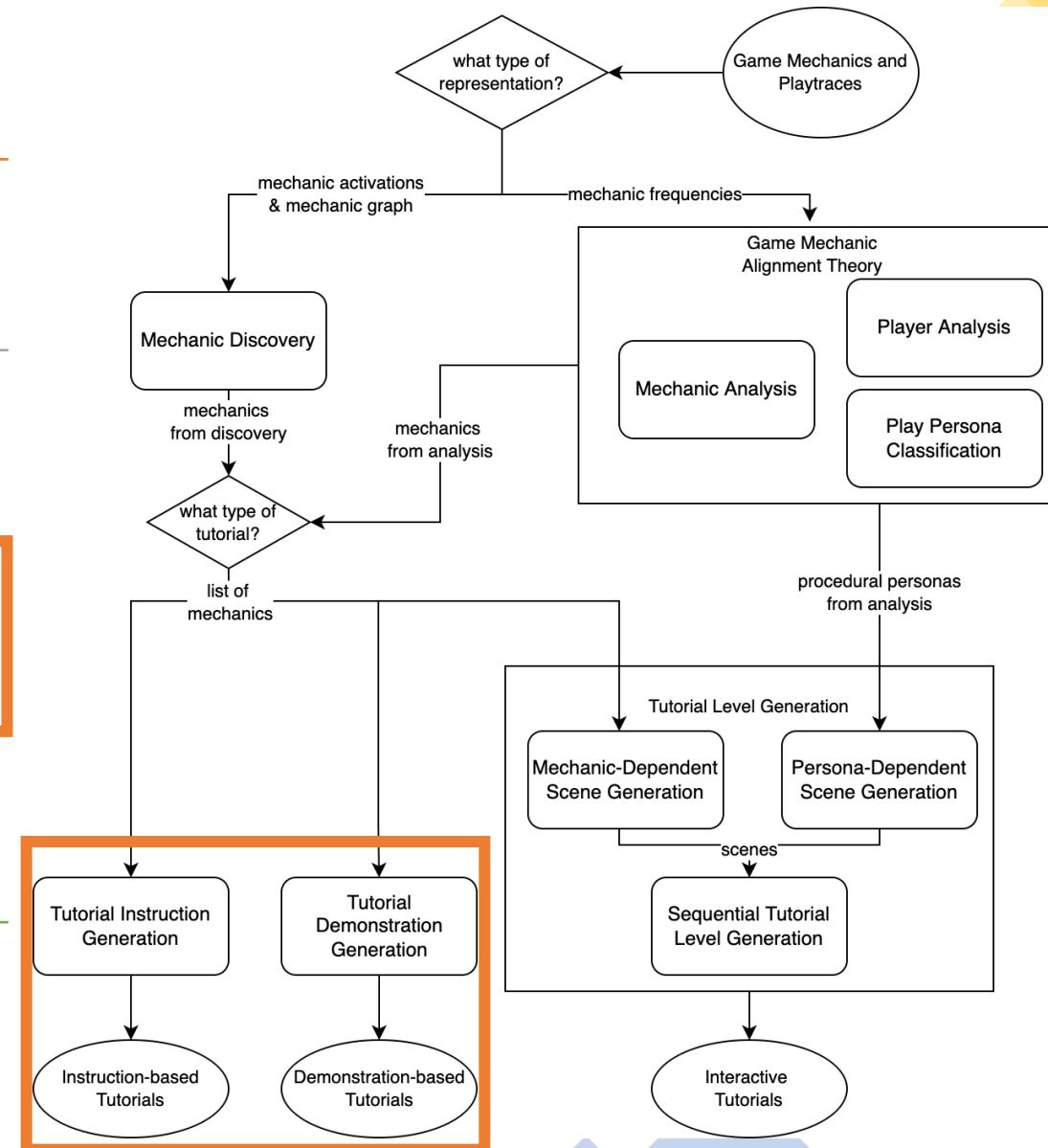
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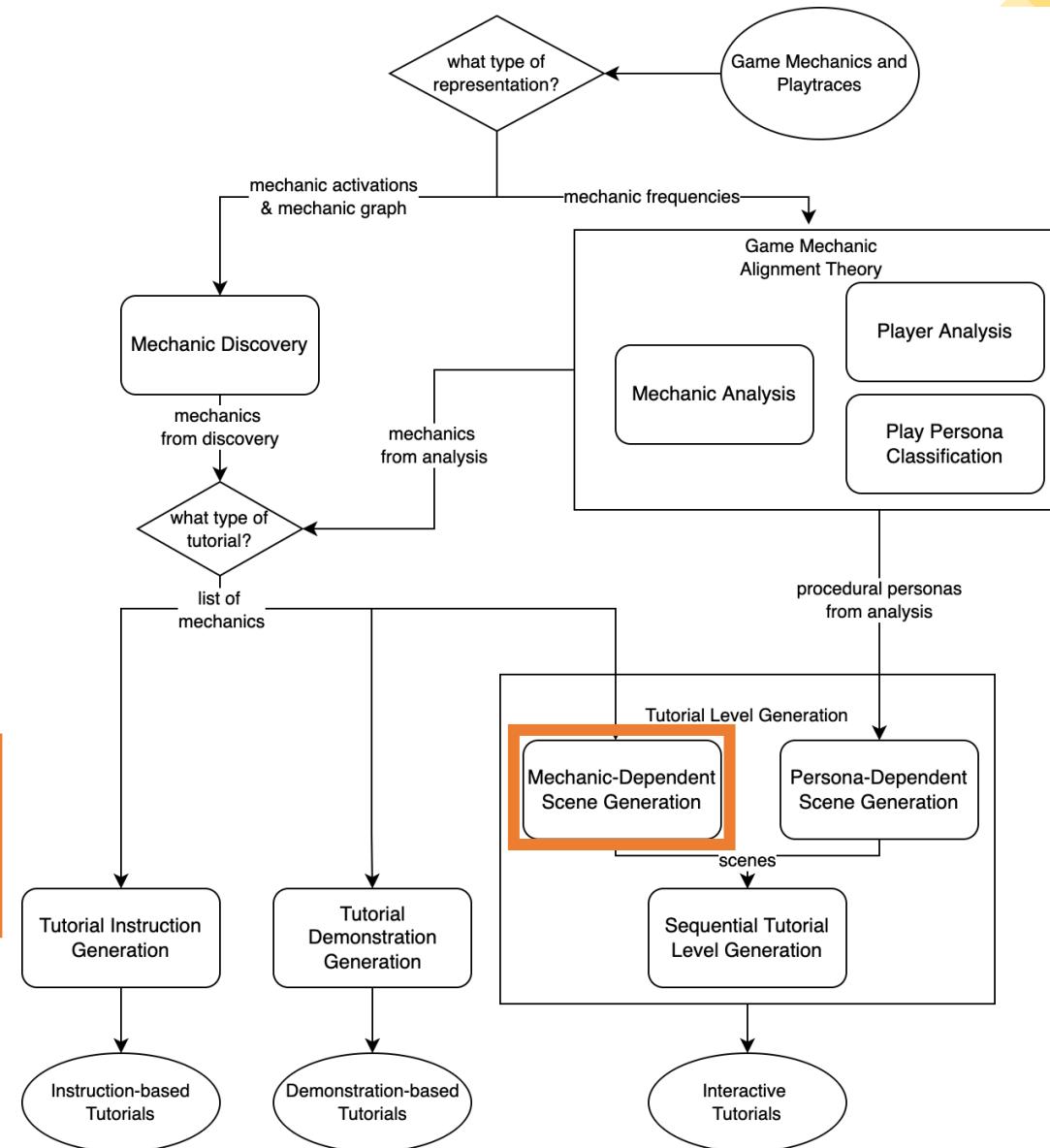
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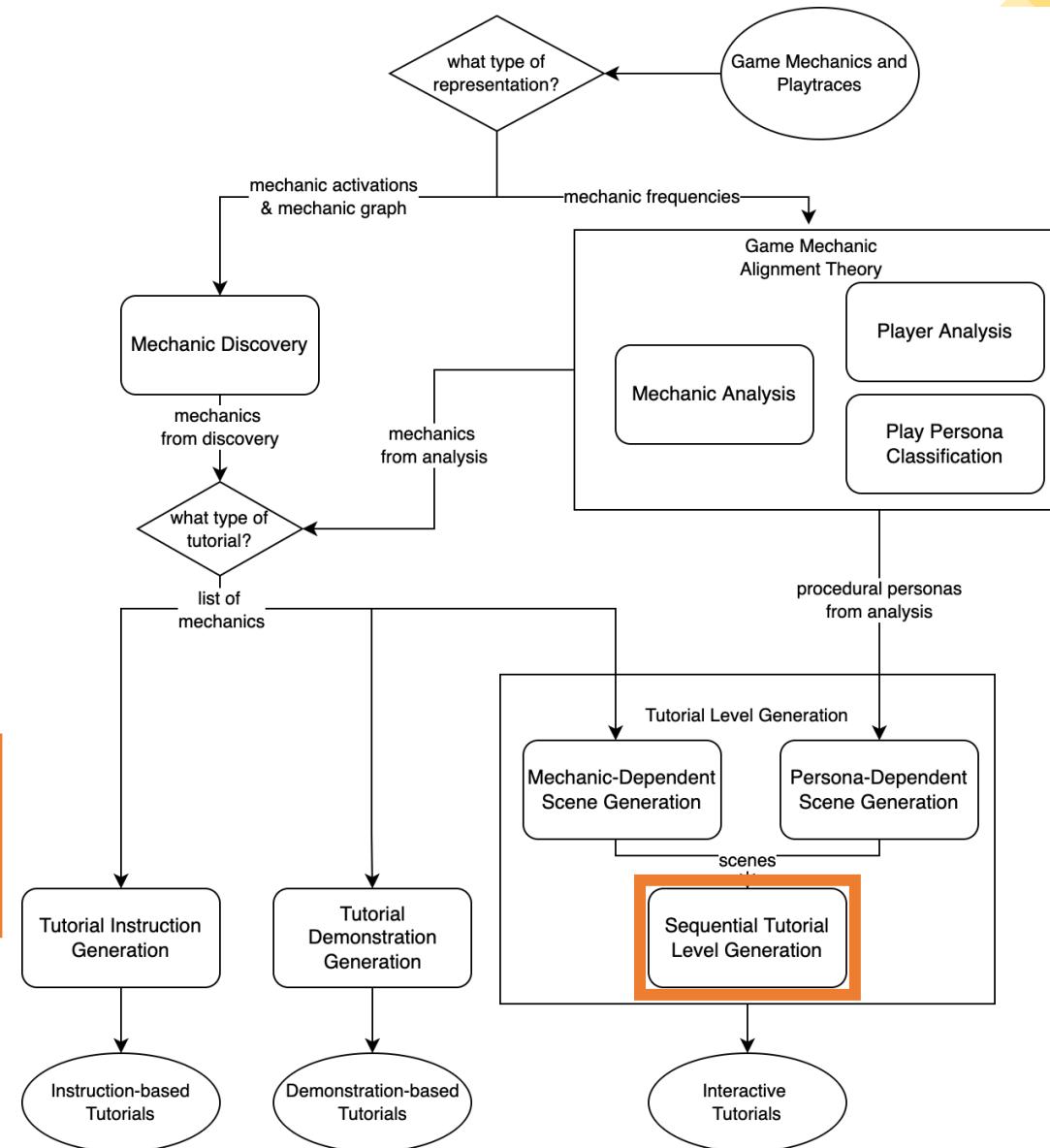
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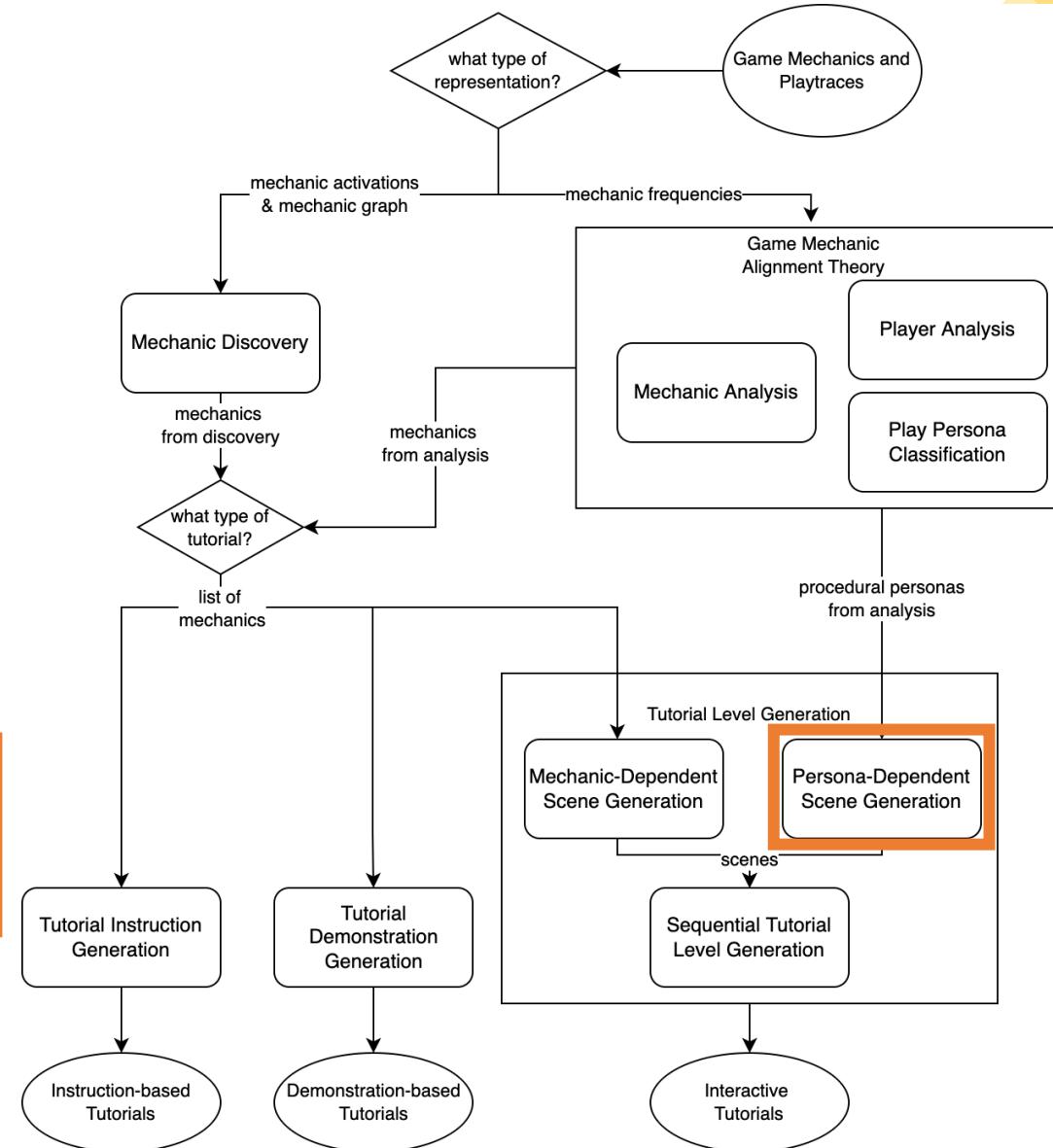
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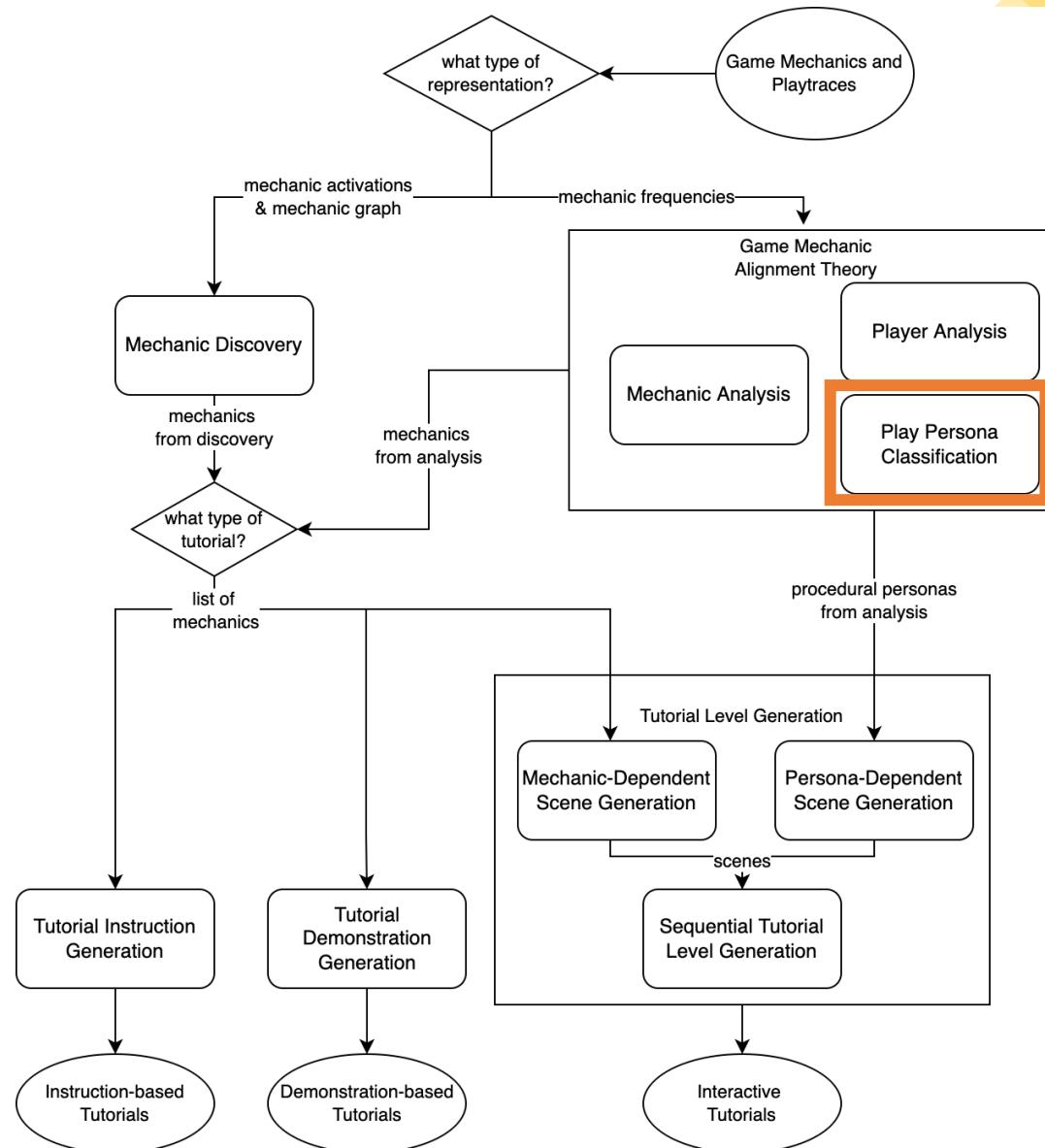
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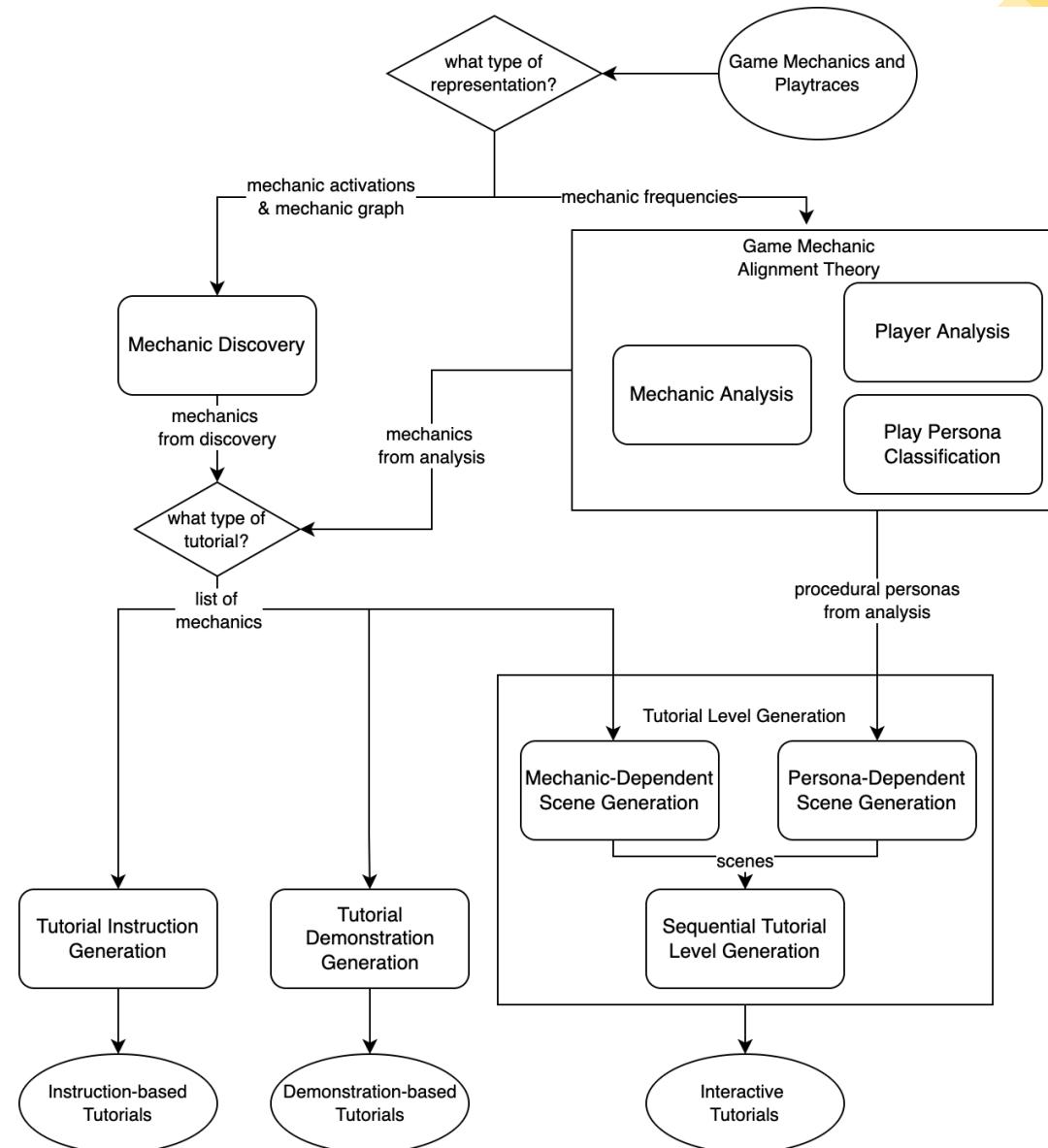
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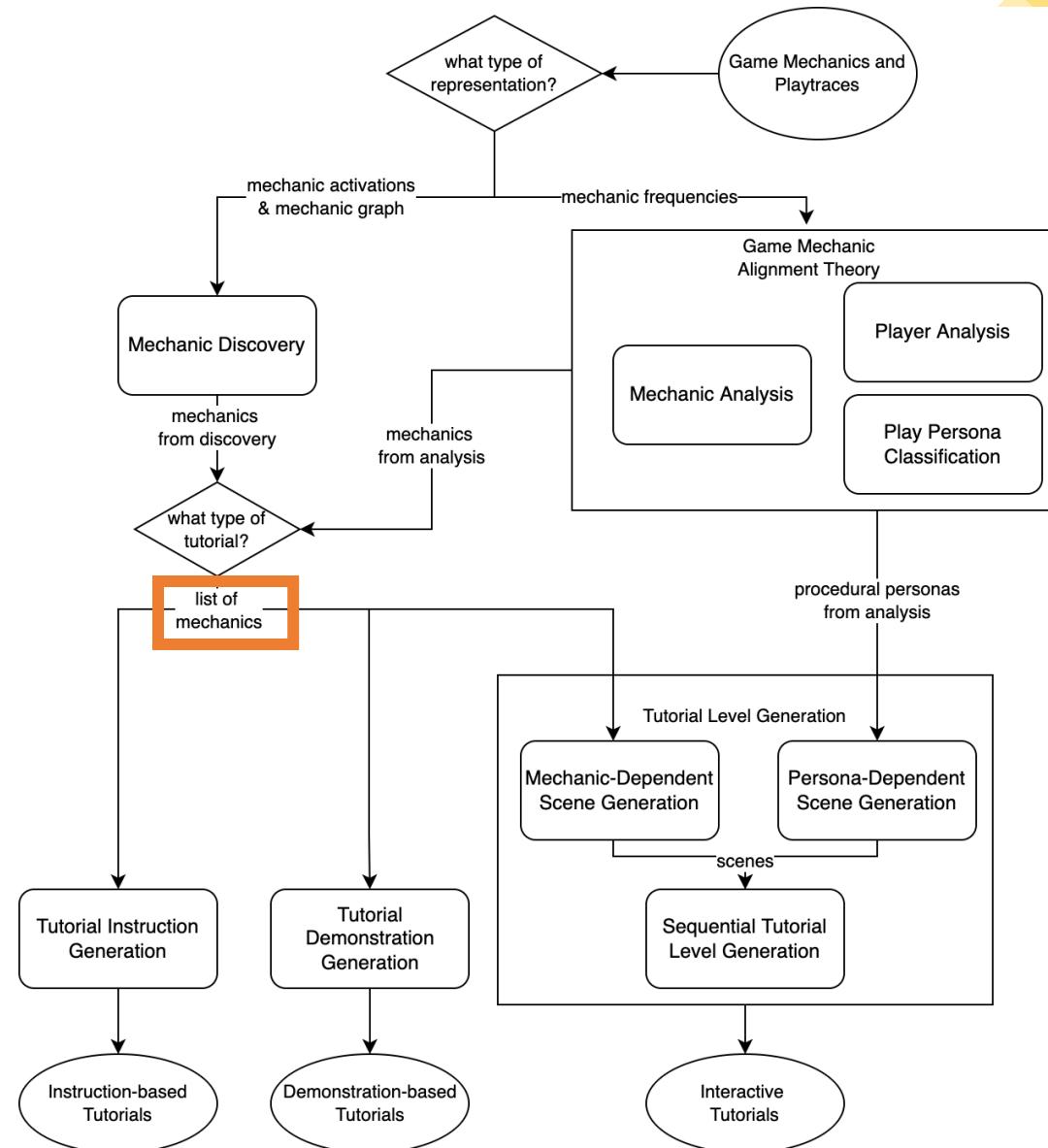
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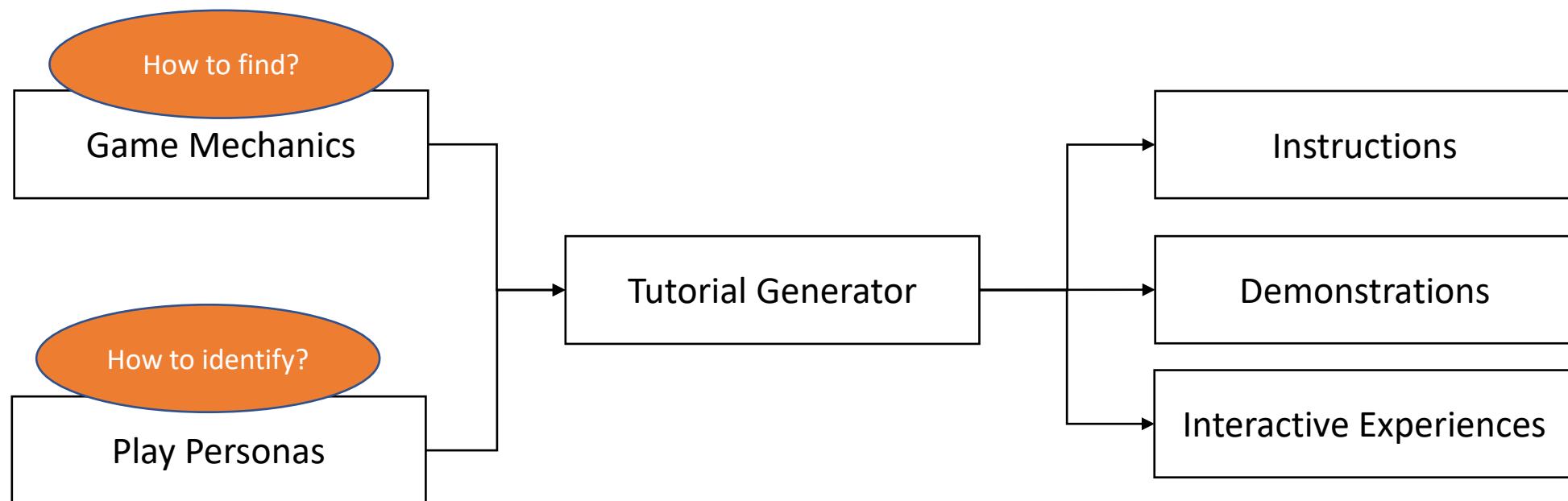
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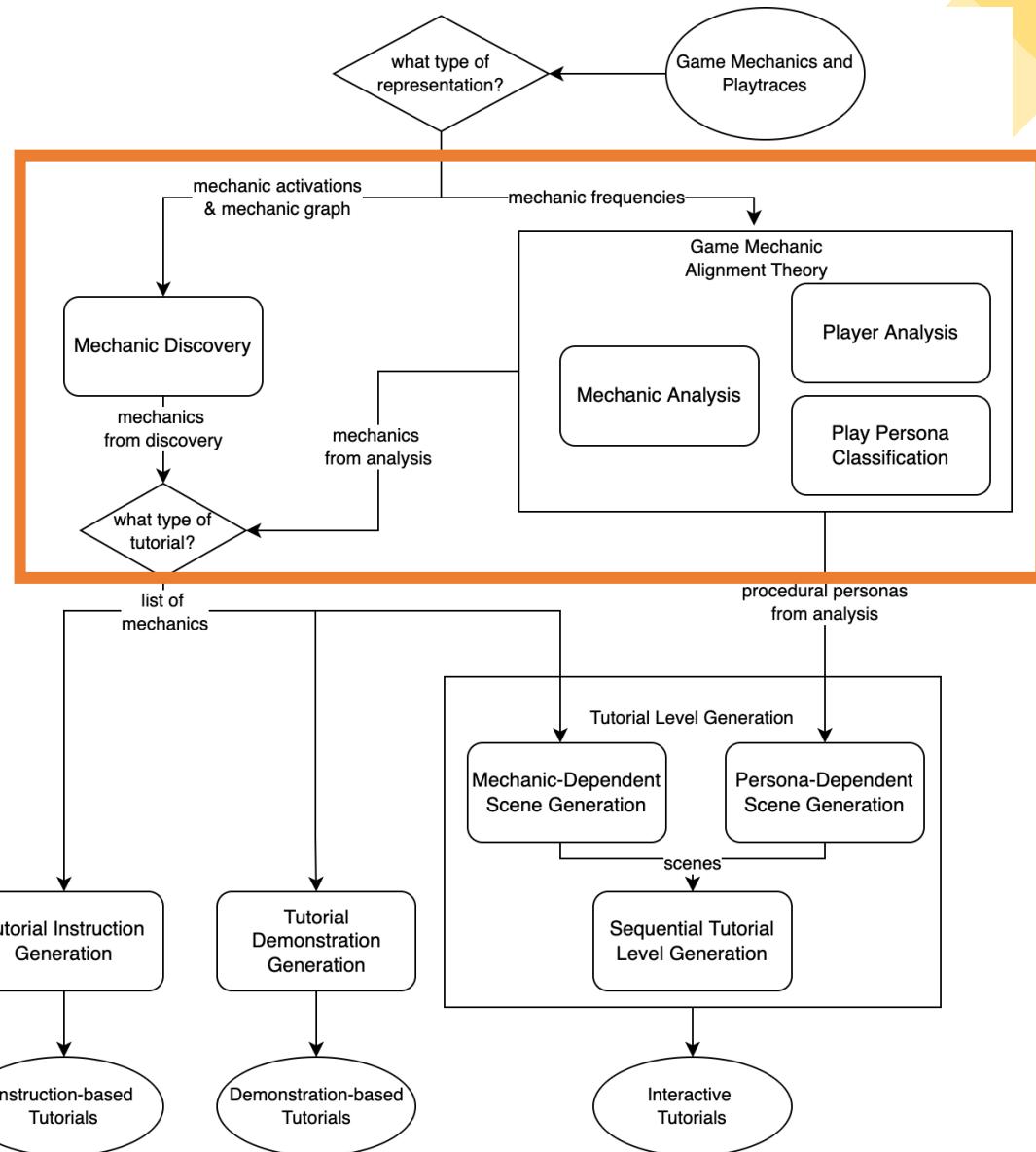
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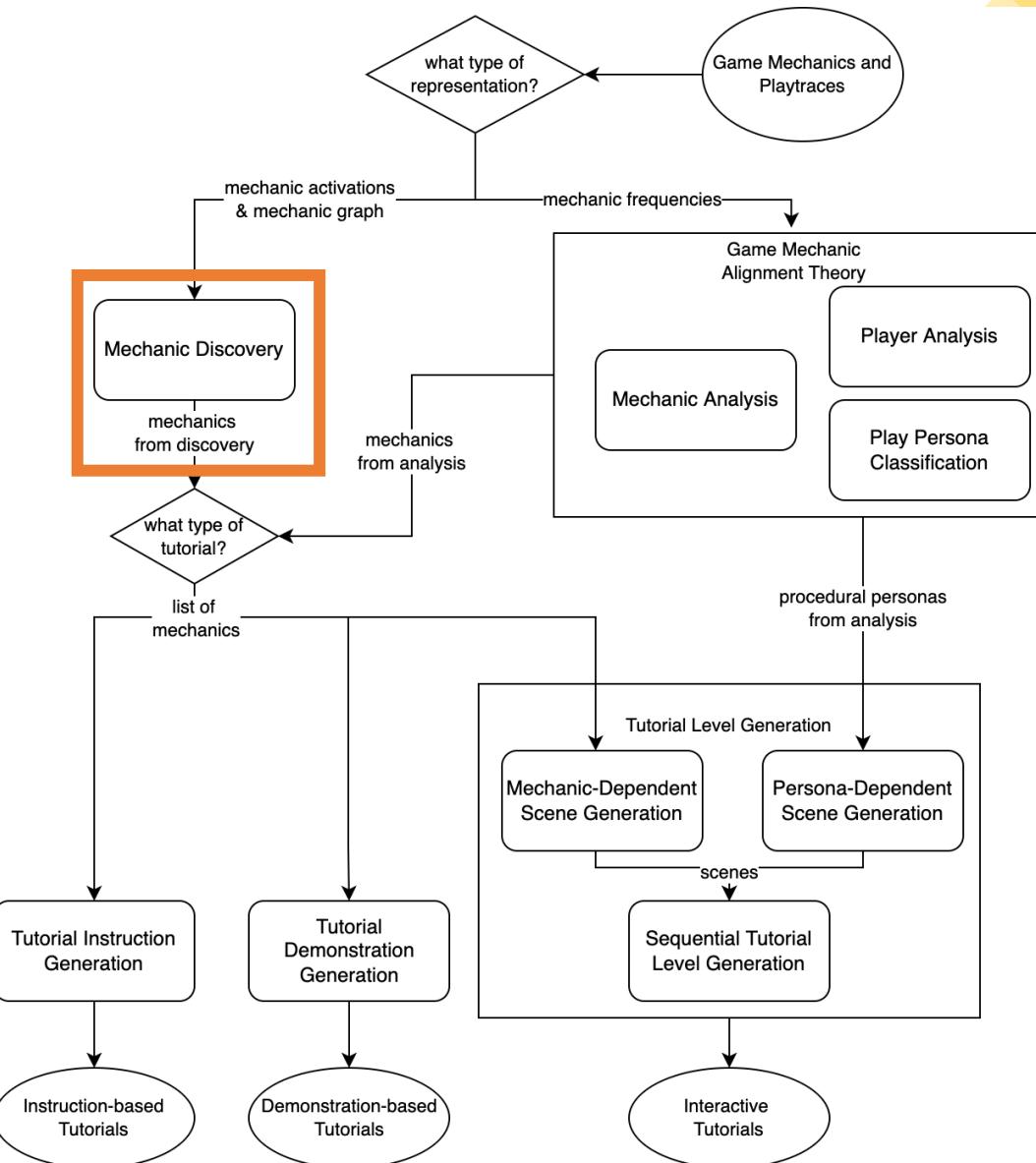
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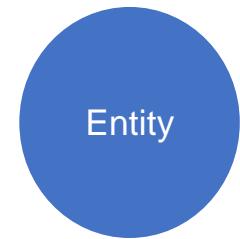
Any event in the game that involves game entities and changes the game's state.

What makes a mechanic *critical*

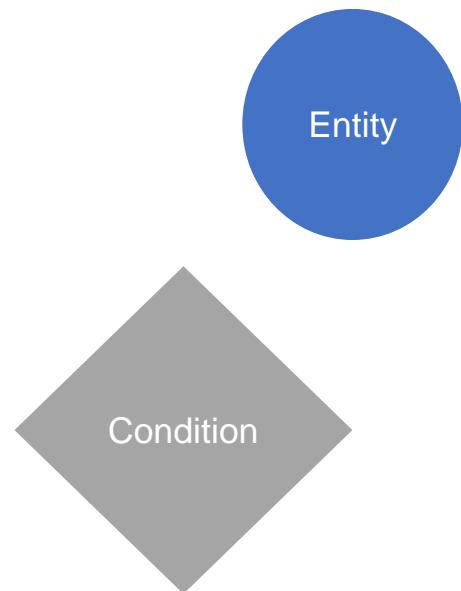
Must be triggered
to win the level

Every winning
playthrough will
contain the set of
critical mechanics

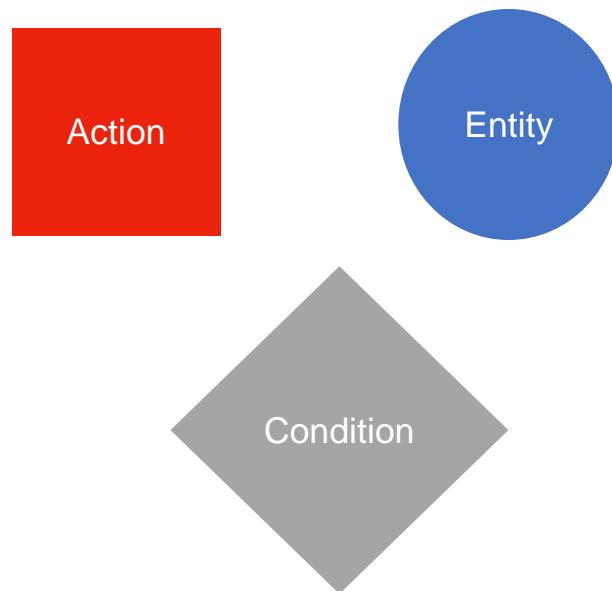
Atomic Interaction Graph



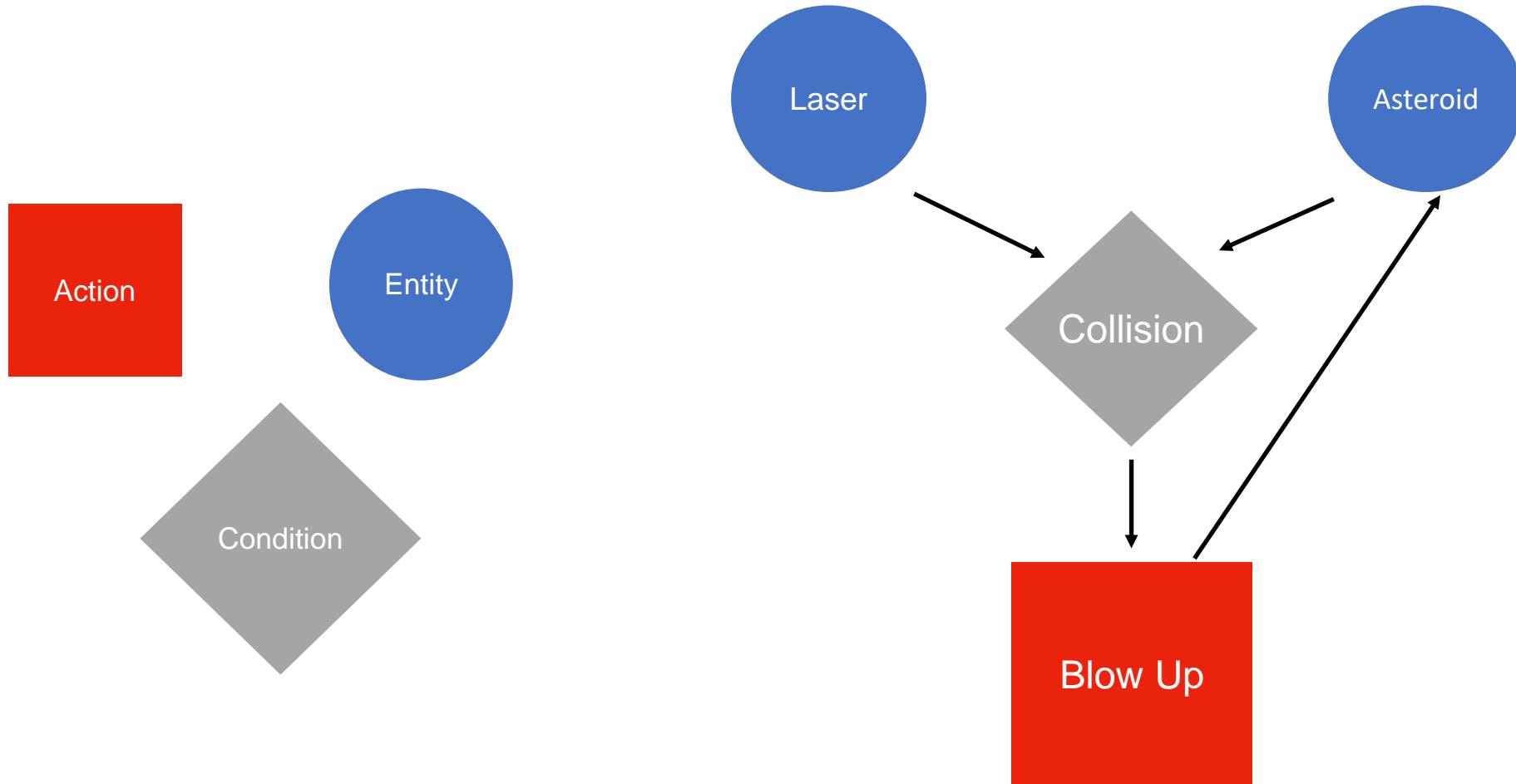
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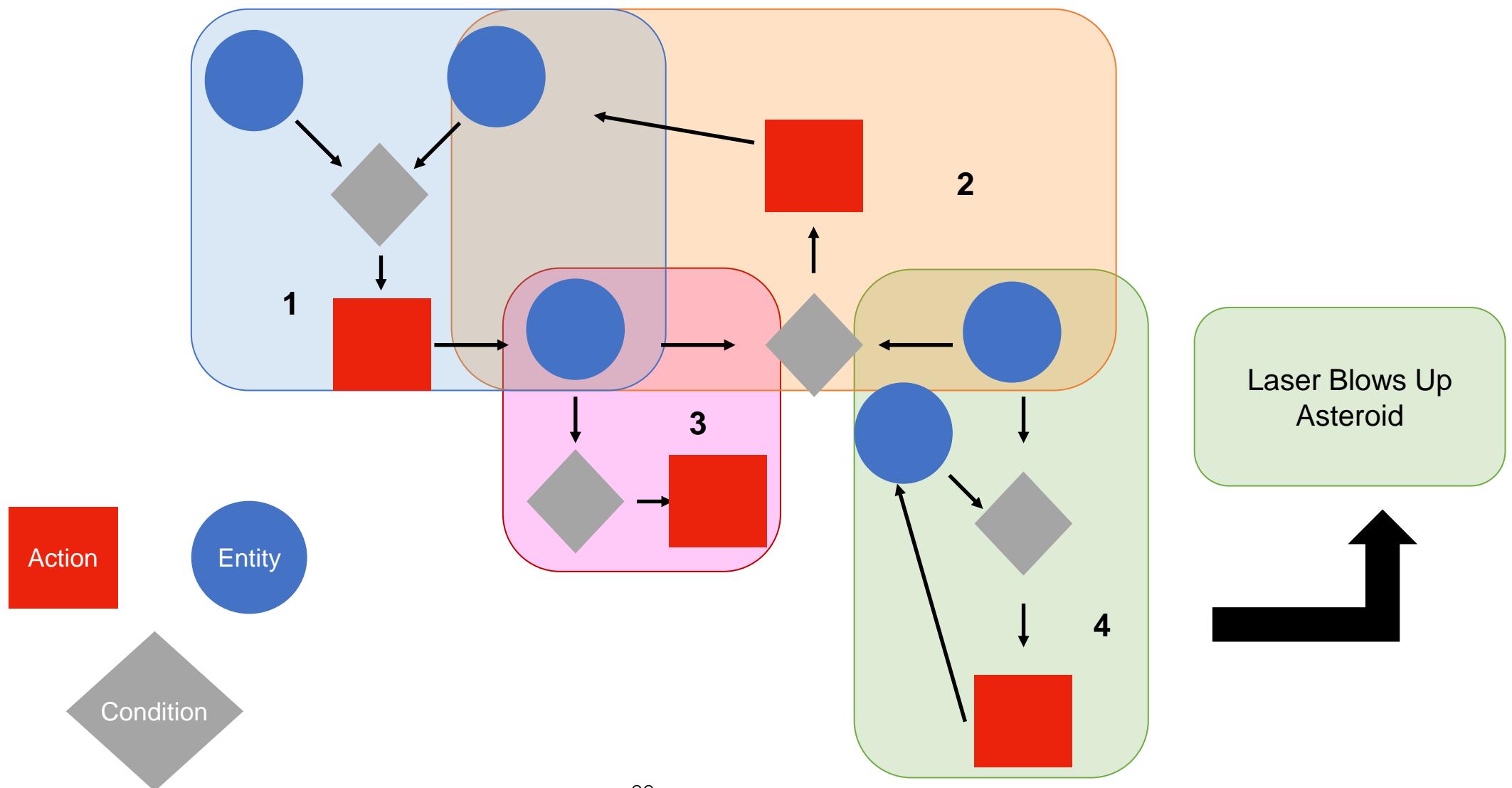
Atomic Interaction Graph



Atomic Interaction Graph



A Directed Mechanic Graph



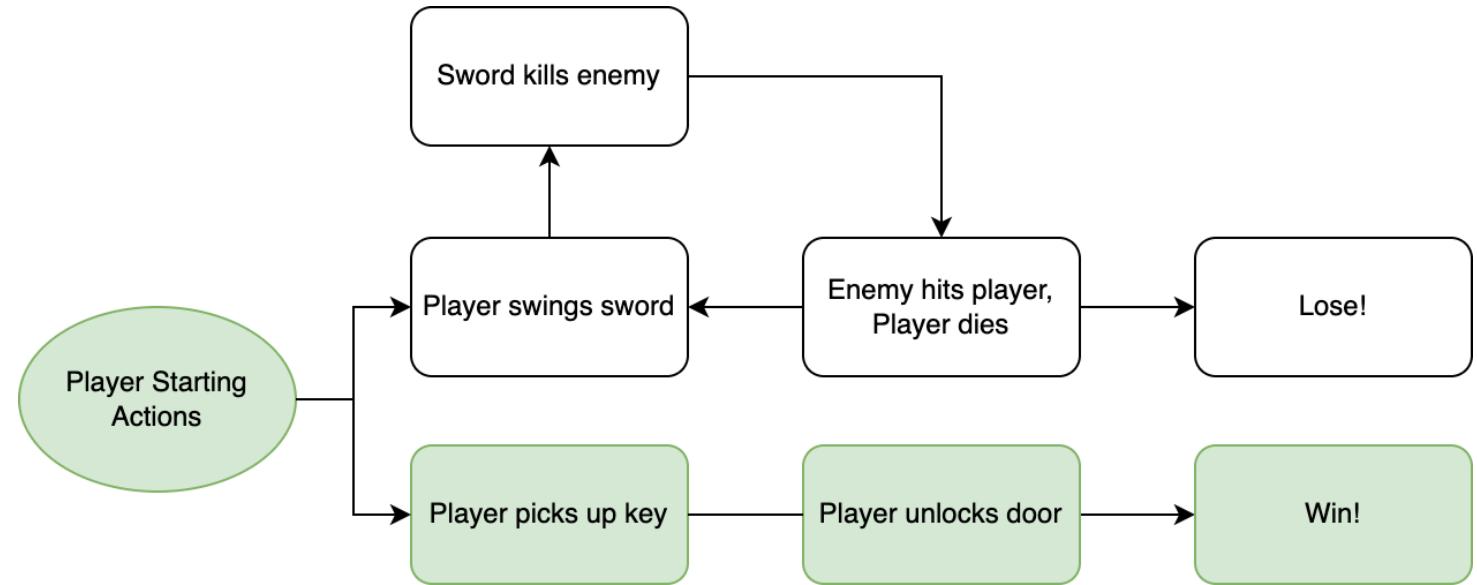
Searching for Critical Mechanics

1. Start from the mechanics a player can trigger
directly
2. ???
3. Critical Mechanics Found!



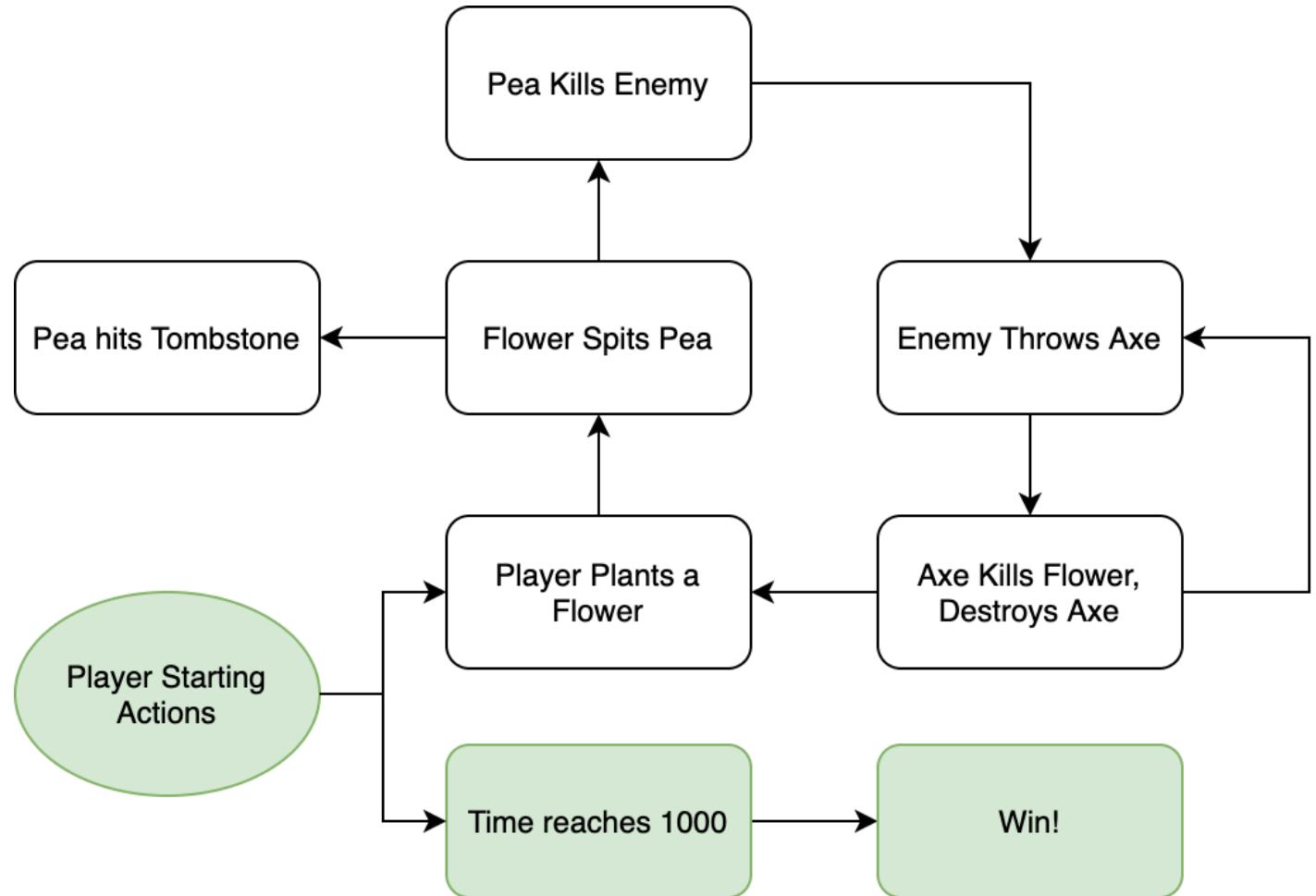
Uninformed Discovery

Zelda

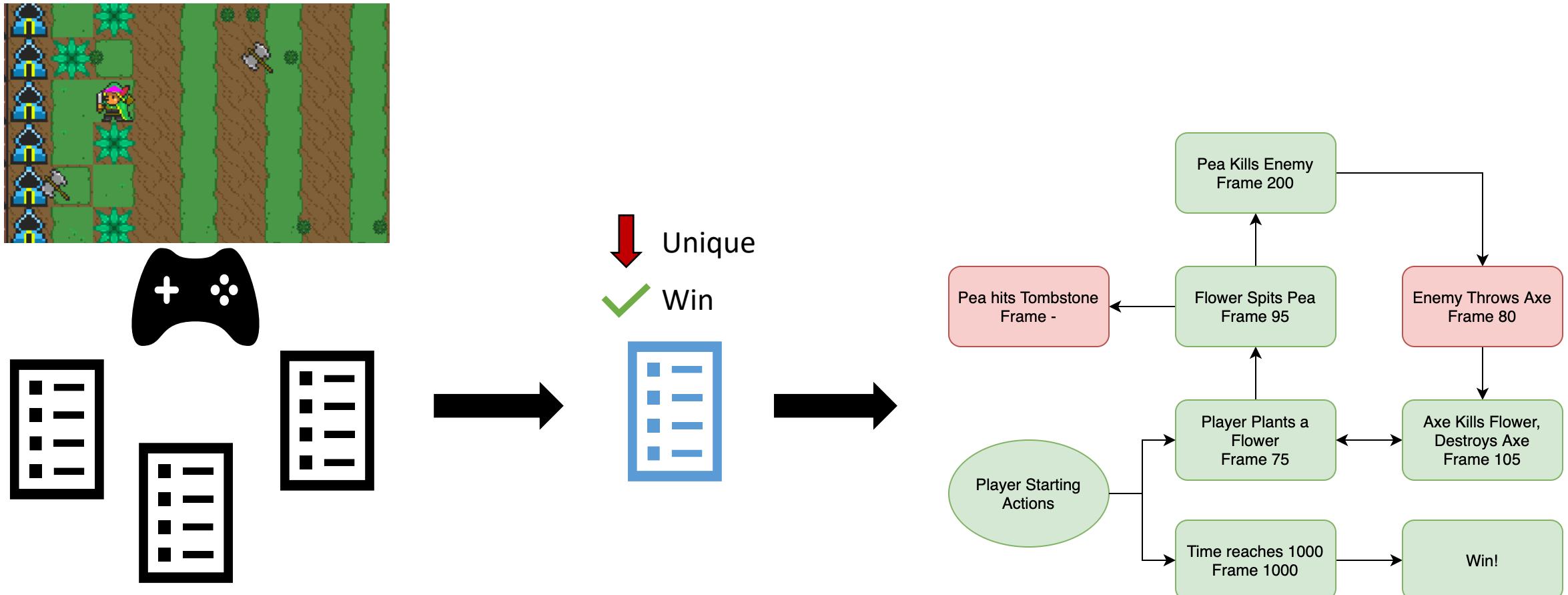


Uninformed
Discovery

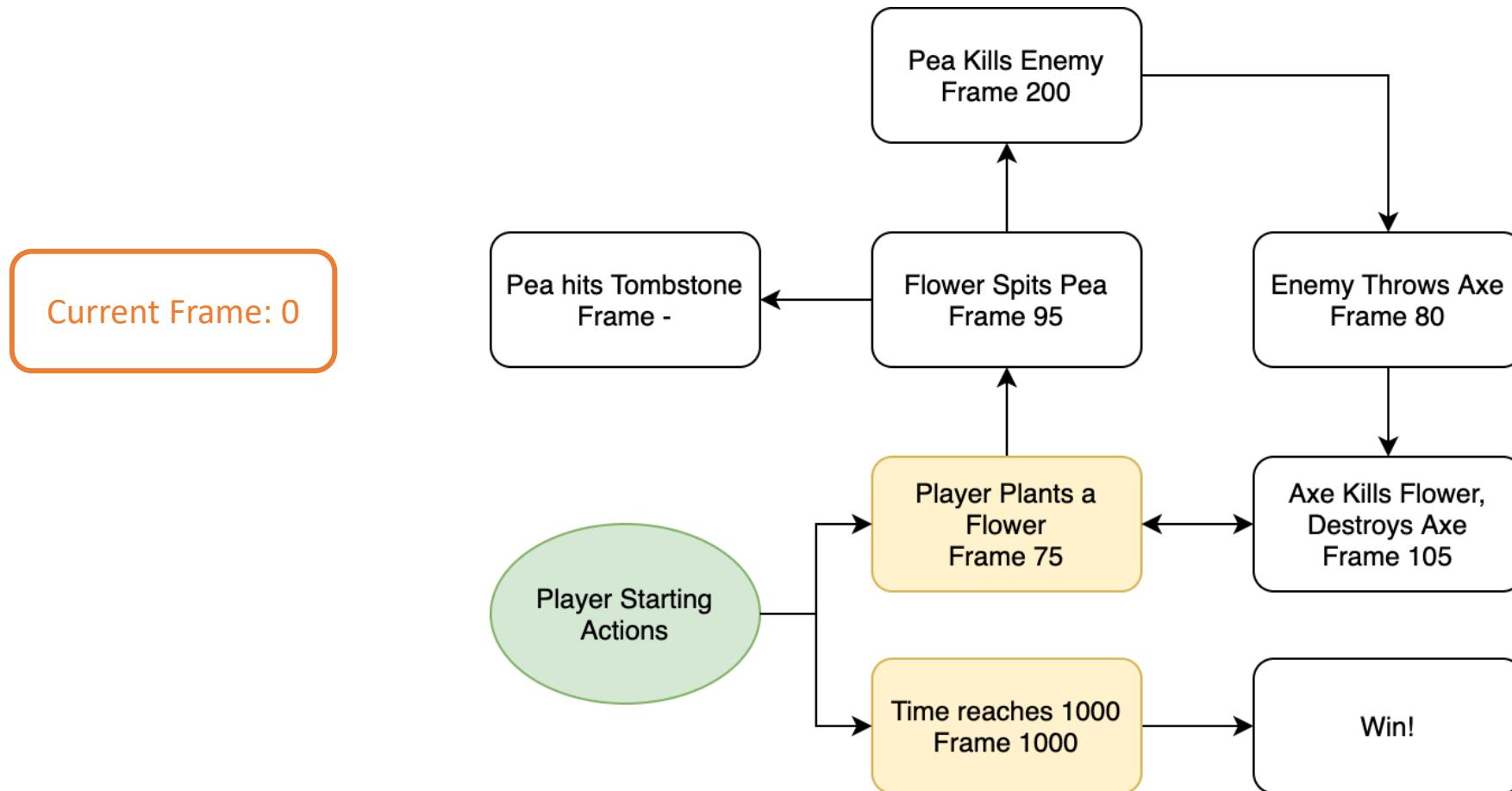
Plants vs Zombies



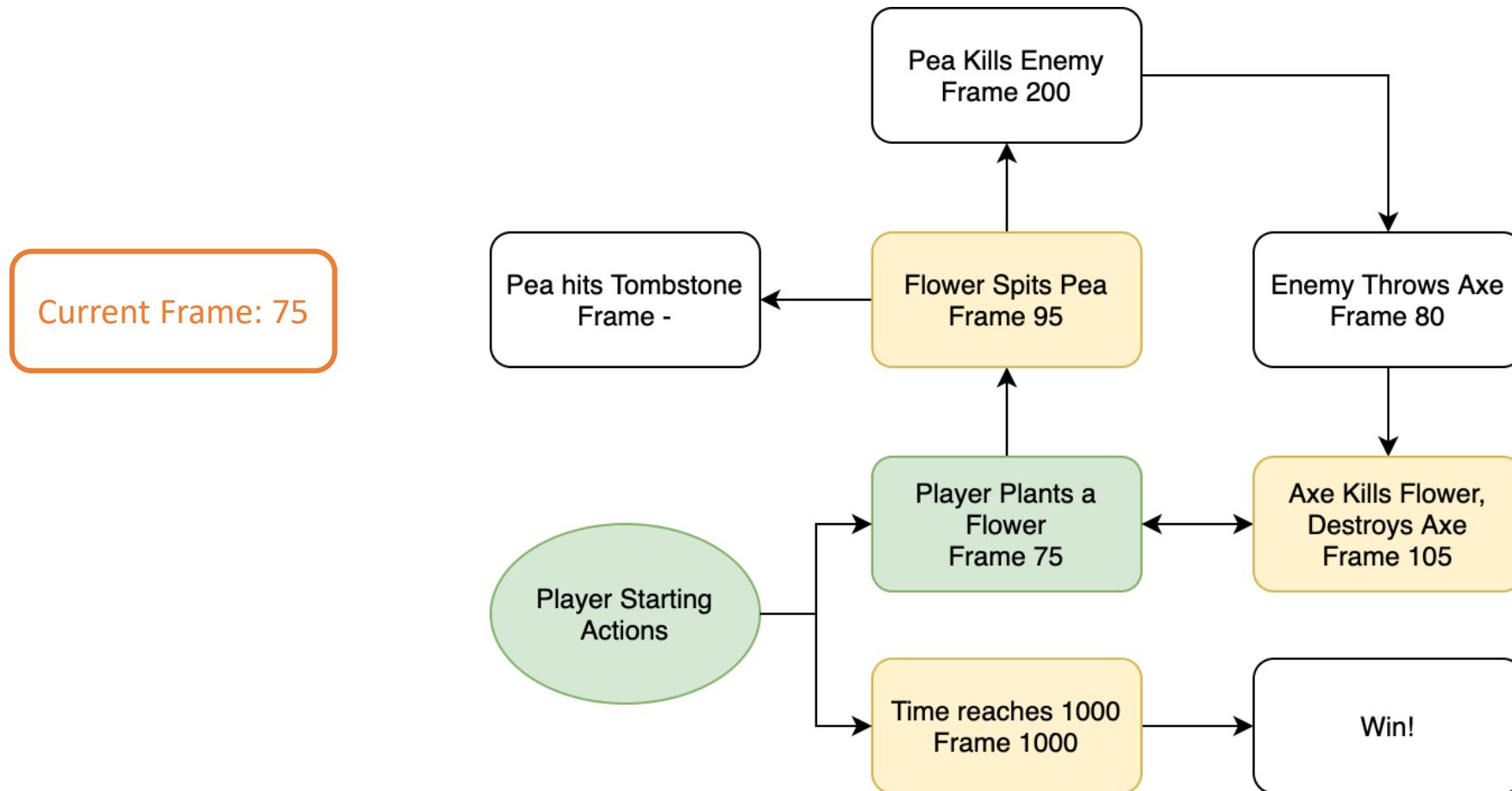
Informed Discovery



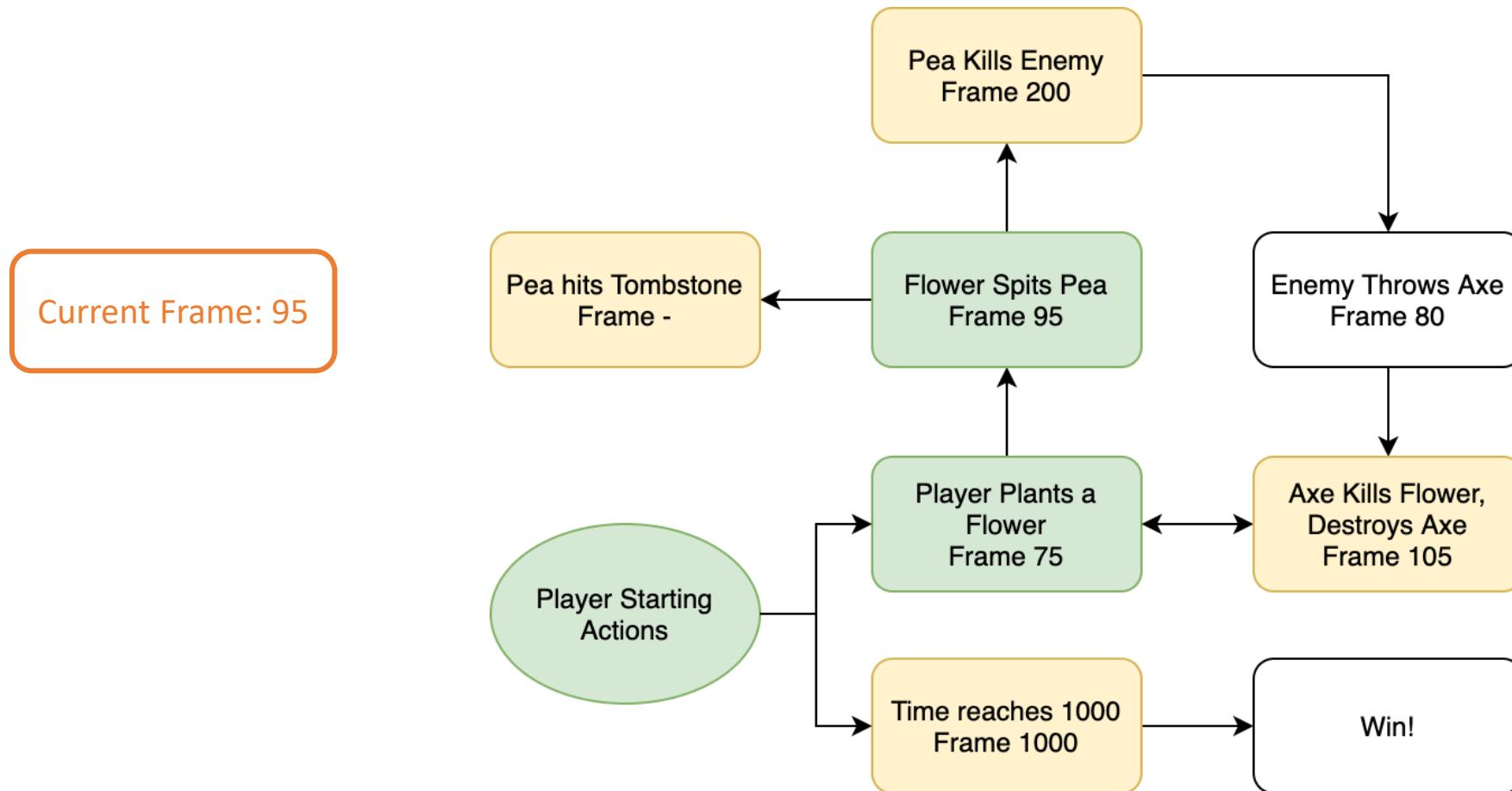
Informed Discovery



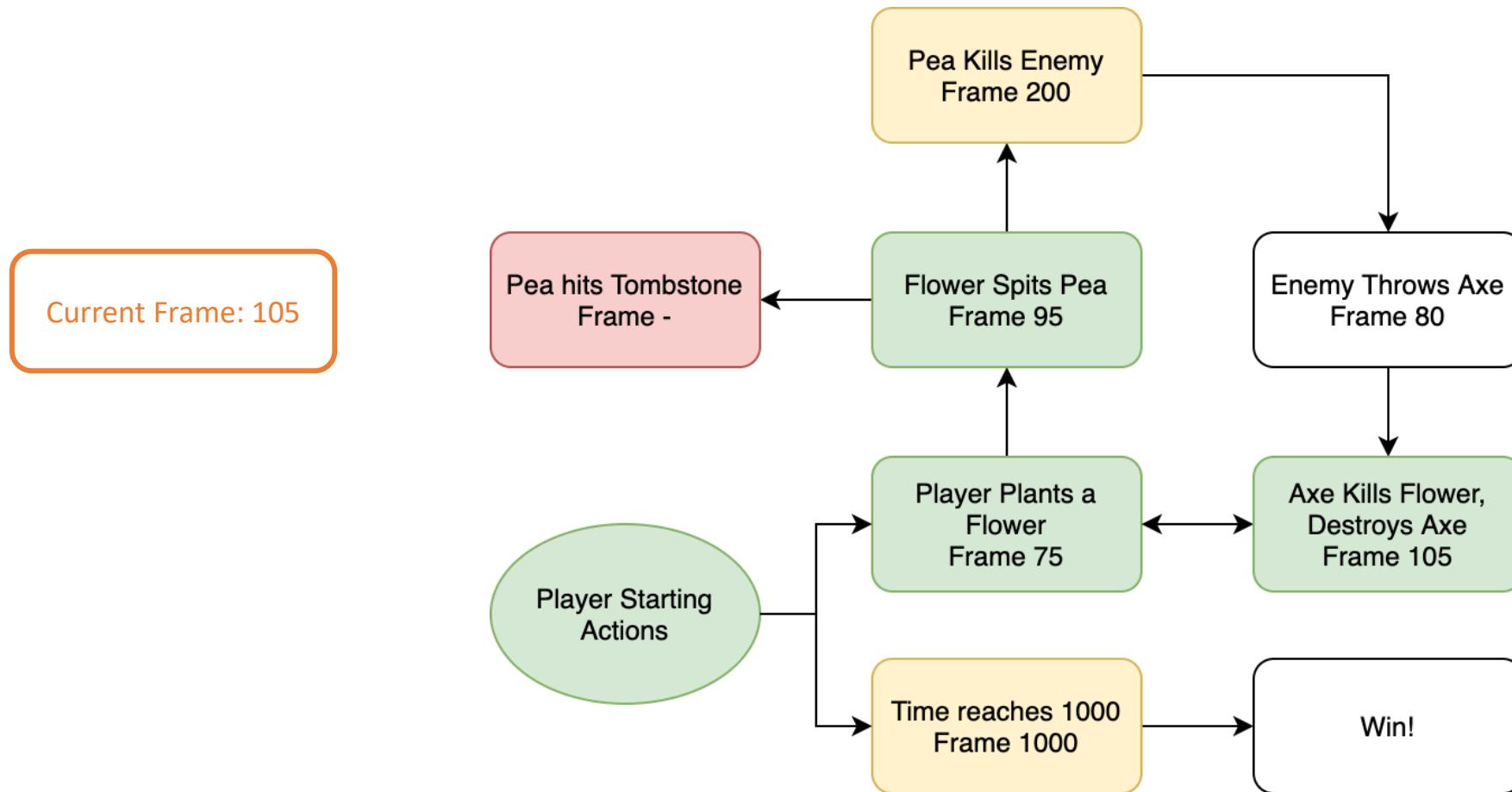
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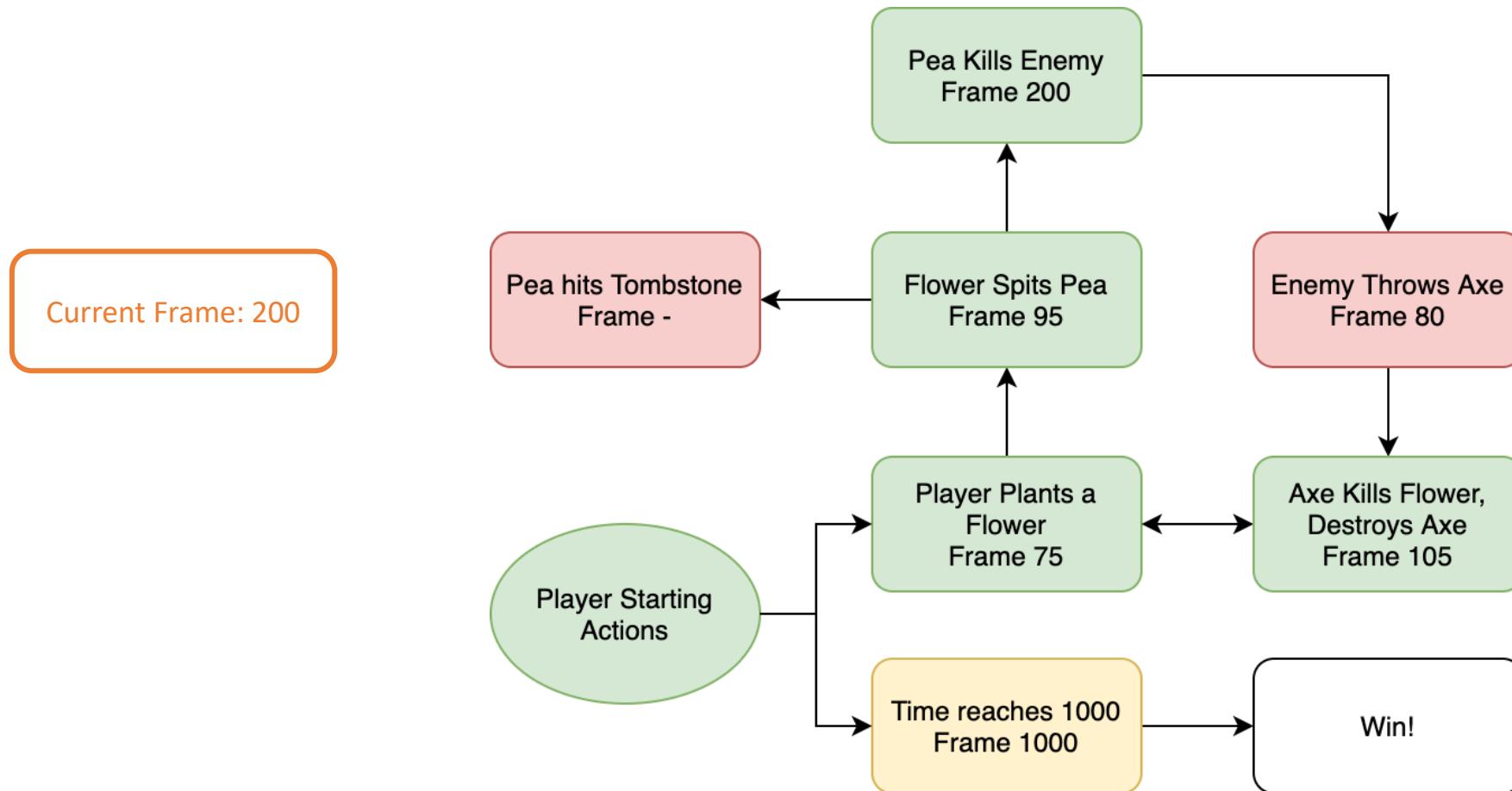
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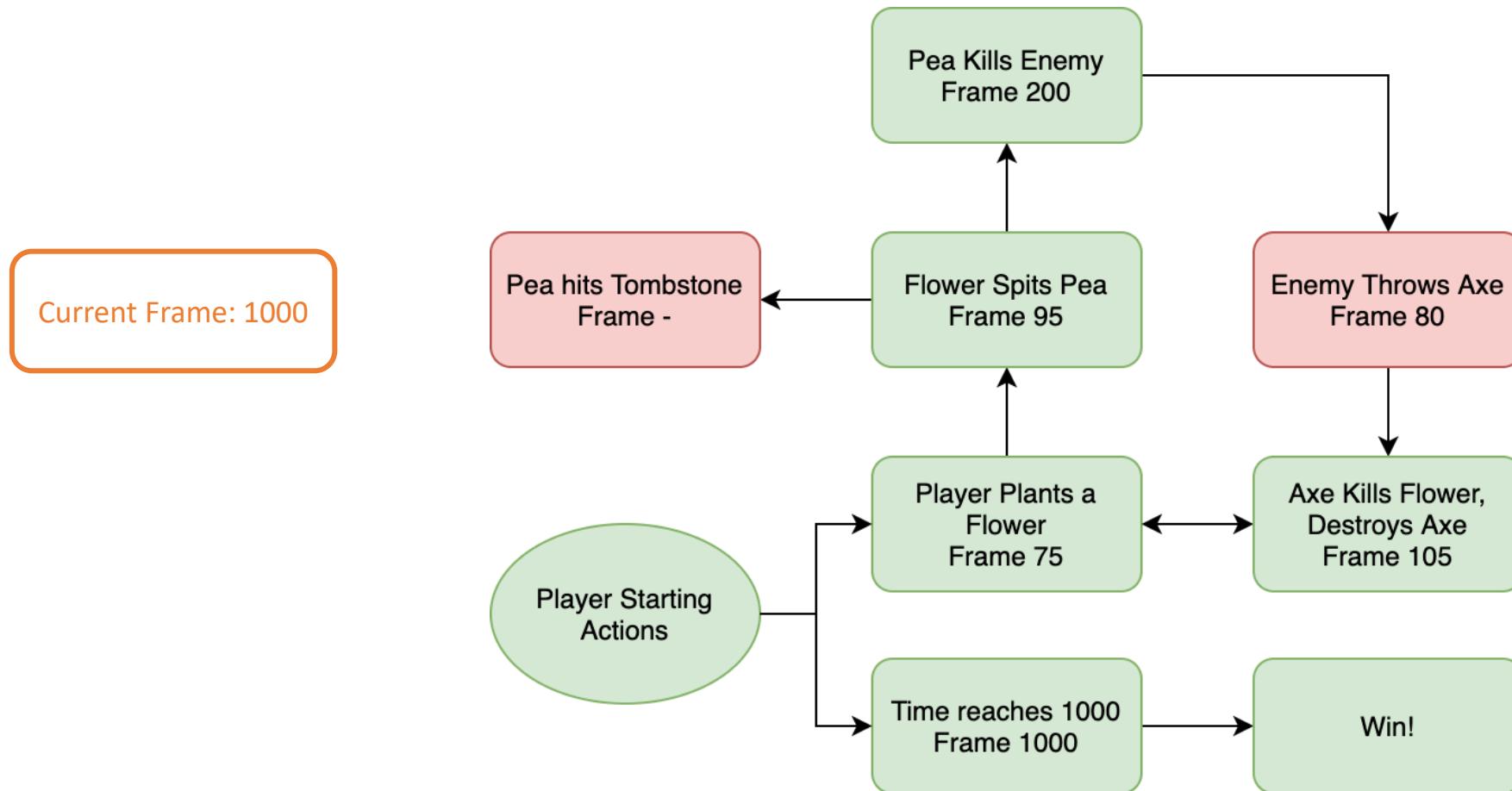
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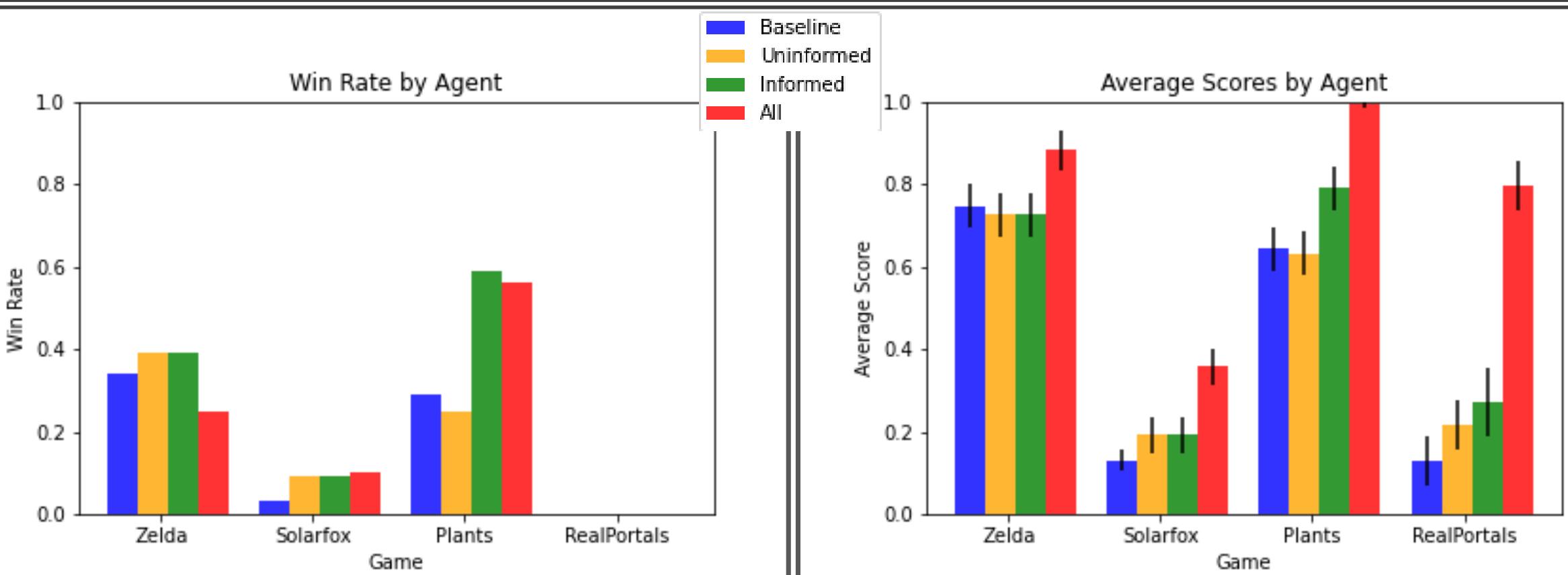
Informed Discovery



Informed Discovery



Agent Reward Evaluation



Game	Mechanic	Percentage	Informed Method	Uninformed Method
Solarfox	Avoid Flames	68%	X	X
	Collide with gems to pick them up	64%		
	Avoid Walls	18%		
	Match Rate	-	45.45%	45.45%
Zelda	Collide with the key to pick it up	80%	X	X
	Unlock the door with the key	80%	X	X
	Kill Enemies with Sword	76%		
	Avoid dying by colliding with Enemies	60%		
	Navigate the level walls using arrow keys	20%		
	Move quickly	12%		
	Match Rate	-	48.8%	48.8%
Plants	Press Space to use the shovel	100%	X	
	Use the shovel on grass to plant plants	100%	X	
	Plants kill zombies by shooting pellets	76%	X	
	When plants get hit with axes, both are destroyed	53%	X	
	Protect the villagers from zombies for some time	35%	X	X
	Add plants to different areas to get good coverage	29%		
	Axes don't affect player	6%		
	Match Rate	-	81.8%	11.9%
RealPortals	Press space to shoot a missile	72%	X	
	If the missile collides with a wall, it turns into a portal	72%	X	
	If a potion collides with water, the water is turned into ground	72%	X	
	Unlock the door with the key	68%	X	
	Collide with the goal to capture it	52%	X	X
	Collide with the key to pick it up	48%	X	
	Pick up different wands to toggle between portal types	44%	X	
	Teleport from the portal entrance to the portal exit	44%	X	
	Collide with a potion to push it	40%	X	
	Avoid dying by colliding with water or portal entrance with no exit	32%		
	If a potion collides with the portal entrance, it is teleported to the portal exit	16%	X	
	You can't go through the portal exit	0%	X	
Match Rate		-	94.3%	9.3%

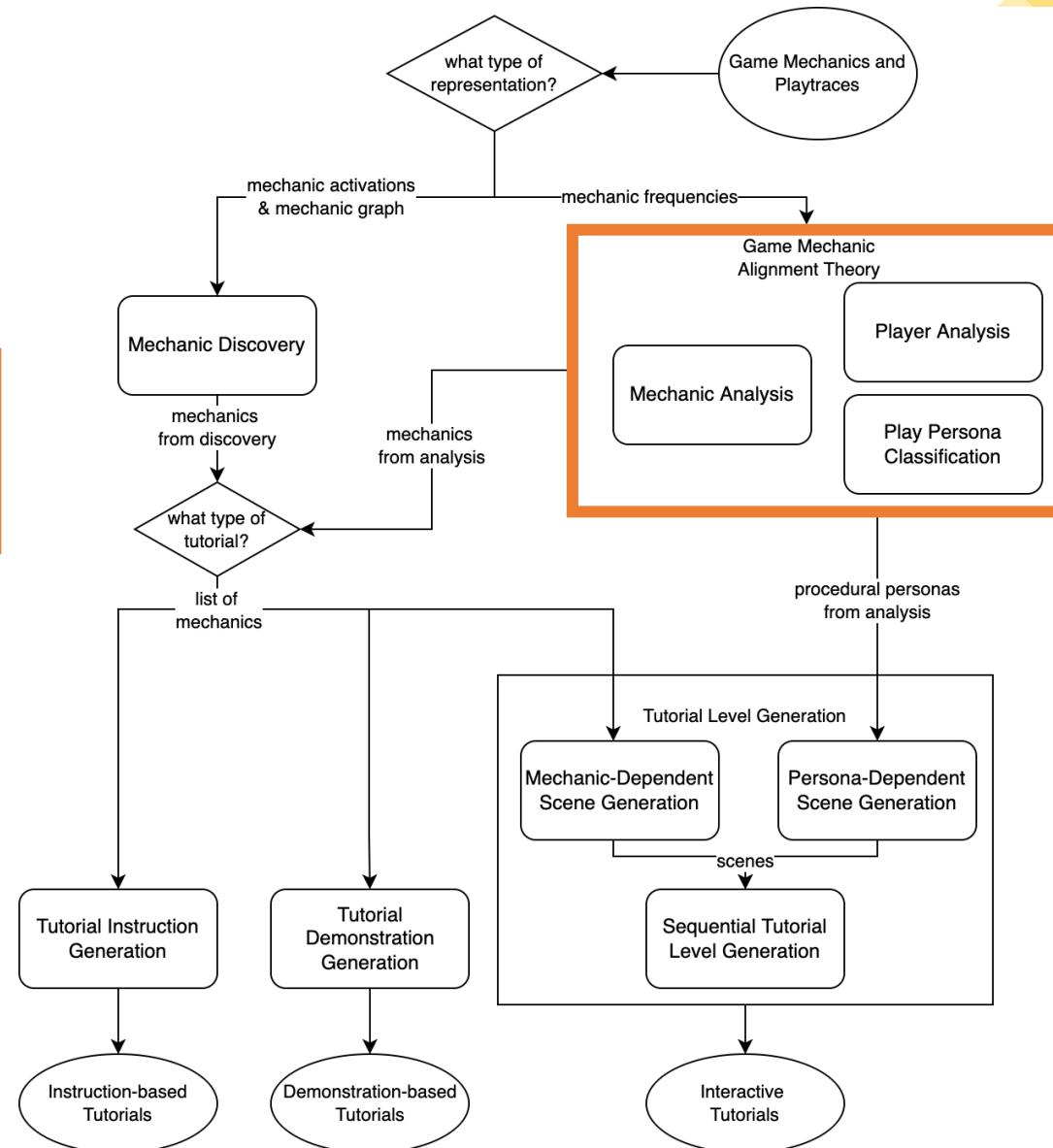
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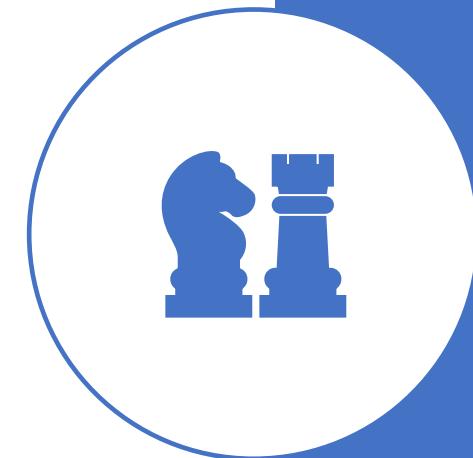
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Play Persona Classification

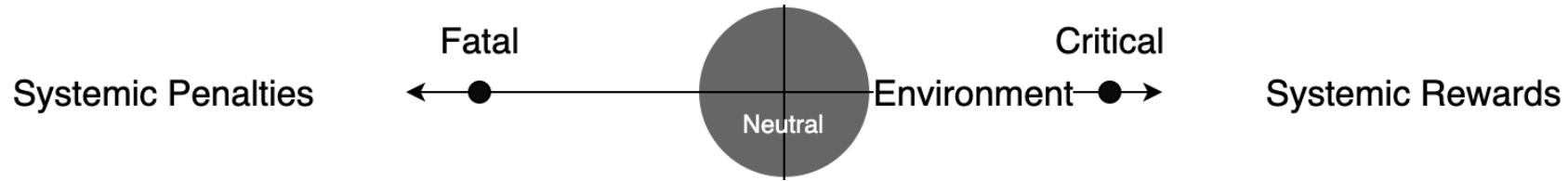


Is it only about winning?

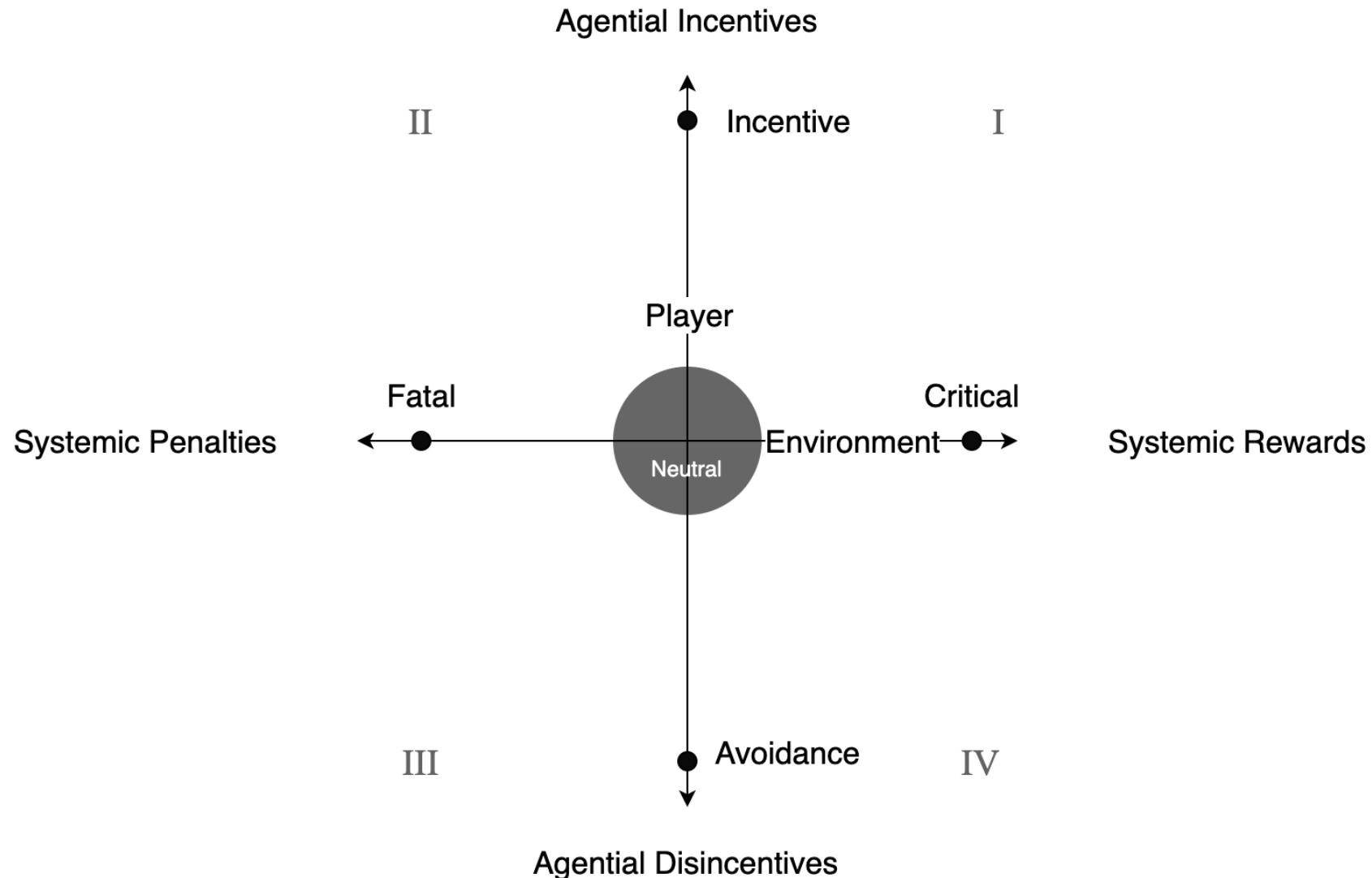
- Critical mechanics = teaching to win
- Players are different!
- They care about different things
- Need a framework for this...



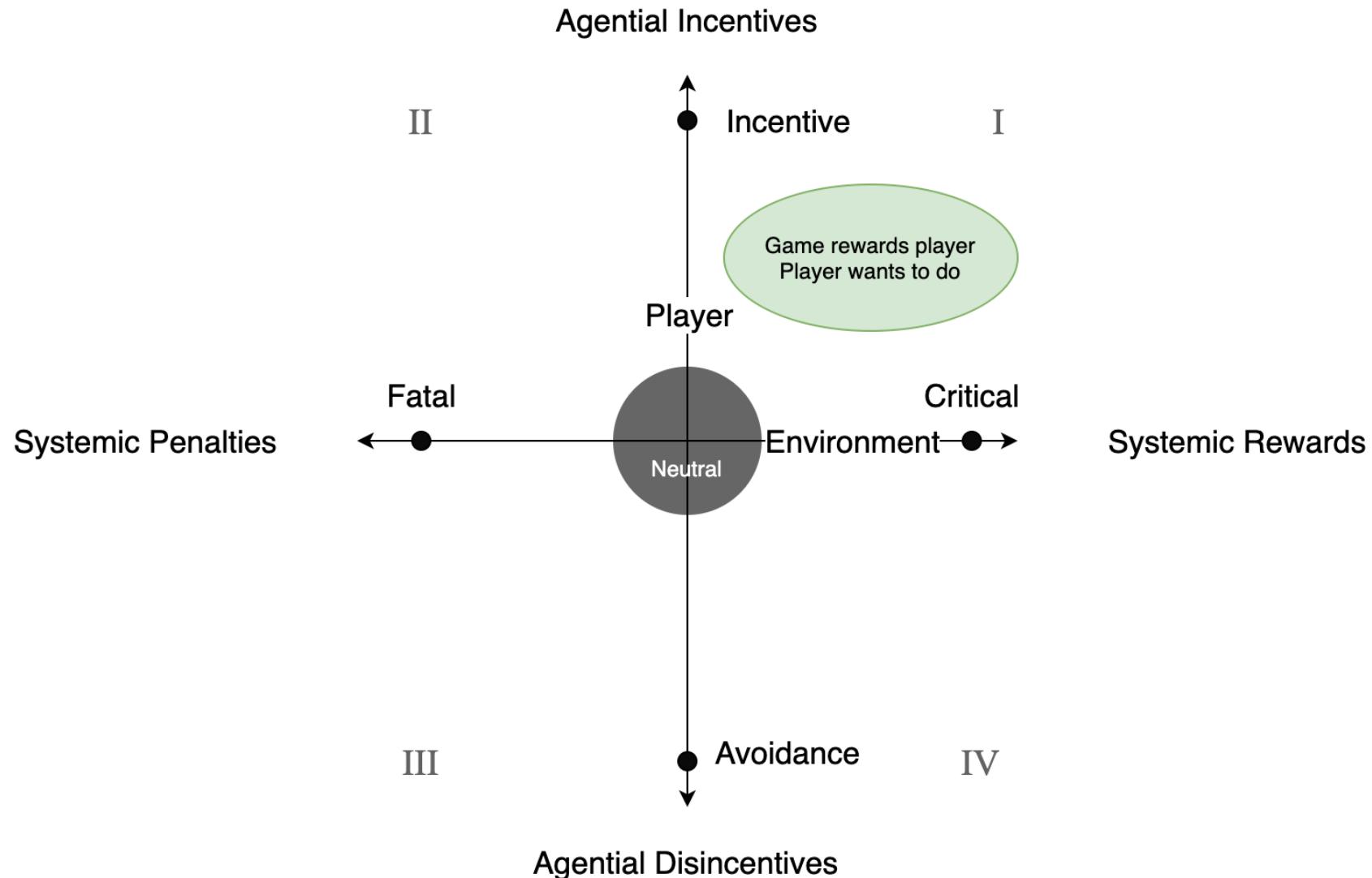
Game Mechanic Alignment Theory



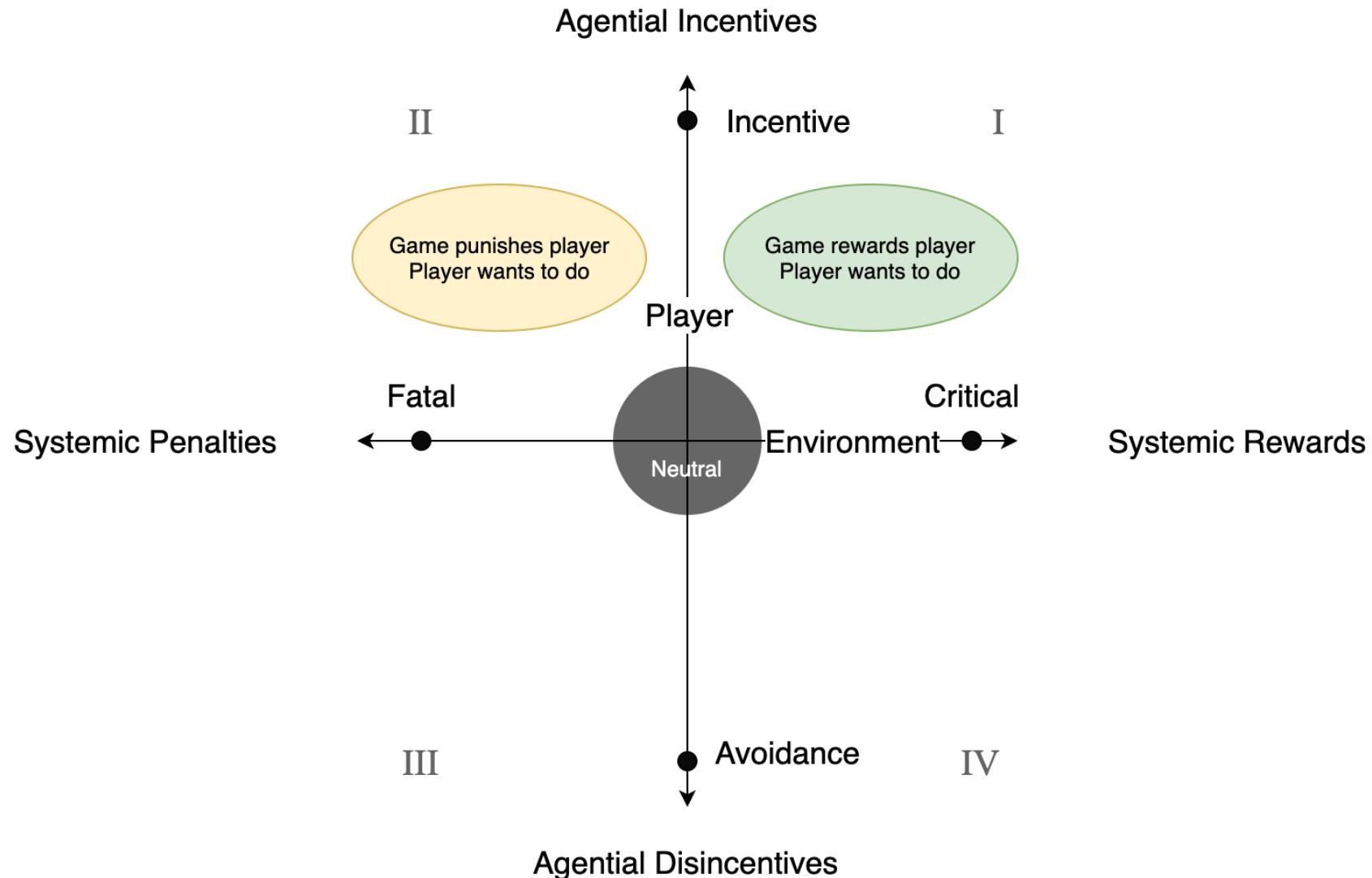
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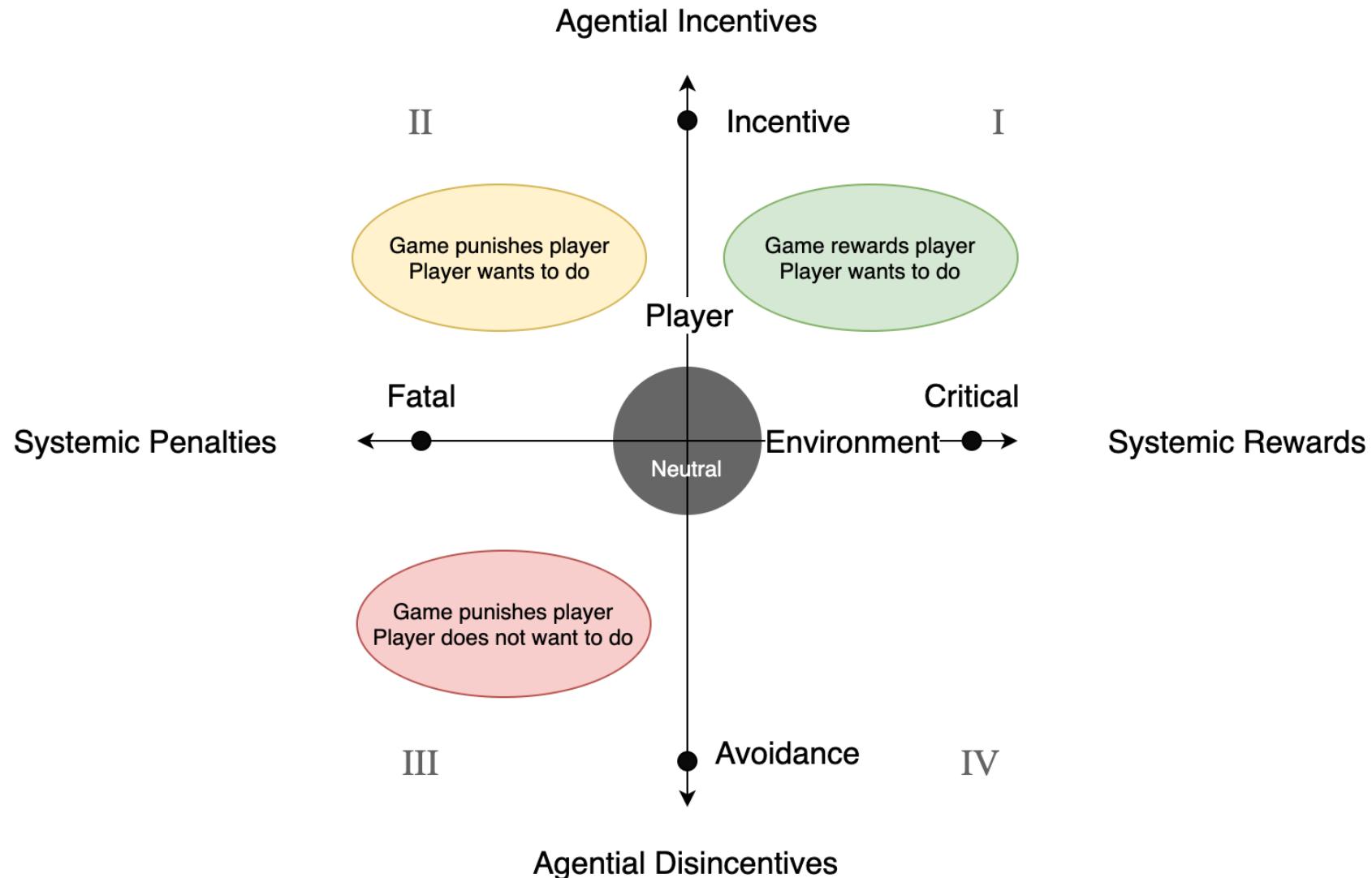
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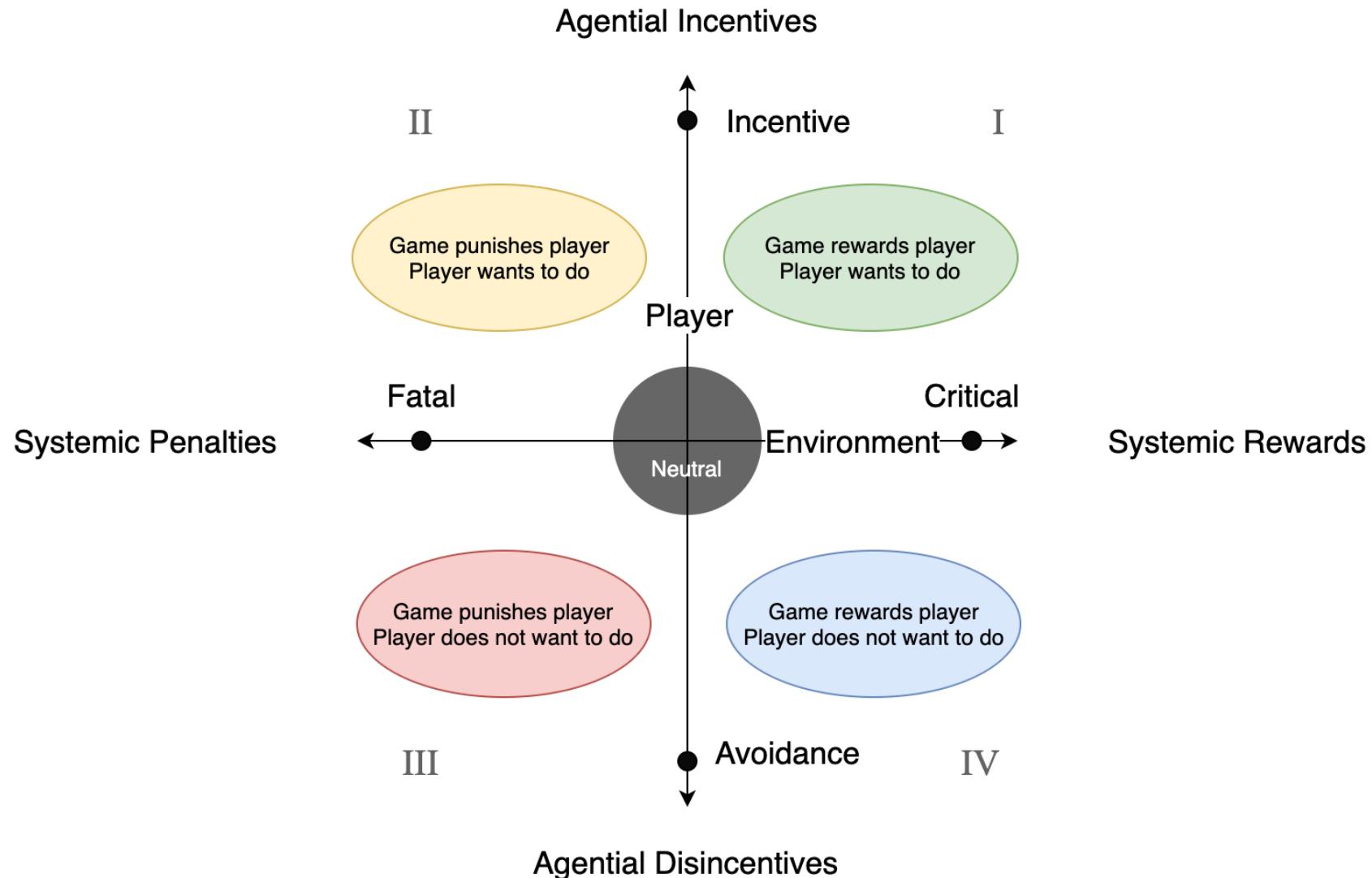
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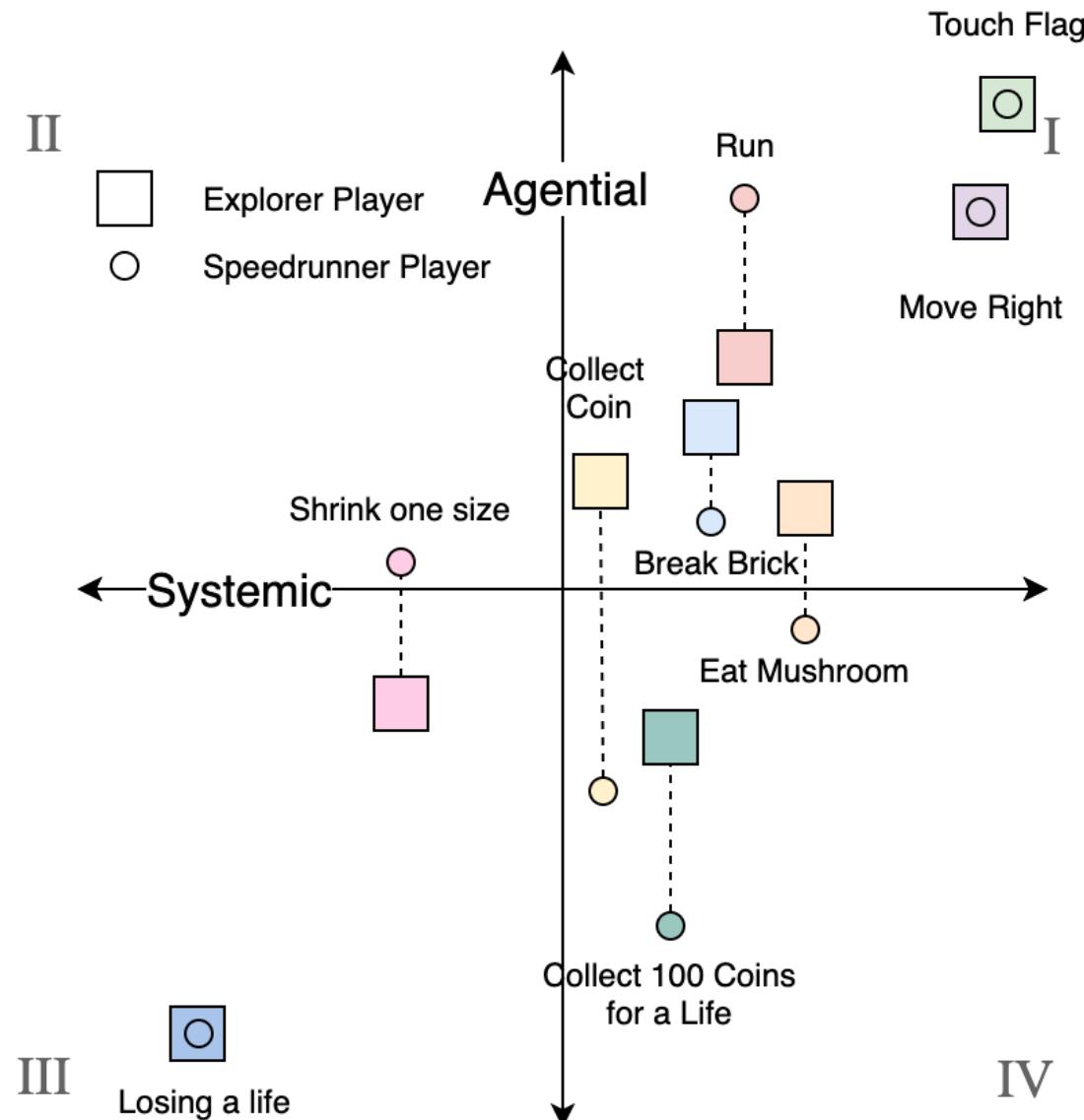
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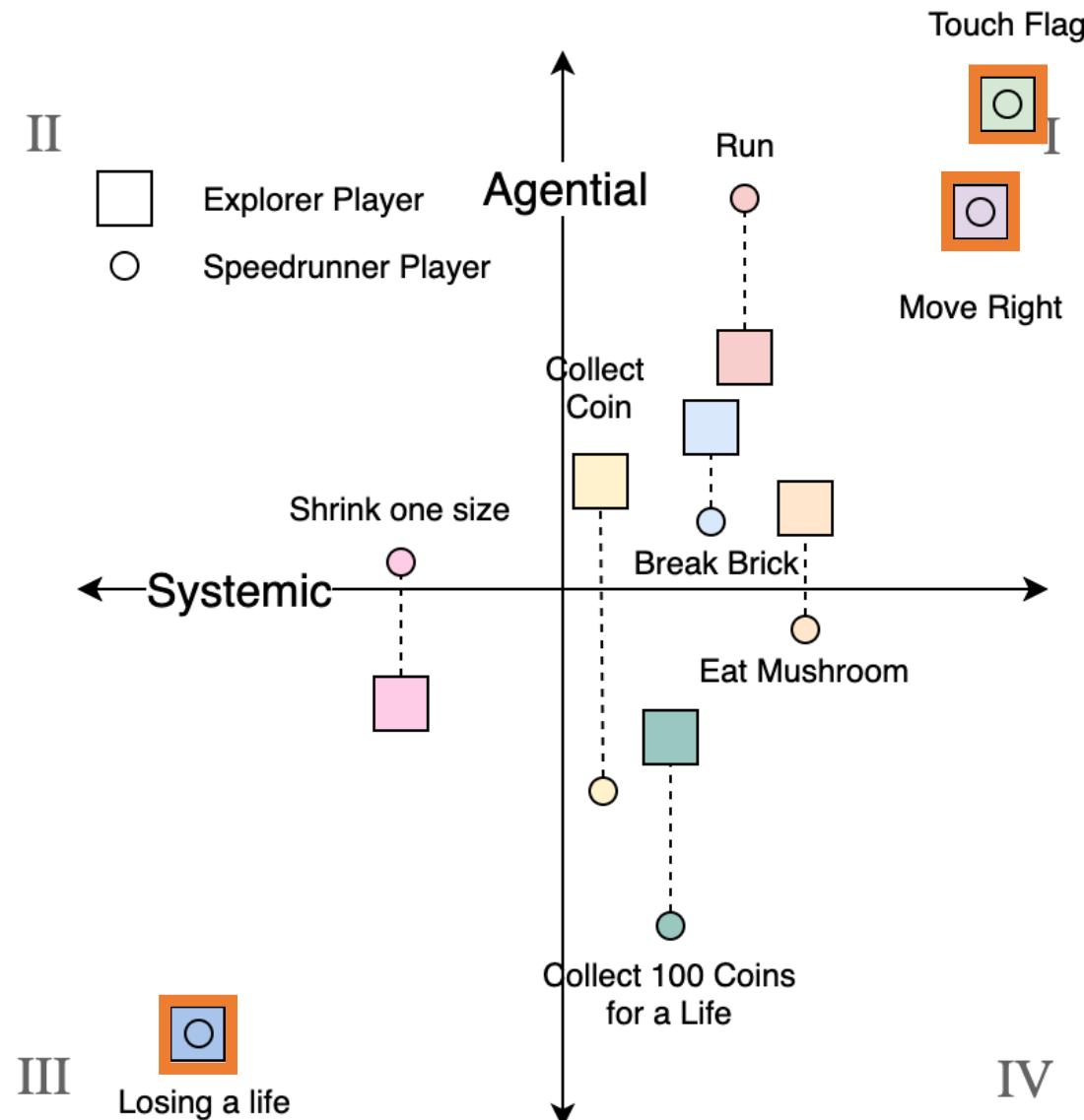
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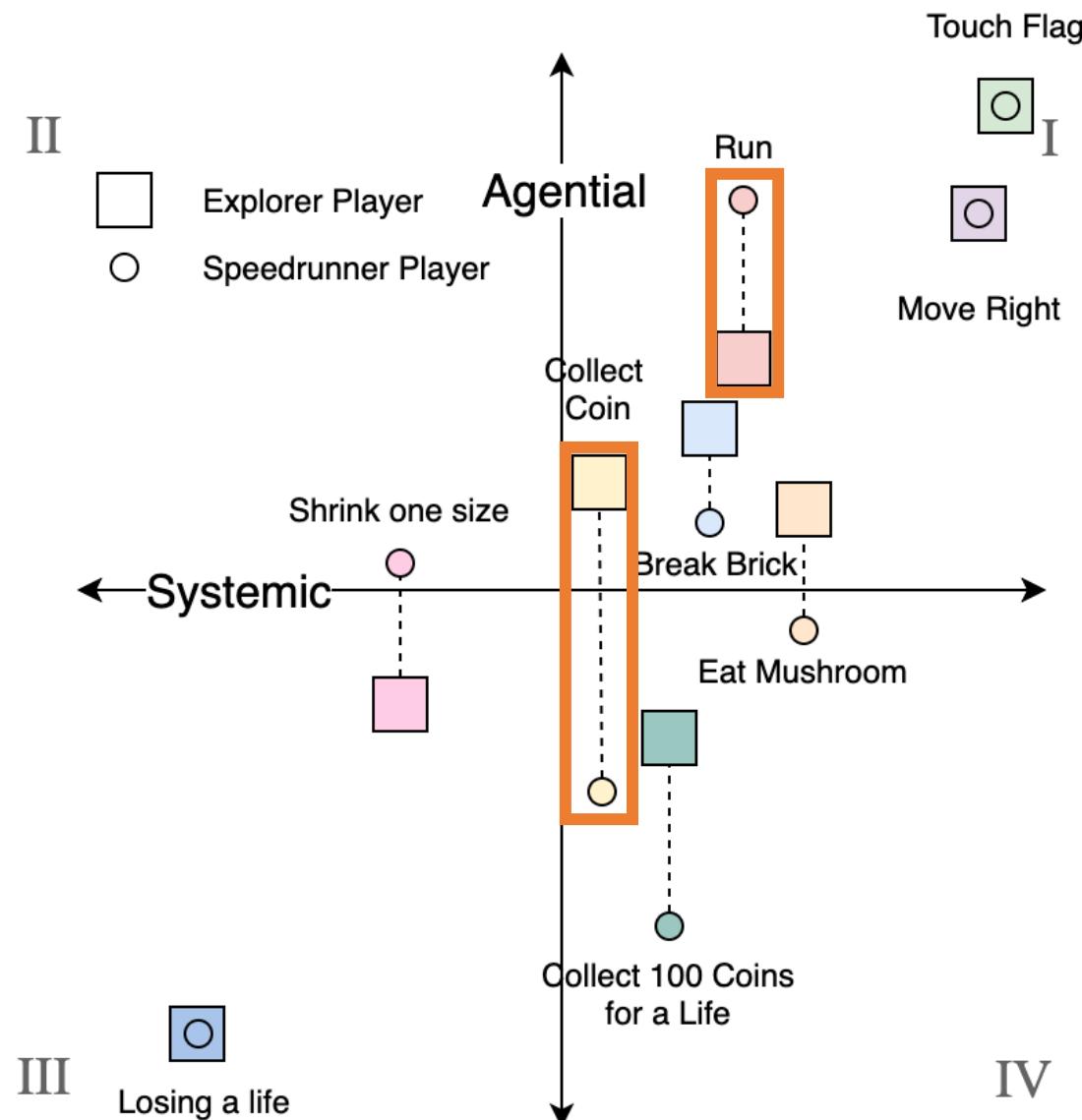
Game Mechanic Alignment in Super Mario



Game Mechanic Alignment in Super Mario



Game Mechanic Alignment in Super Mario



Mechanic Frequency

“The number of times a mechanic is used within a single session/level”



$$D_{m,c} = W_1(PDF(m|c), PDF(m))$$

$$S_{m,c} = Sign(\mu_{PDF(m|c)} - \mu_{PDF(m)})$$

$$I_m = S_{m,agent} \cdot D_{m,agent}$$

$$E_m = S_{m,win} \cdot D_{m,win}$$

Calculating Systemic GMA (X-Axis)

1. Winning/Losing Distribution

$$D_{m,win} = W_1(PDF(m|win), PDF(m))$$

2. Distance from entire distribution

$$S_{m,win} = Sign(\mu_{PDF(m|win)}, \mu_{PDF(m)})$$

3. Sign = Sign(Difference of means)

4. Multiply!

$$E_m = S_{m,win} \cdot D_{m,win}$$

Calculating Agential GMA (Y-Axis)

1. Agent Distribution

- “Player 1”

$$D_{m,agent} = W_1(PDF(m|agent), PDF(m))$$

2. Distance from entire distribution

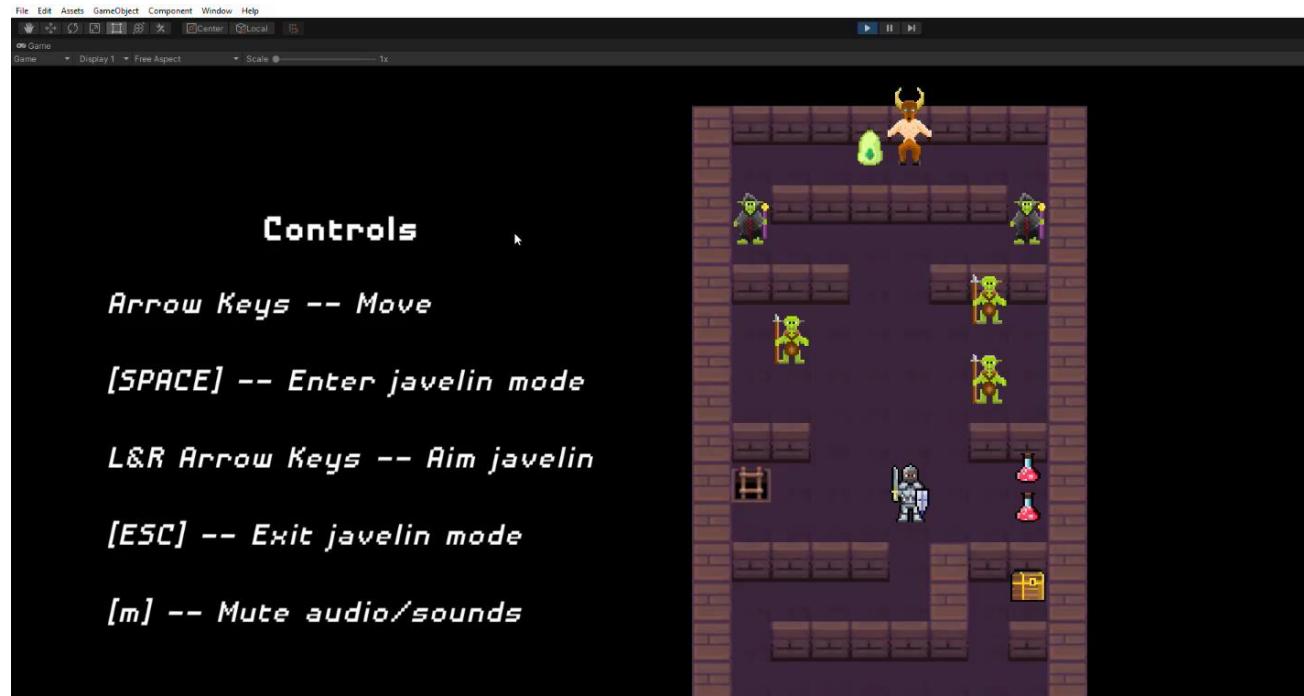
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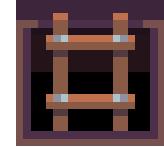
$$I_m = S_{m,agent} \cdot D_{m,agent}$$

GMA in Minidungeons 2

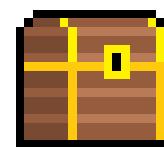


Playstyles in Minidungeons 2

Runner



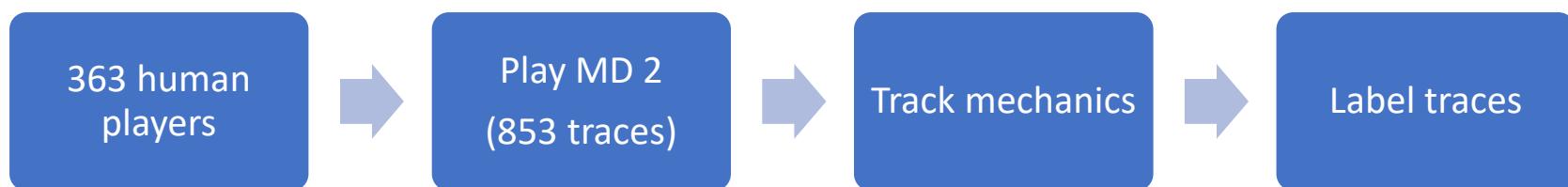
Treasure Collector



Monster Killer



Dataset of MD2 Players



	Count
No Label	136
R	243
TC	92
MK	3
R/TC	108
R/MK	69
TC/MK	34
R/TC/MK	173

Application to Minidungeons 2

	Count	EnemyKill	TakeTurn	UsePortal	CollectTreasure	CollectPotion	JavelinThrow
No Label	136	-0.147	-0.105	0.026	-0.202	-0.177	-0.013
R	243	-0.11	-0.122	-0.022	-0.213	-0.225	-0.035
TC	92	0.113	0.242	0.05	0.397	0.206	0.104
MK	3	0.157	0.309	-0.044	0.212	0.324	0.174
R/TC	108	0.052	-0.046	0.016	0.113	-0.07	-0.014
R/MK	69	-0.119	-0.132	-0.035	-0.22	0.16	-0.029
TC/MK	34	0.232	0.494	-0.044	0.517	0.584	0.058
R/TC/MK	173	0.161	0.083	0.009	0.161	0.209	0.015

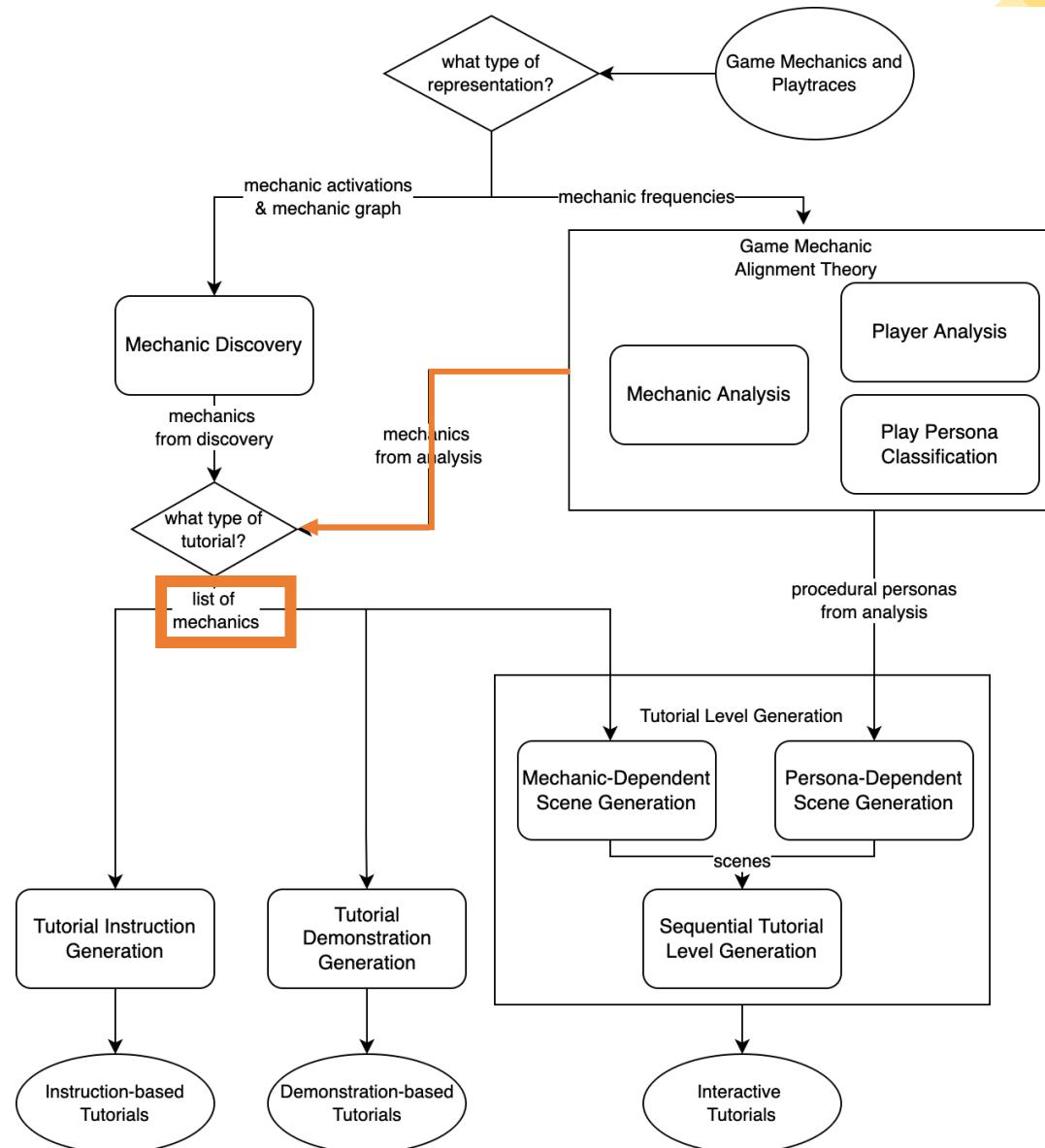
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R/TC/MK	173	0.161	0.083	0.009	0.161	0.209	0.015

Application to Minidungeons 2

	1	2	3	4	5	6
No Label	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
TC	CollectTreasure	TakeTurn	CollectPotion	EnemyKill	JavelinThrow	UsePortal
MK	CollectPotion	TakeTurn	CollectTreasure	JavelinThrow	EnemyKill	UsePortal
R/TC	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R/MK	CollectTreasure	CollectPotion	TakeTurn	EnemyKill	UsePortal	JavelinThrow
TC/MK	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
R/TC/MK	CollectPotion	CollectTreasure	EnemyKill	TakeTurn	JavelinThrow	UsePortal

Application to Minidungeons 2

	1	2	3	4	5	6
No Label	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
TC	CollectTreasure	TakeTurn	CollectPotion	EnemyKill	JavelinThrow	UsePortal
MK	CollectPotion	TakeTurn	CollectTreasure	JavelinThrow	EnemyKill	UsePortal
R/TC	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R/MK	CollectTreasure	CollectPotion	TakeTurn	EnemyKill	UsePortal	JavelinThrow
TC/MK	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
R/TC/MK	CollectPotion	CollectTreasure	EnemyKill	TakeTurn	JavelinThrow	UsePortal

Application to Minidungeons 2

	1	2	3	4	5	6
No Label	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
TC	CollectTreasure	TakeTurn	CollectPotion	EnemyKill	JavelinThrow	UsePortal
MK	CollectPotion	TakeTurn	CollectTreasure	JavelinThrow	EnemyKill	UsePortal
R/TC	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R/MK	CollectTreasure	CollectPotion	TakeTurn	EnemyKill	UsePortal	JavelinThrow
TC/MK	CollectPotion	CollectTreasure	TakeTurn	EnemyKill	JavelinThrow	UsePortal
R/TC/MK	CollectPotion	CollectTreasure	EnemyKill	TakeTurn	JavelinThrow	UsePortal

Application to Minidungeons 2

	1	2	3	4	5	6
No Label	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
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MK	CollectPotion	TakeTurn	CollectTreasure	JavelinThrow	EnemyKill	UsePortal
R/TC	CollectTreasure	CollectPotion	EnemyKill	TakeTurn	UsePortal	JavelinThrow
R/MK	CollectTreasure	CollectPotion	TakeTurn	EnemyKill	UsePortal	JavelinThrow
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R/TC/MK	CollectPotion	CollectTreasure	EnemyKill	TakeTurn	JavelinThrow	UsePortal

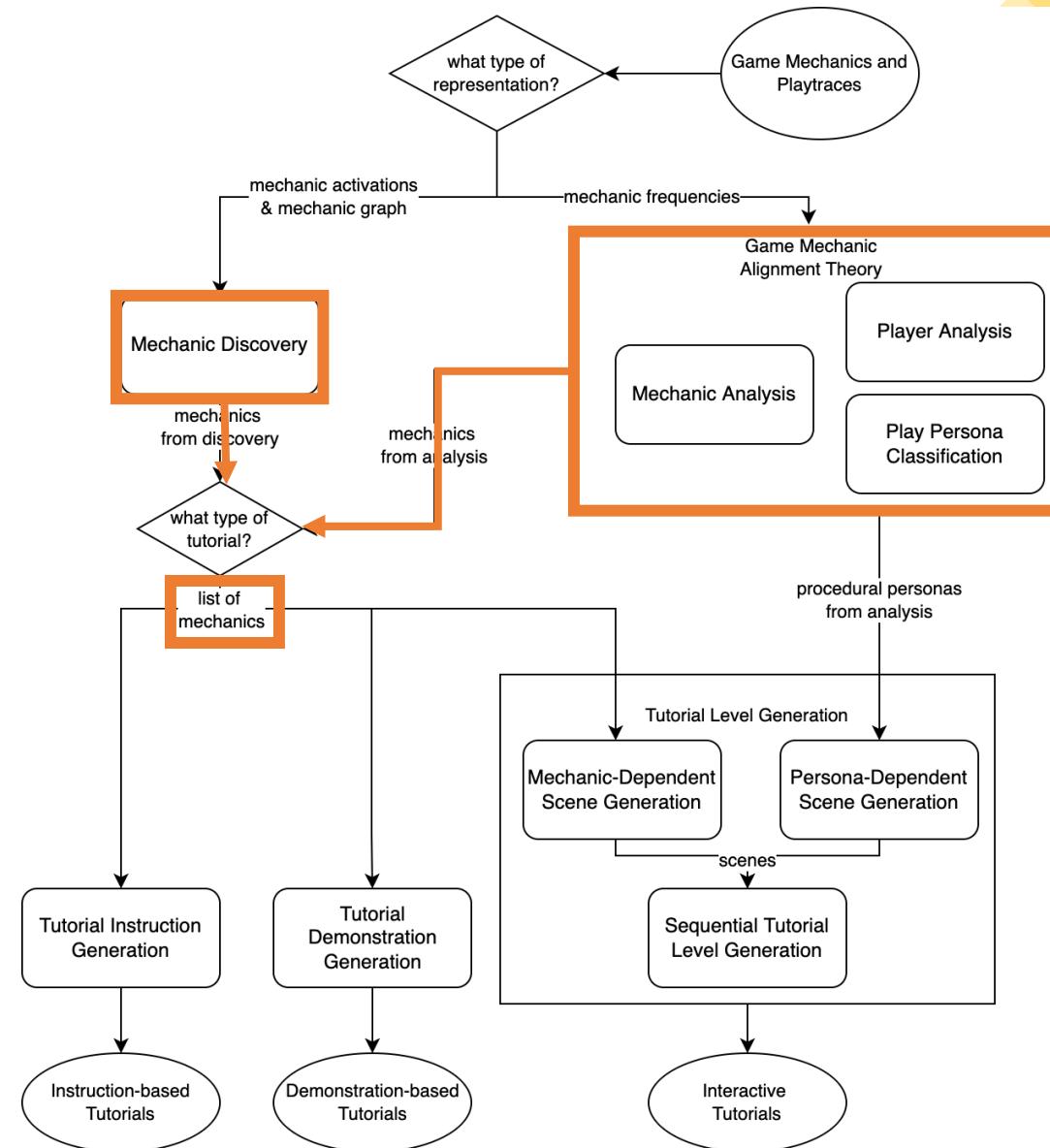
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Types of Tutorials



Instructions



Demonstrations



Interactive
Experiences

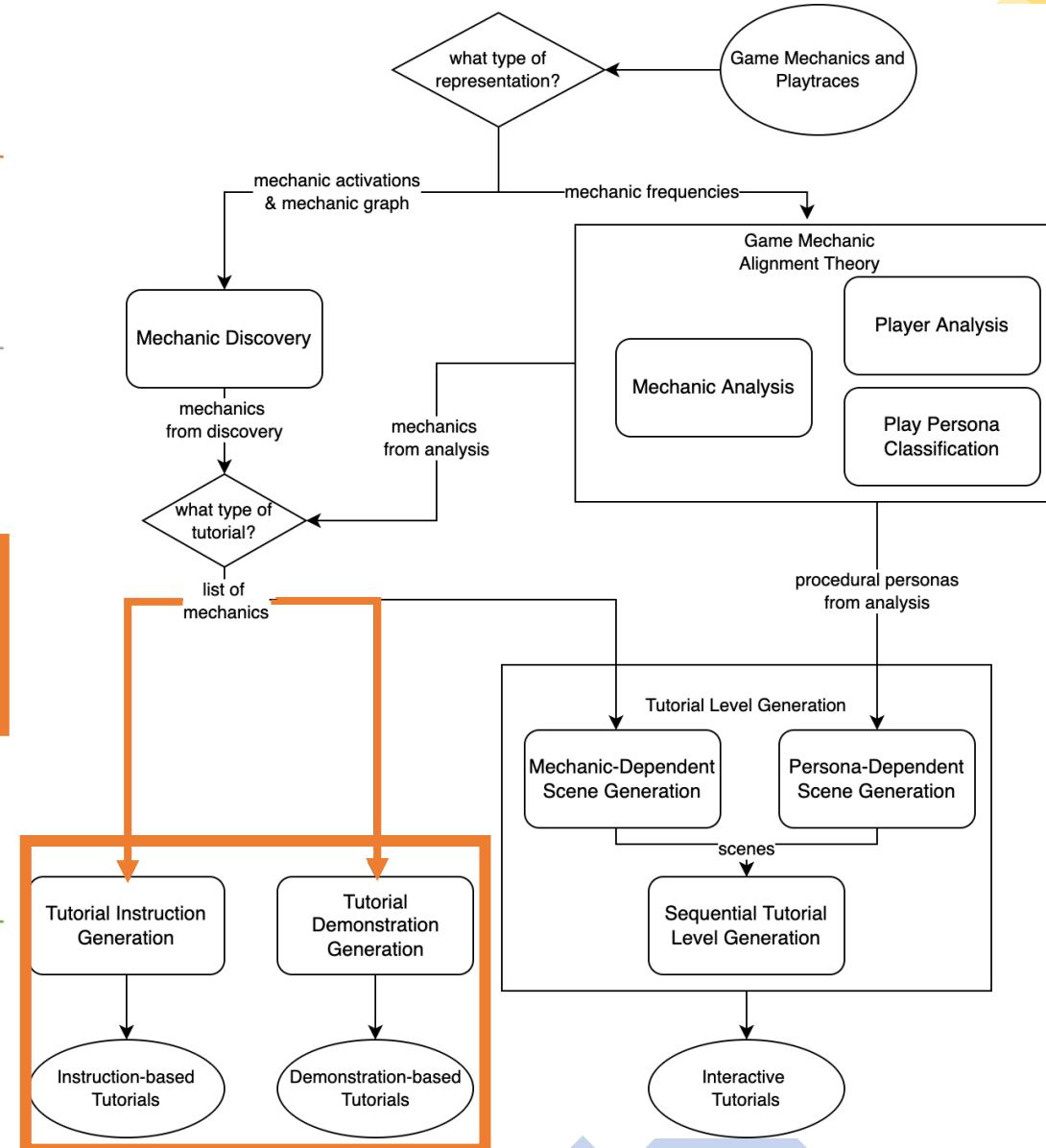
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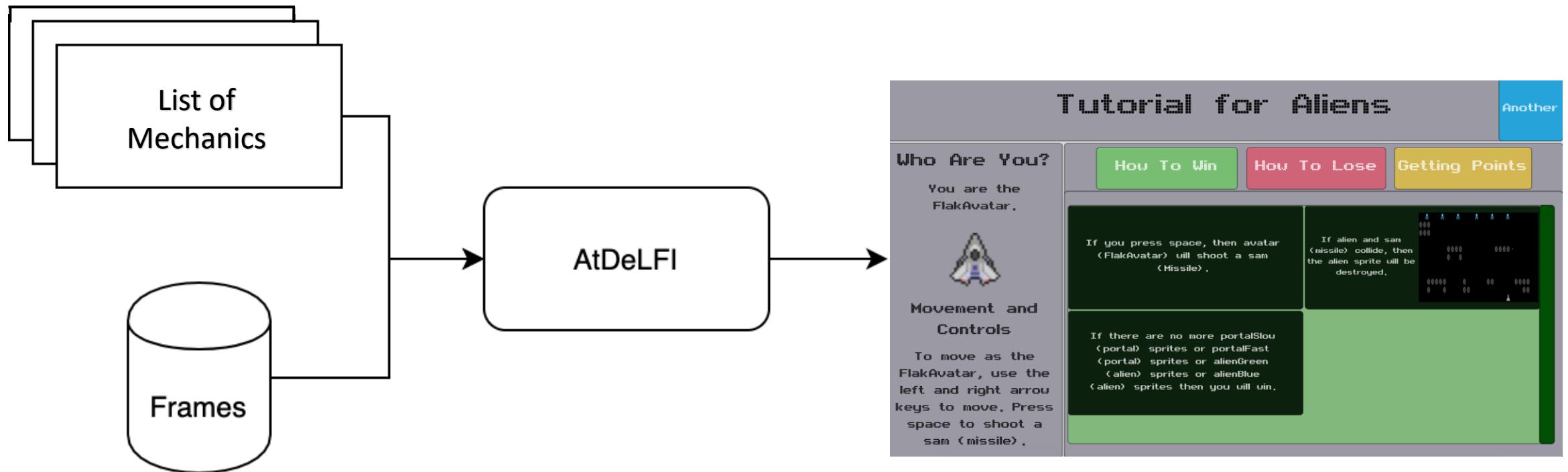
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The AtDeLF1 System

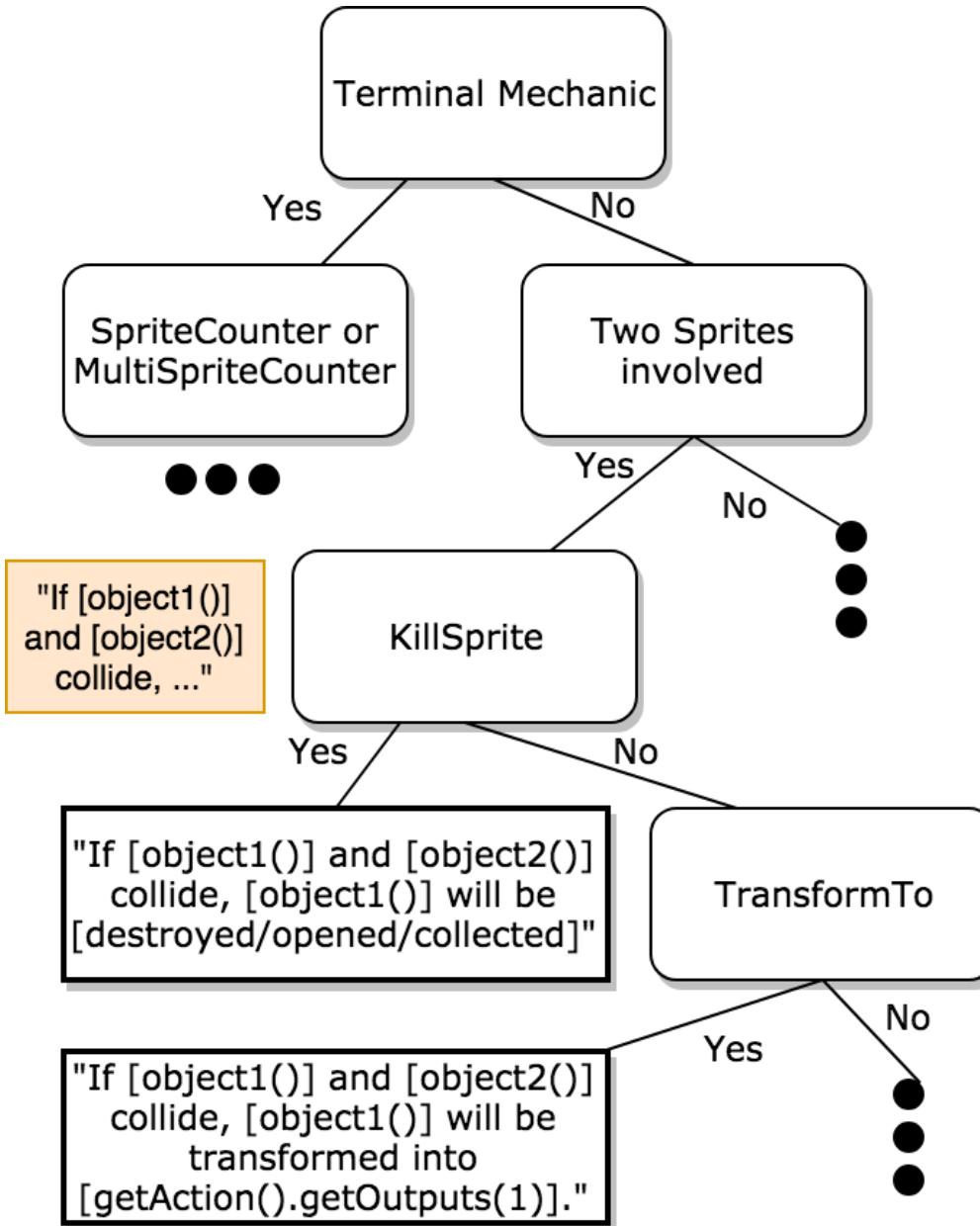
- **A**t – Automatically
- **D**e – Designing
- **L** – Legible
- **F** – Full
- **I** – Instructions





<https://game.engineering.nyu.edu/tutorial-generator/>

Grammar Transformation Tree



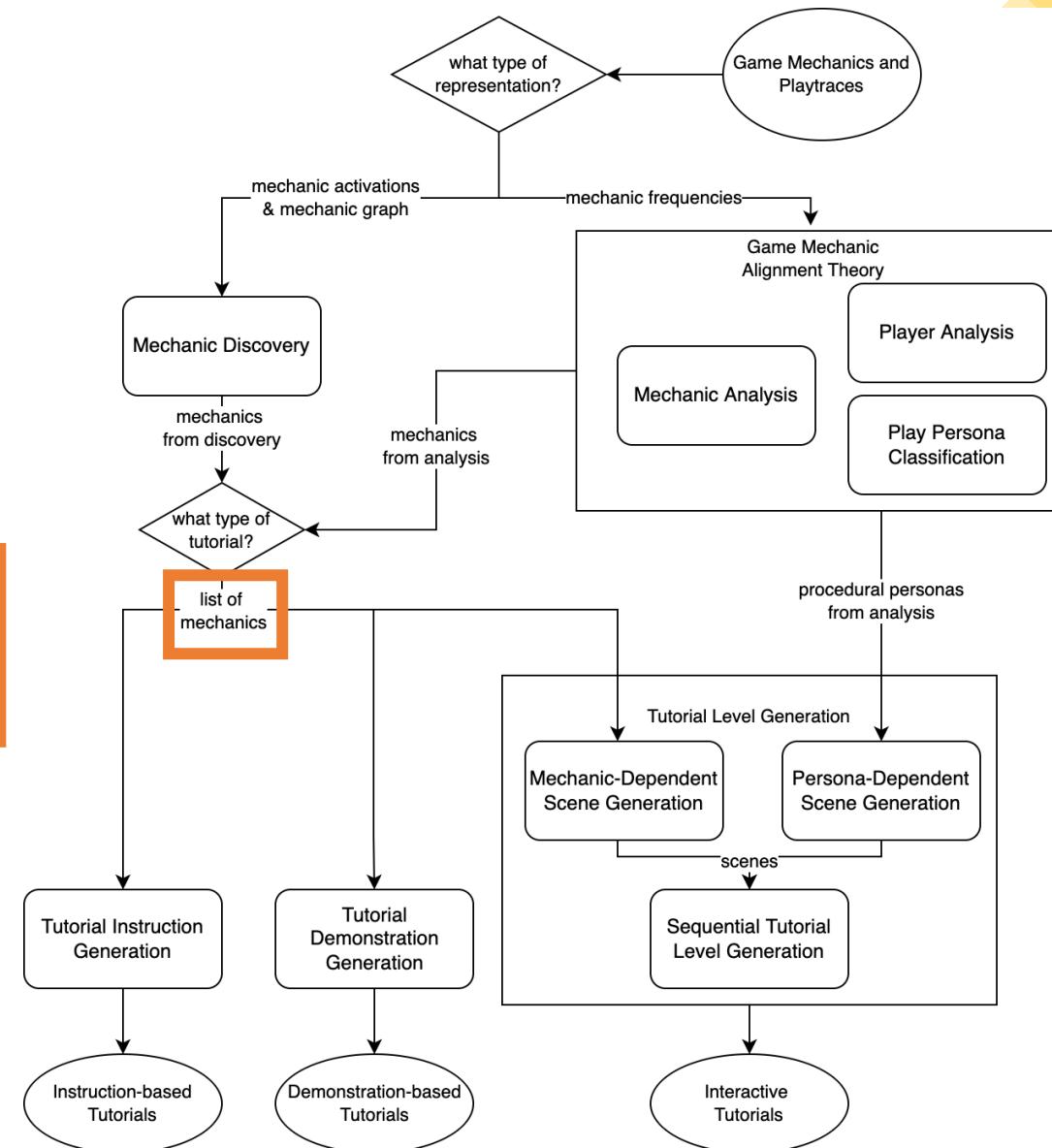
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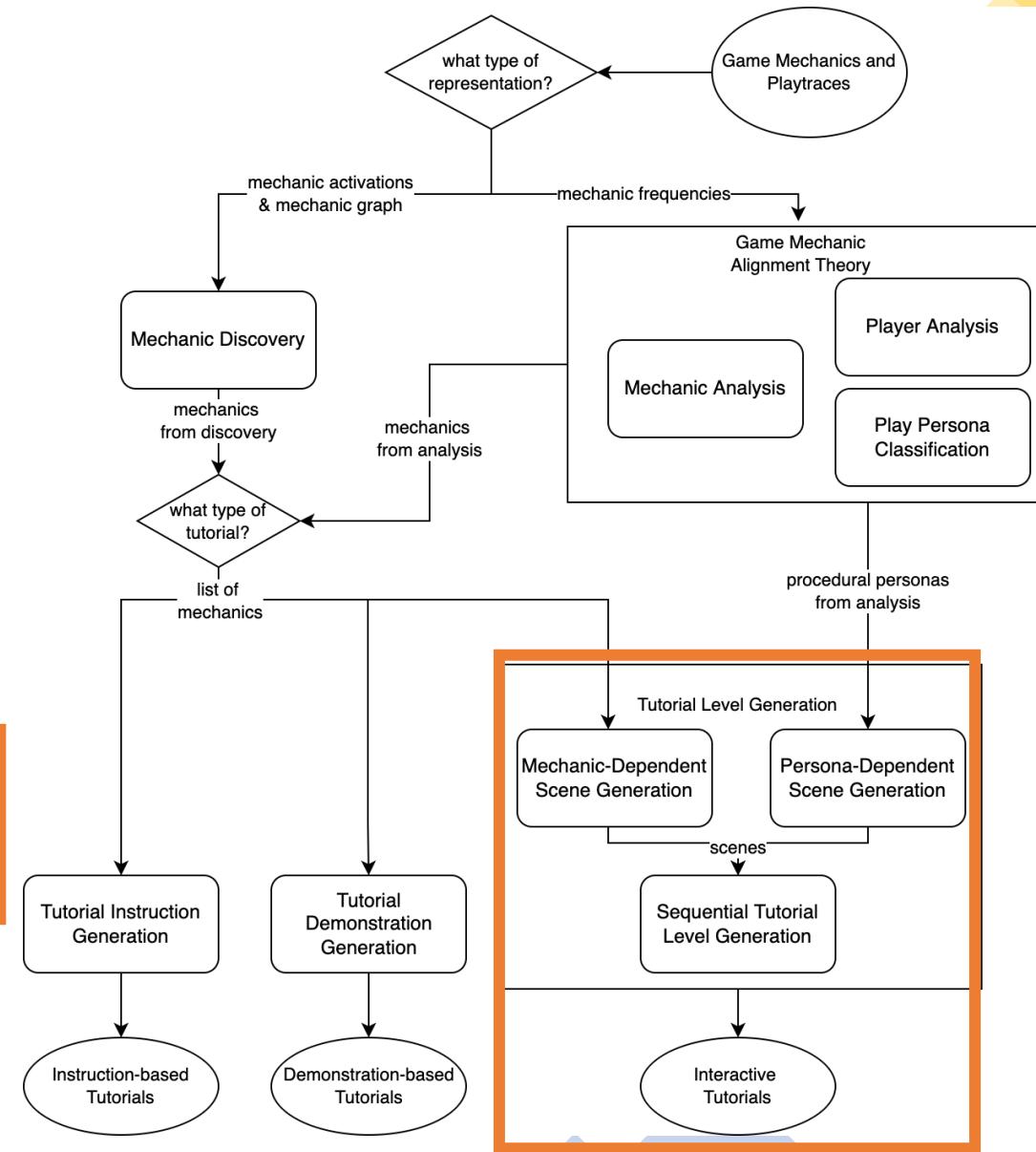
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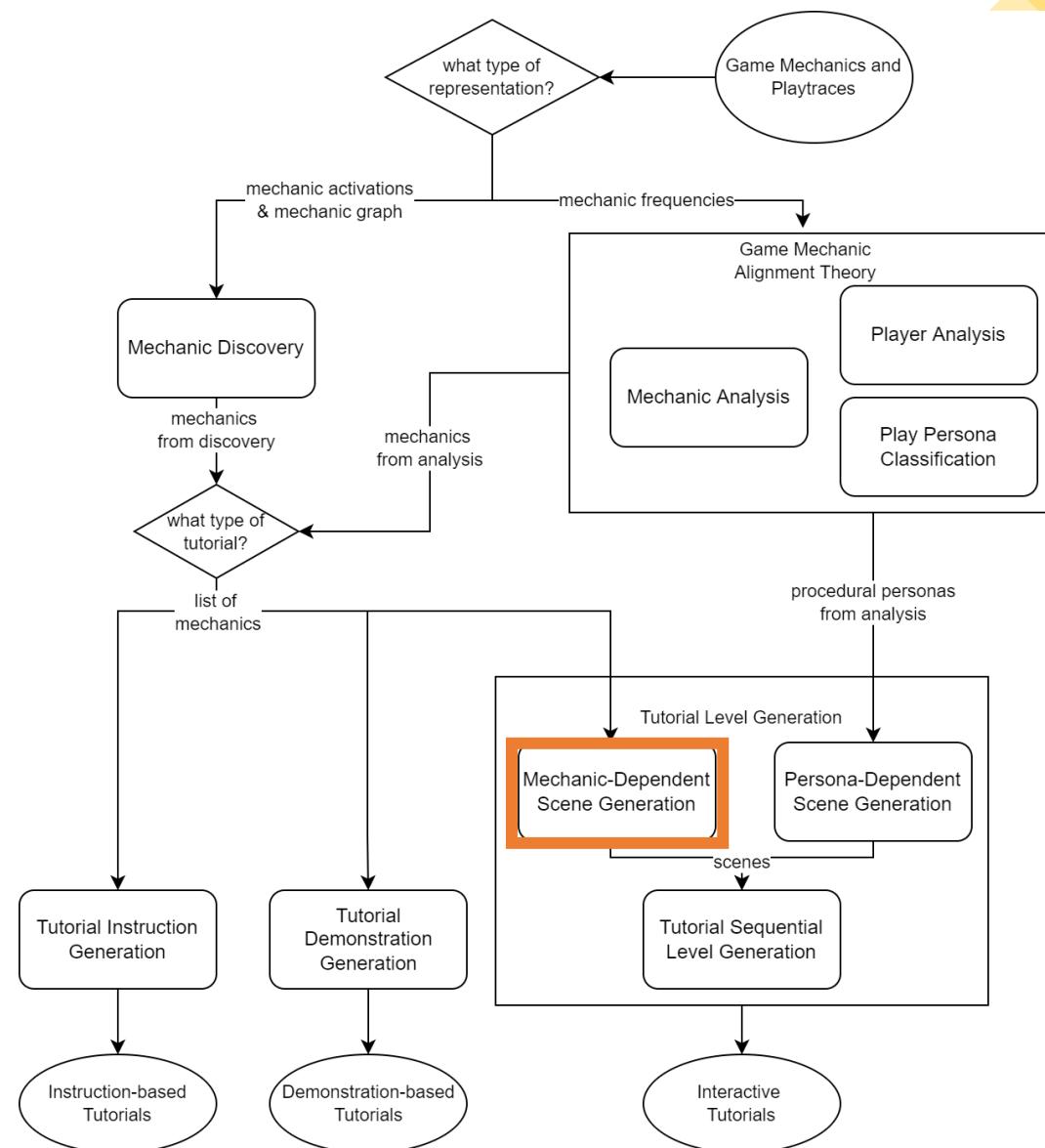
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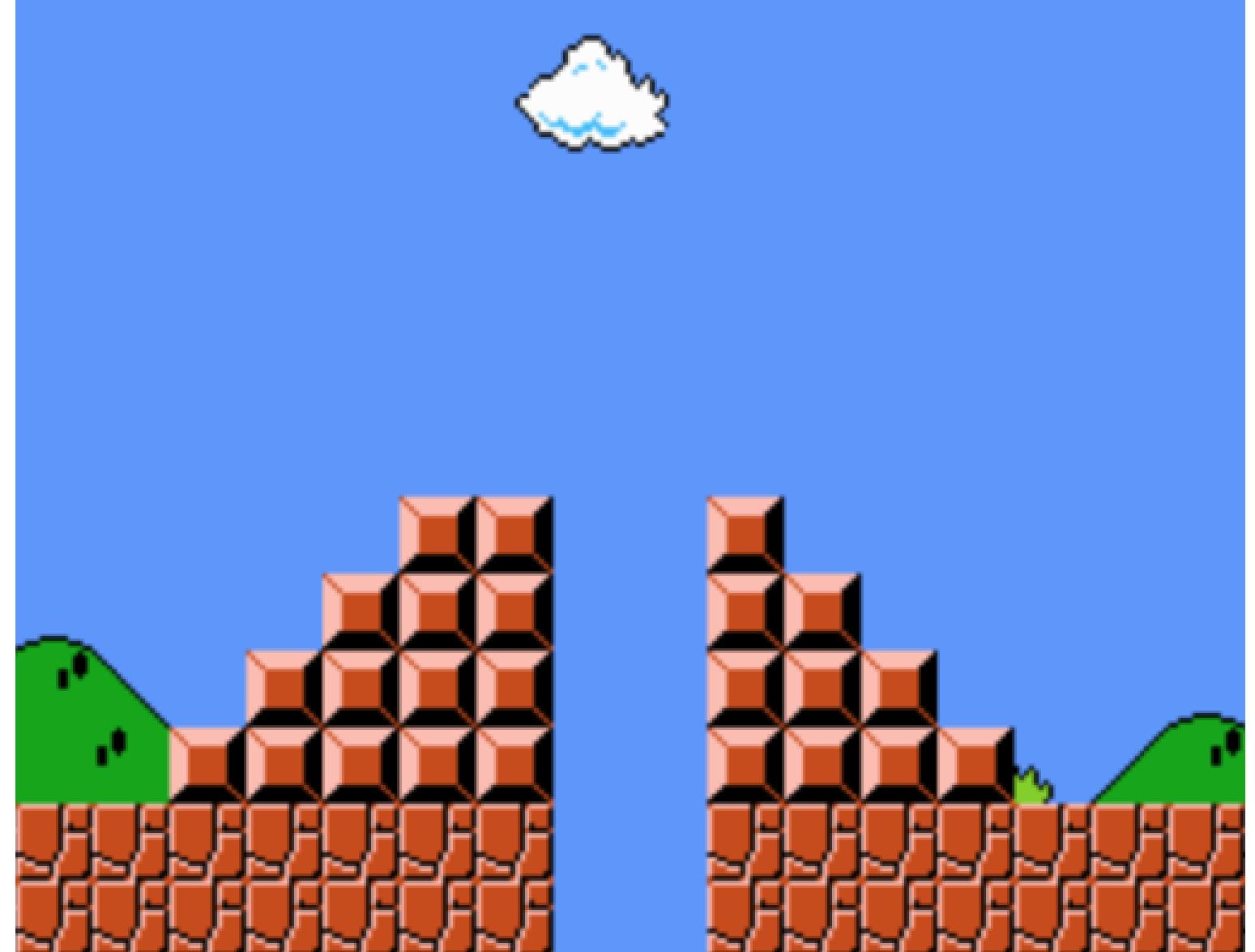




Mechanic-dependent Scene Generation



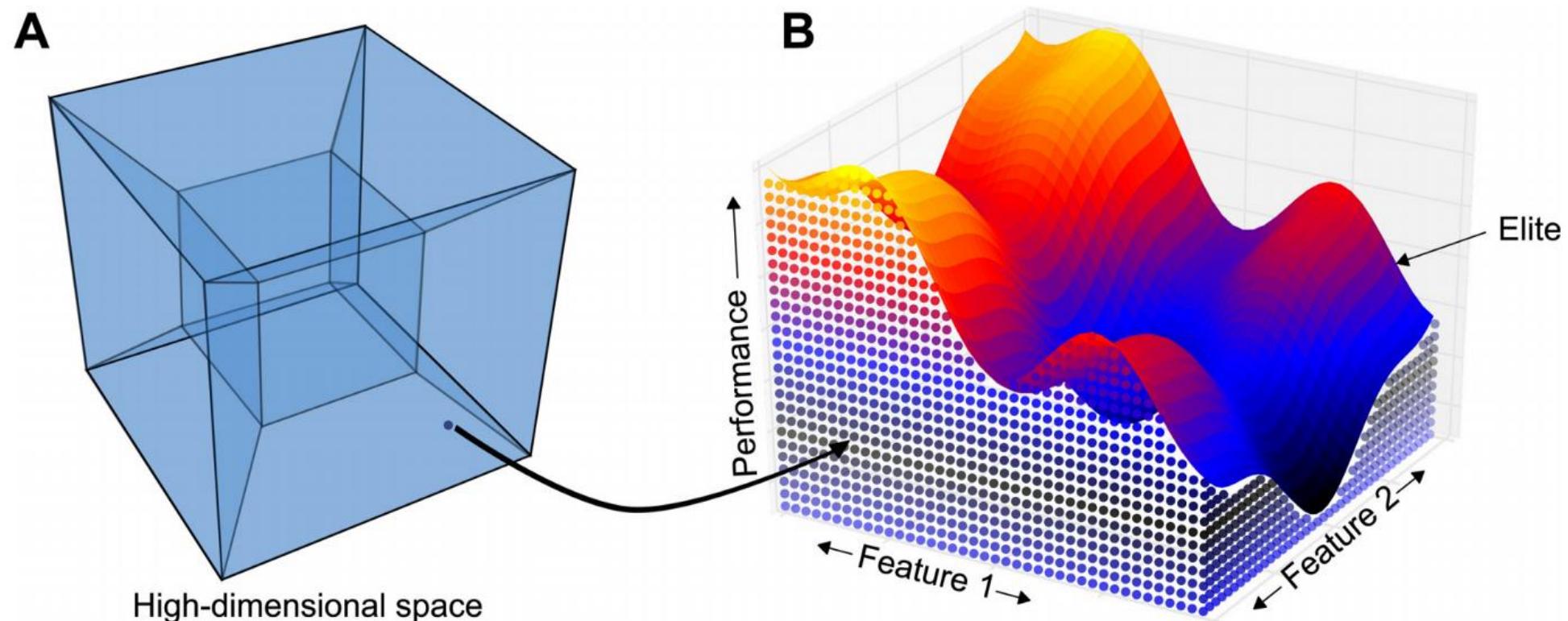
What is a scene?



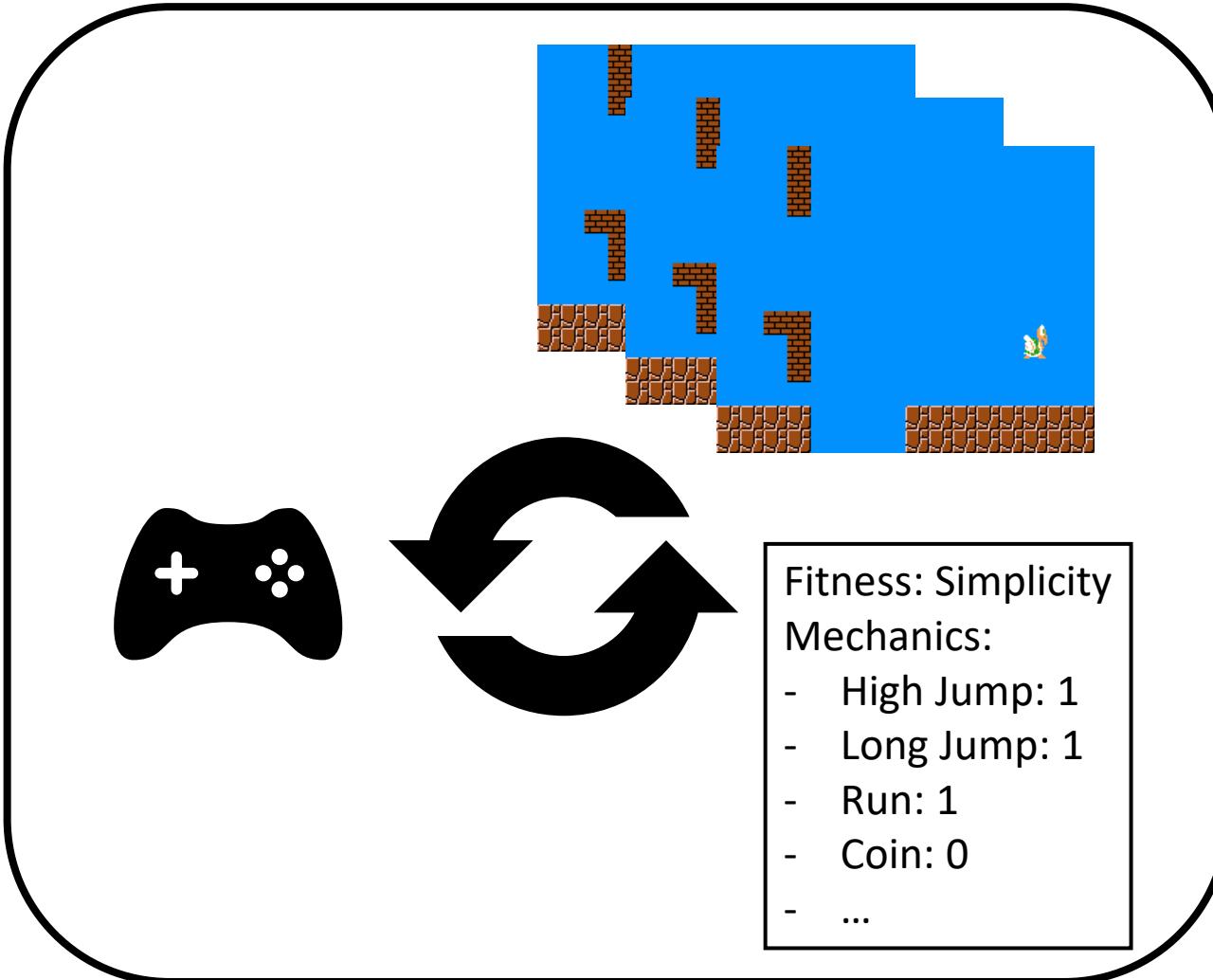
Mechanic-Dependent Scenes



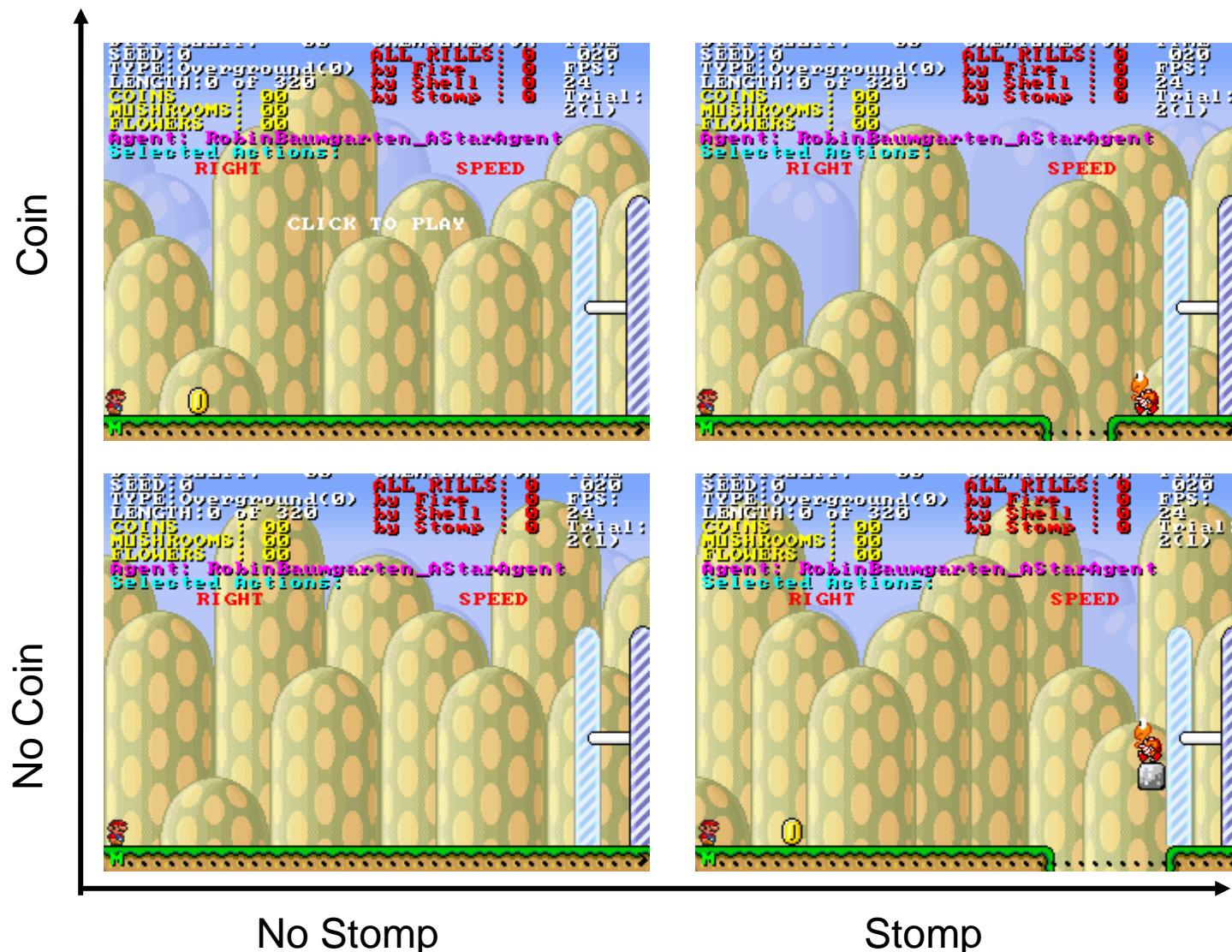
MAP-Elites



Evolution Process



Evolution using Constrained MAP-Elites



Dimension	Description
Jump	is 1 if the player jumped in the level and 0 otherwise.
High Jump	is 1 if the player jumped higher than a certain value and 0 otherwise.
Long Jump	is 1 if the player's horizontal traversed distance after landing is larger than a certain value and 0 otherwise.
Stomp	is 1 if the player stomped on an enemy and 0 otherwise.
Shell Kill	is 1 if the player killed an enemy using a koopa shell and 0 otherwise.
Fall Kill	is 1 if an enemy dies because of falling out of the scene and 0 otherwise.
Mushroom	is 1 if the player collected a mushroom during the scene and 0 otherwise.
Coin	is 1 if the player collected a coin during the scene and 0 otherwise.

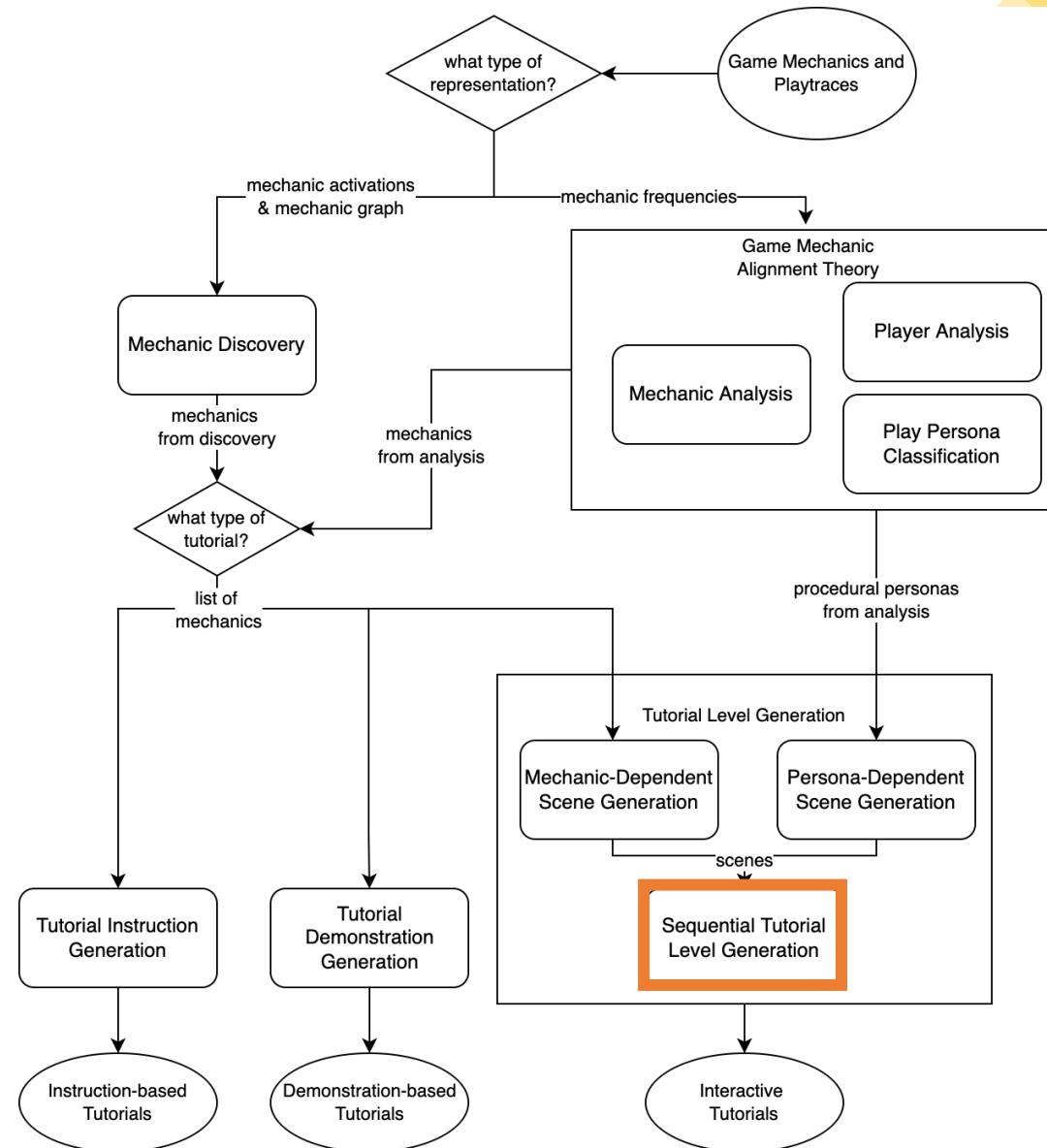
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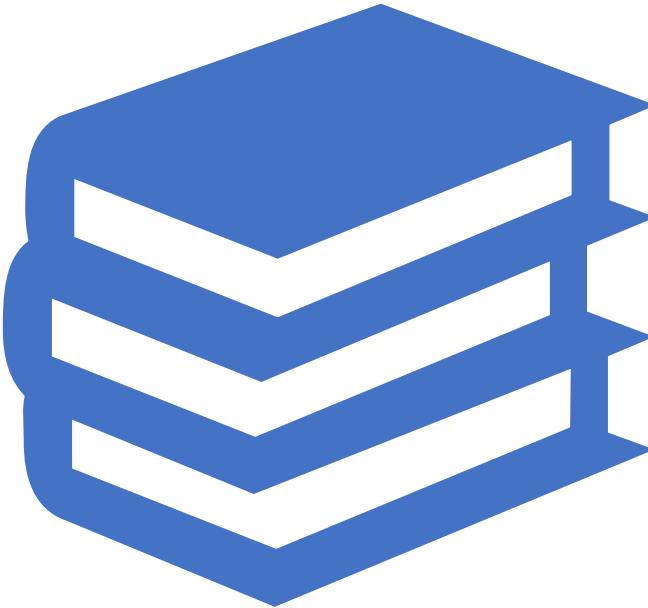
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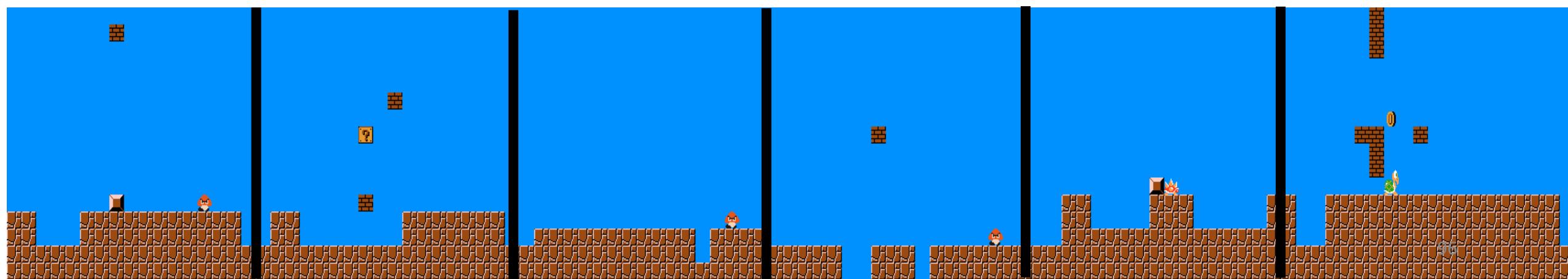
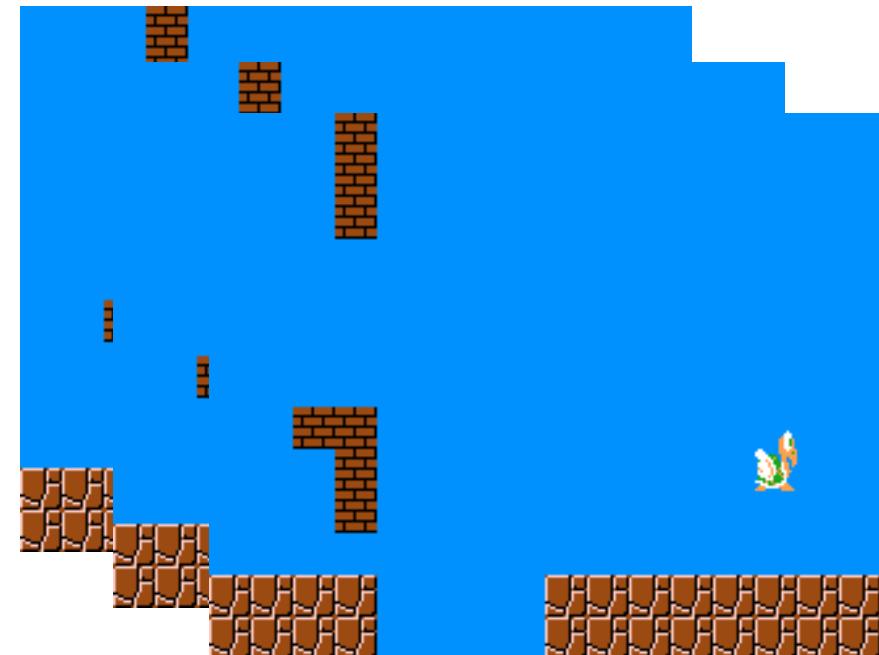
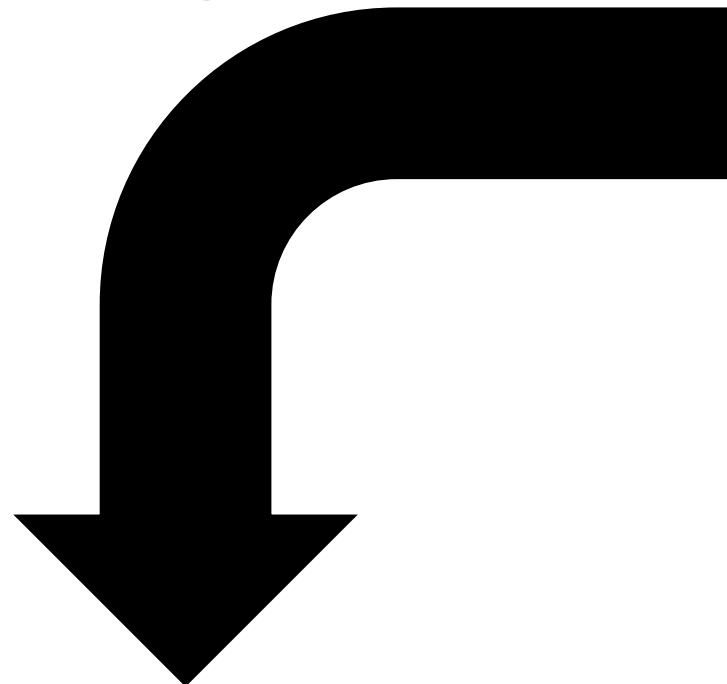




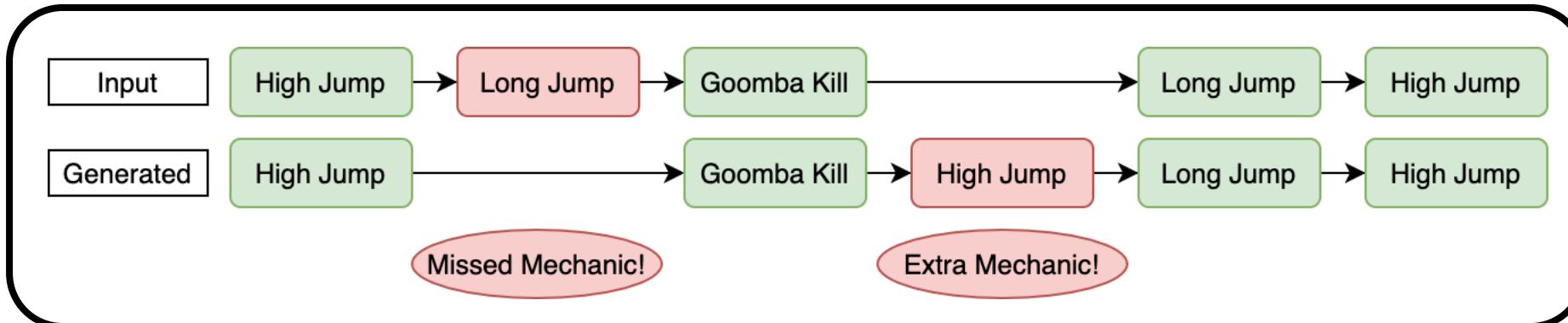
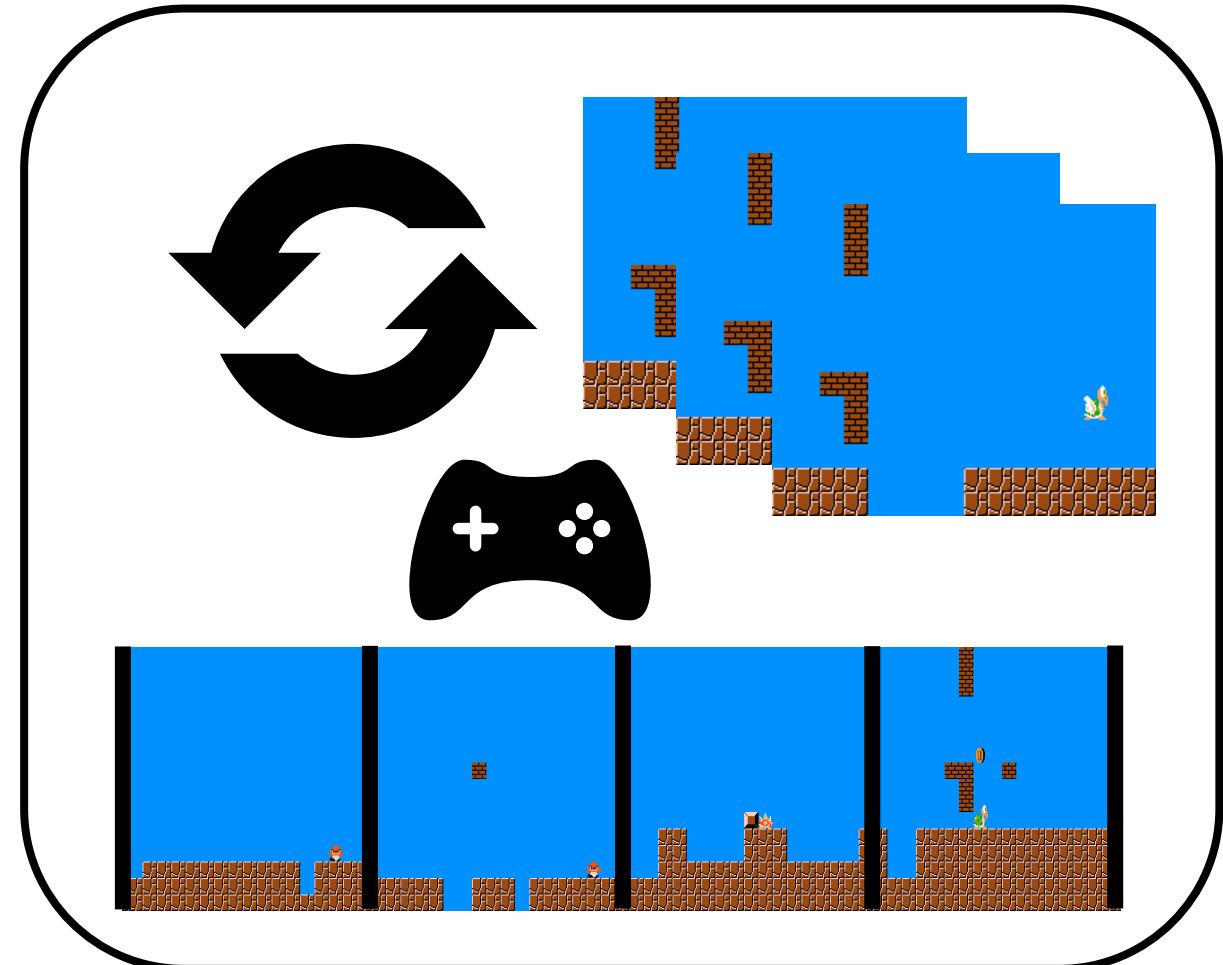
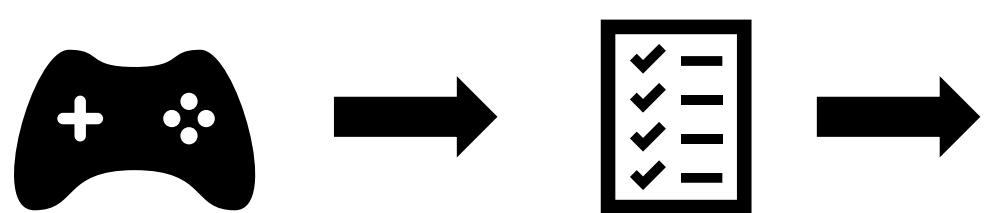
Sequential Tutorial Level Generation

- Concatenate scenes
- Sequence level curriculums
- Scenes can come from anywhere

Scene Stitching



Evolution Process



Show off some results for world 1-1



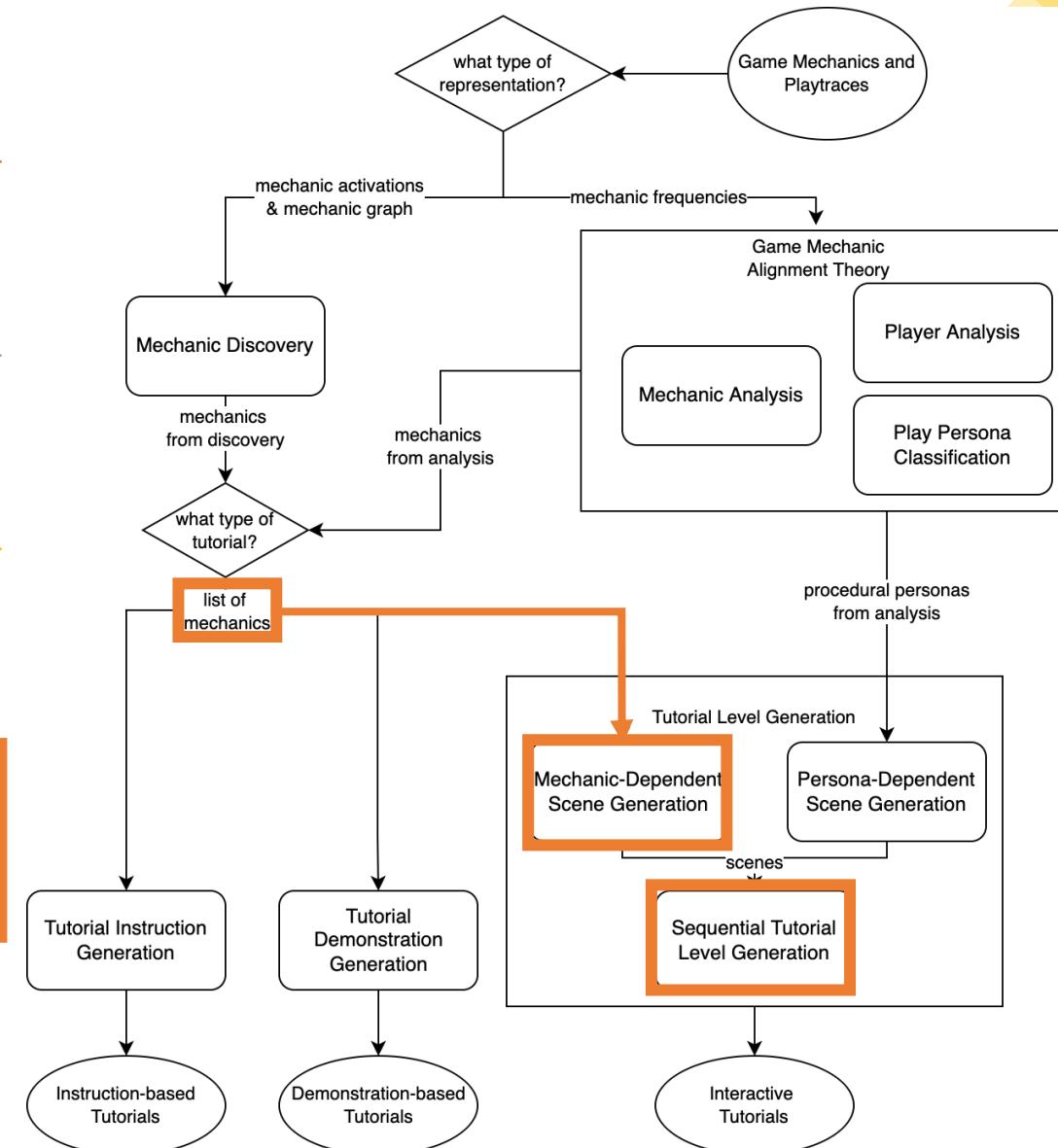
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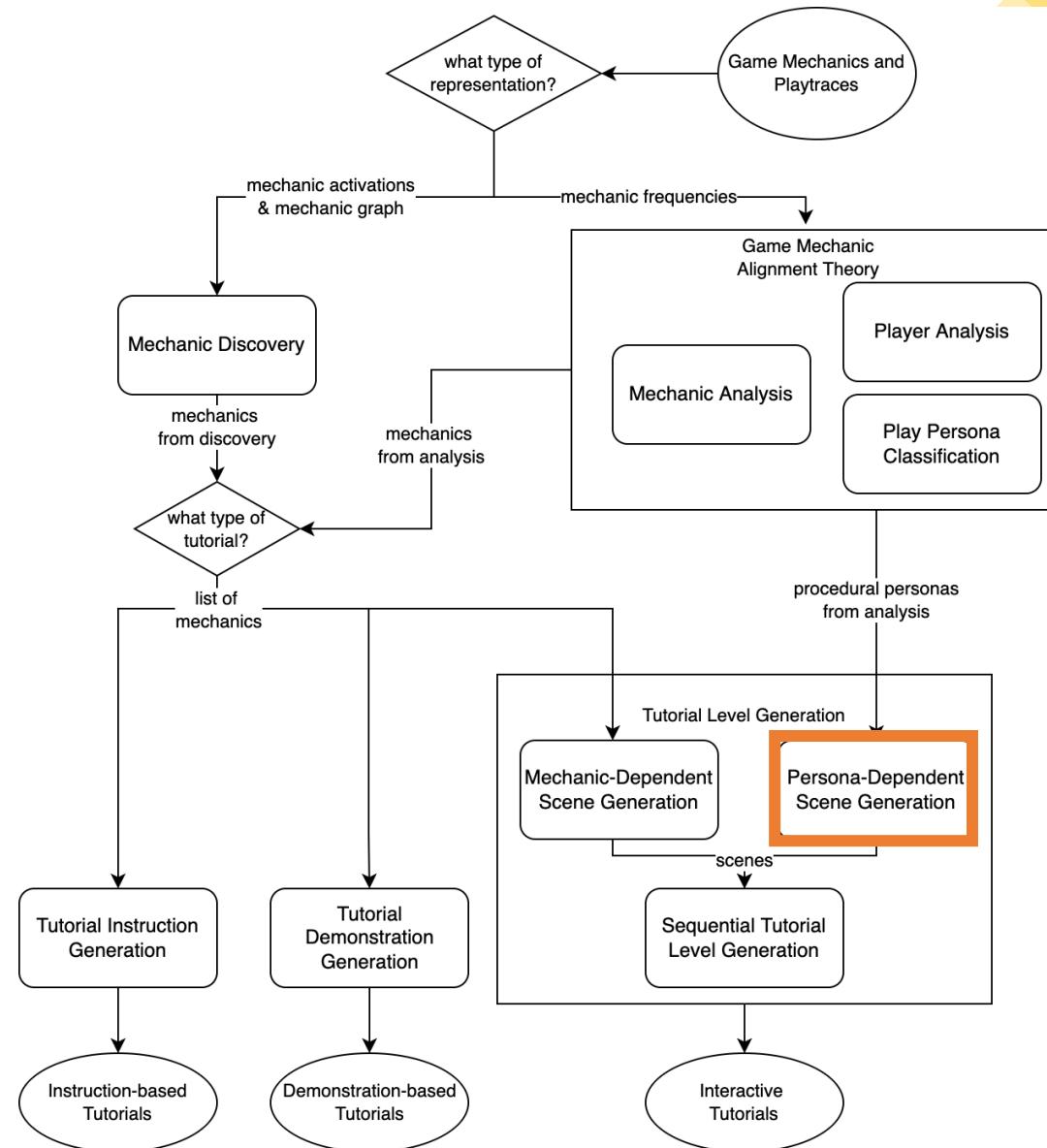
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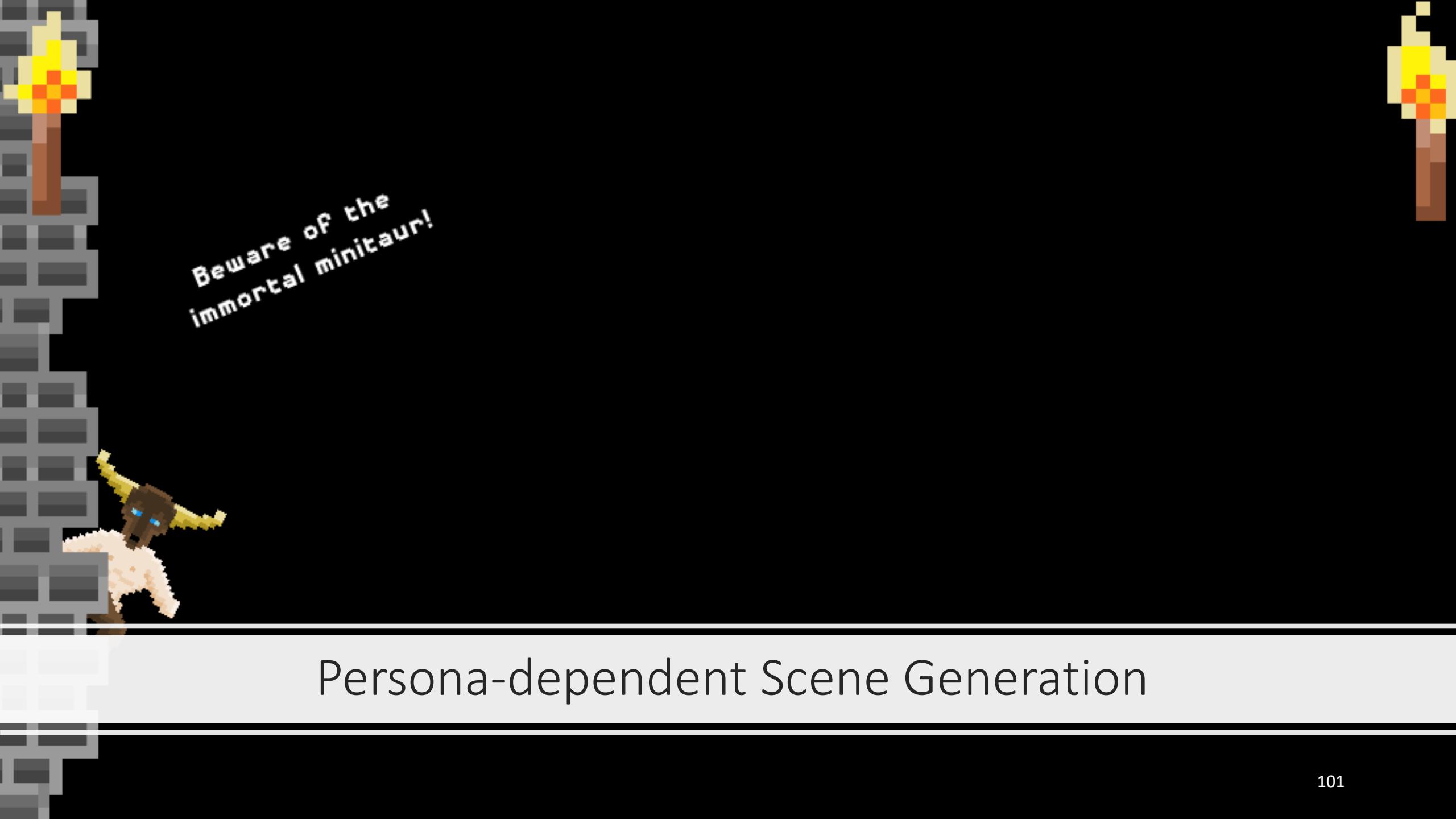
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*Beware of the
immortal minotaur!*

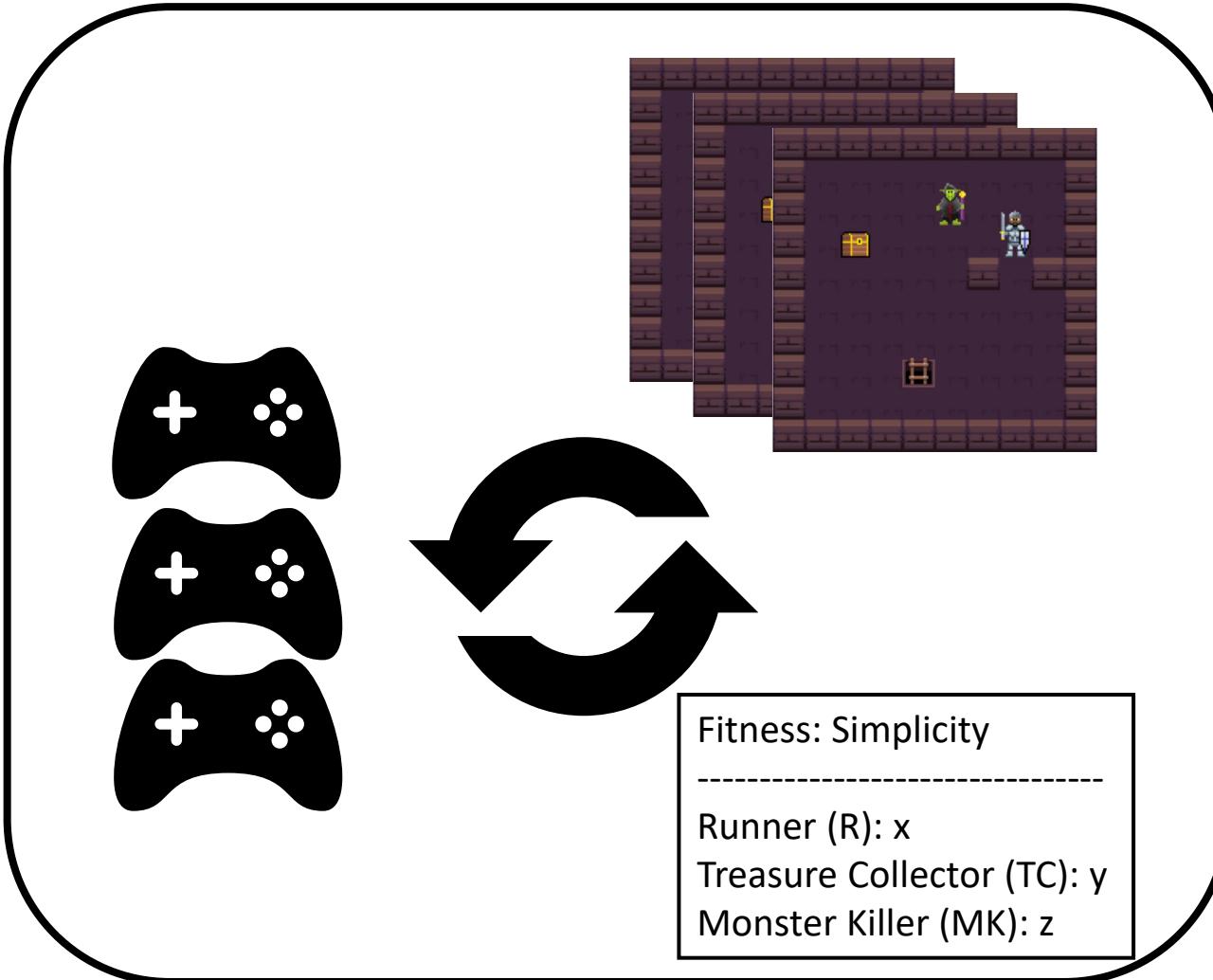
Persona-dependent Scene Generation

Persona-dependent Scenes

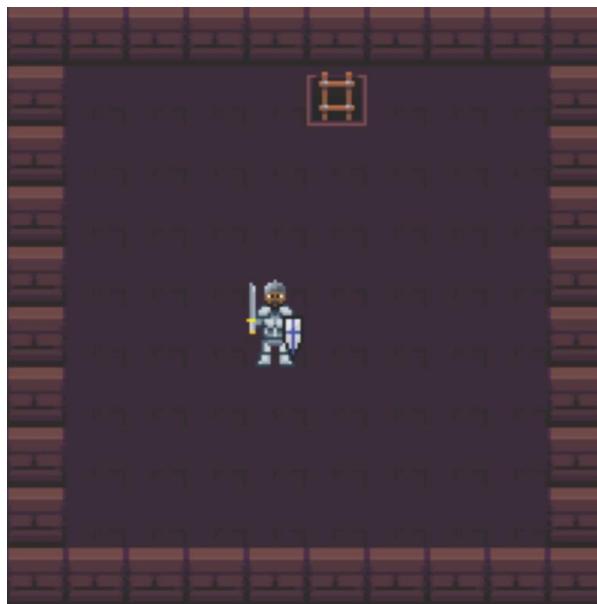
Promote/dissuade playstyles



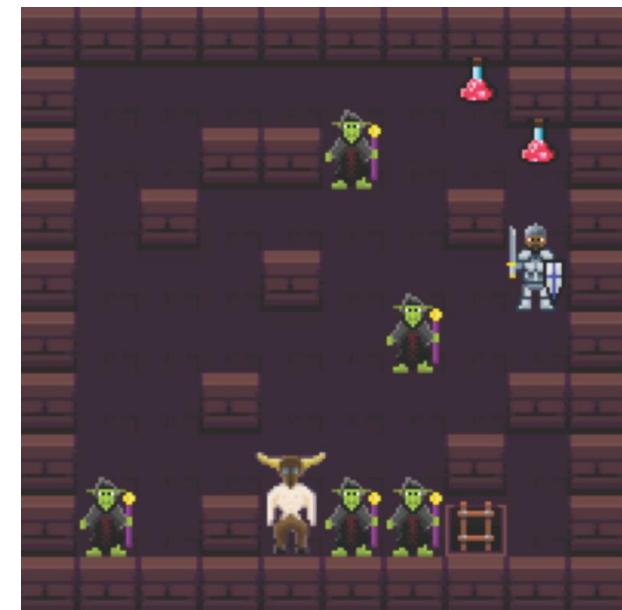
Evolution Process



Balanced Levels



R: 4 | TC: 4 | MK: 4
Fitness: 0.67



R: 0 | TC: 0 | MK: 0
Fitness: 0.53

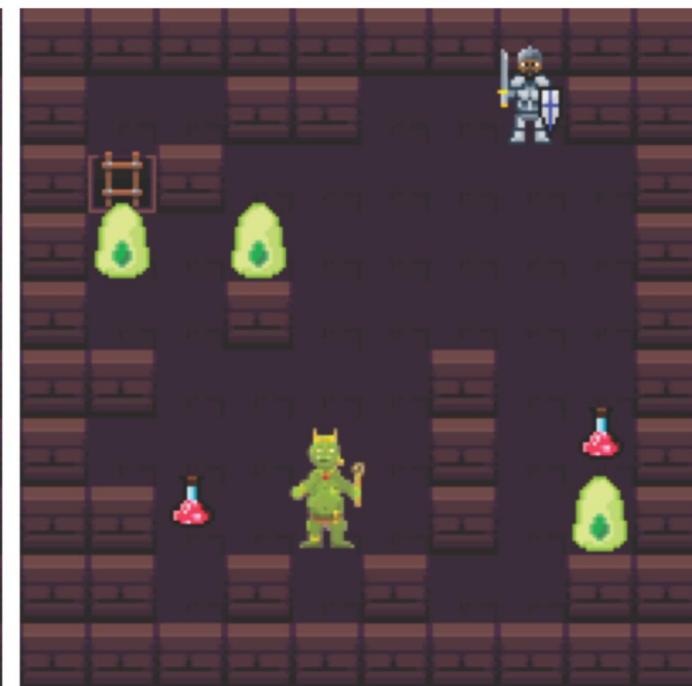
Unbalanced Levels



R: 4 | TC: 2 | MK: 2
Fitness: 0.56



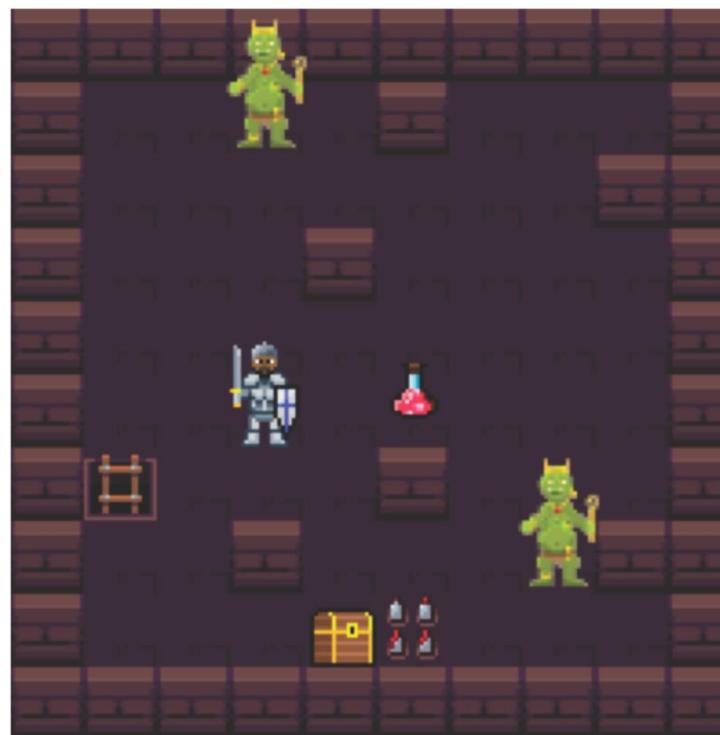
R: 3 | TC: 2 | MK: 1
Fitness: 0.56



R: 4 | TC: 2 | MK: 2
Fitness: 0.55

Unbalanced Levels

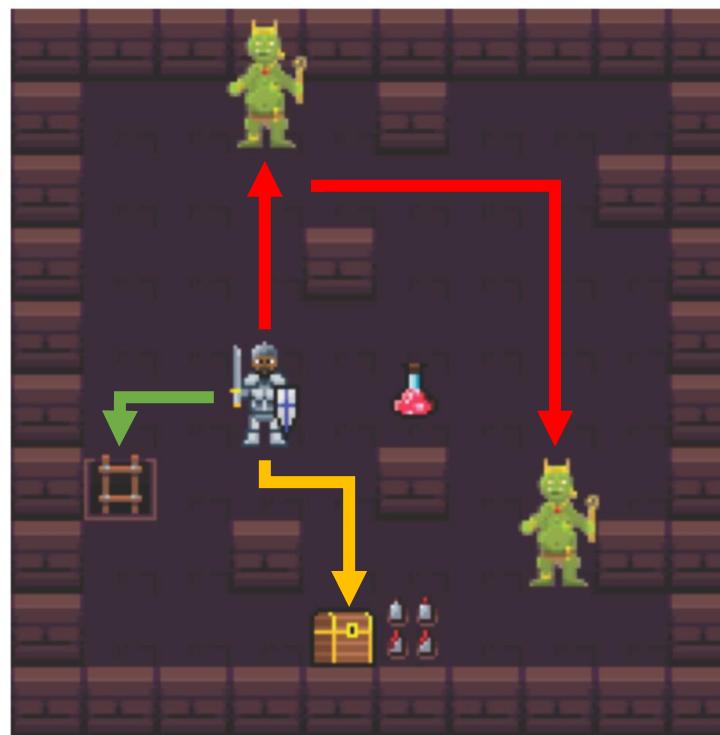
- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 2 | MK: 2
Fitness: 0.56

Unbalanced Levels

- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 2 | MK: 2
Fitness: 0.56

Unbalanced Levels

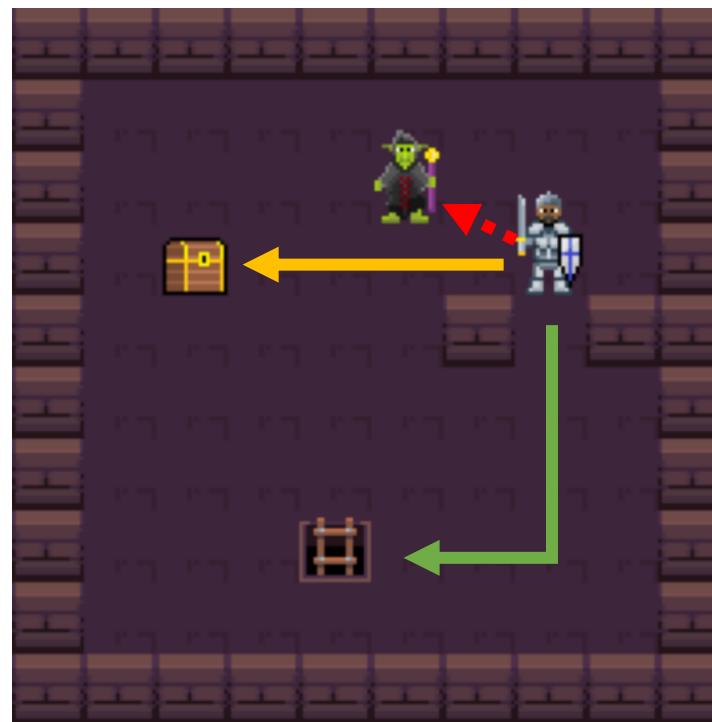
- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 1 | MK: 4
Fitness: 0.62

Unbalanced Levels

- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 1 | MK: 4
Fitness: 0.62

Extremely Unbalanced Levels

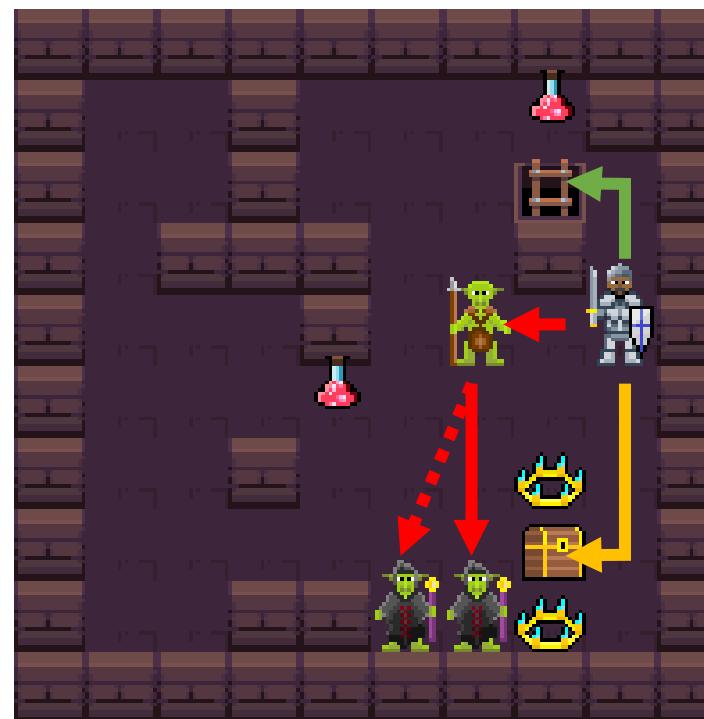
- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 0 | MK: 3
Fitness: 0.506

Extremely Unbalanced Levels

- Runner
- Treasure Collector
- Monster Killer



R: 4 | TC: 0 | MK: 3
Fitness: 0.506

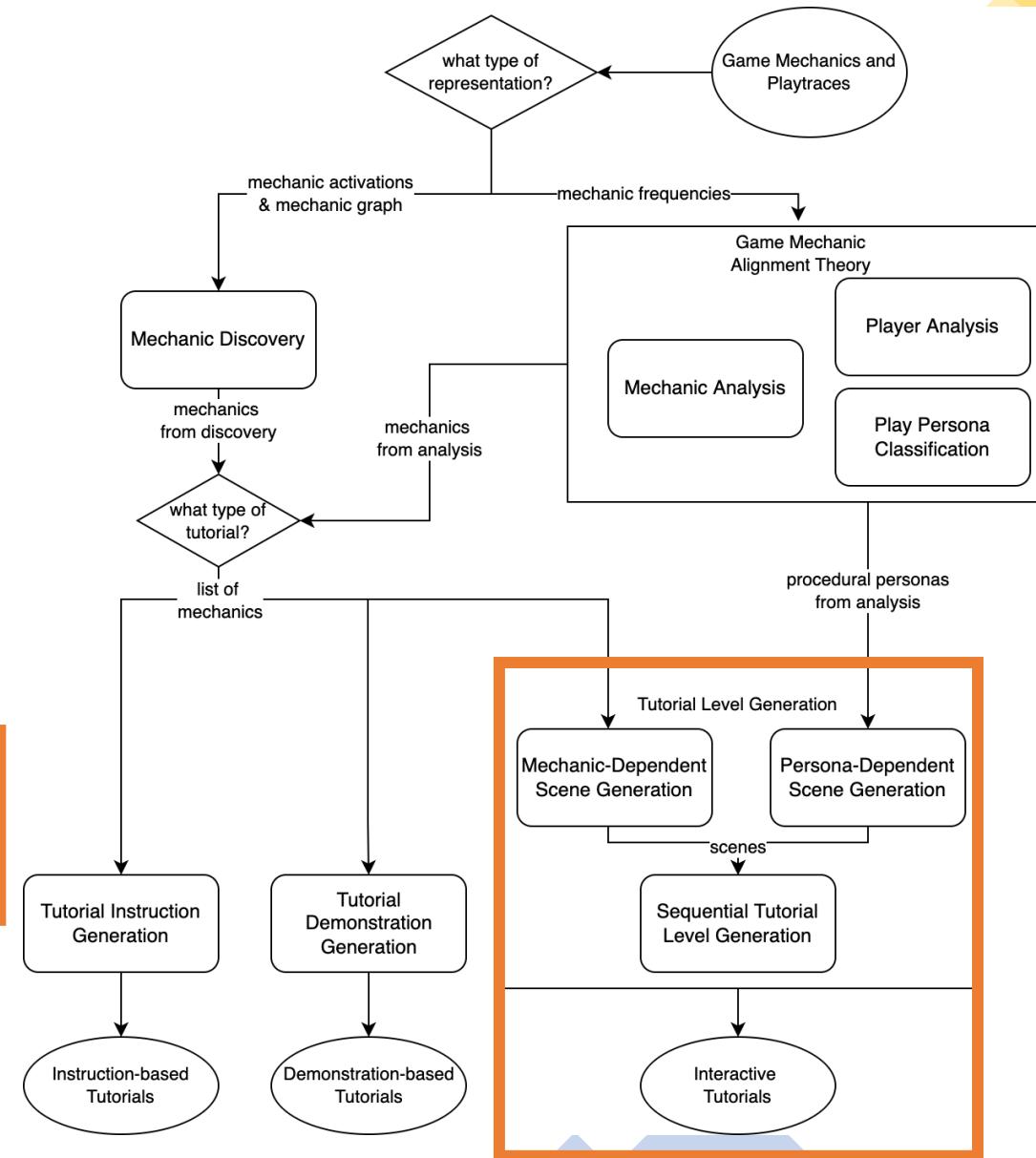
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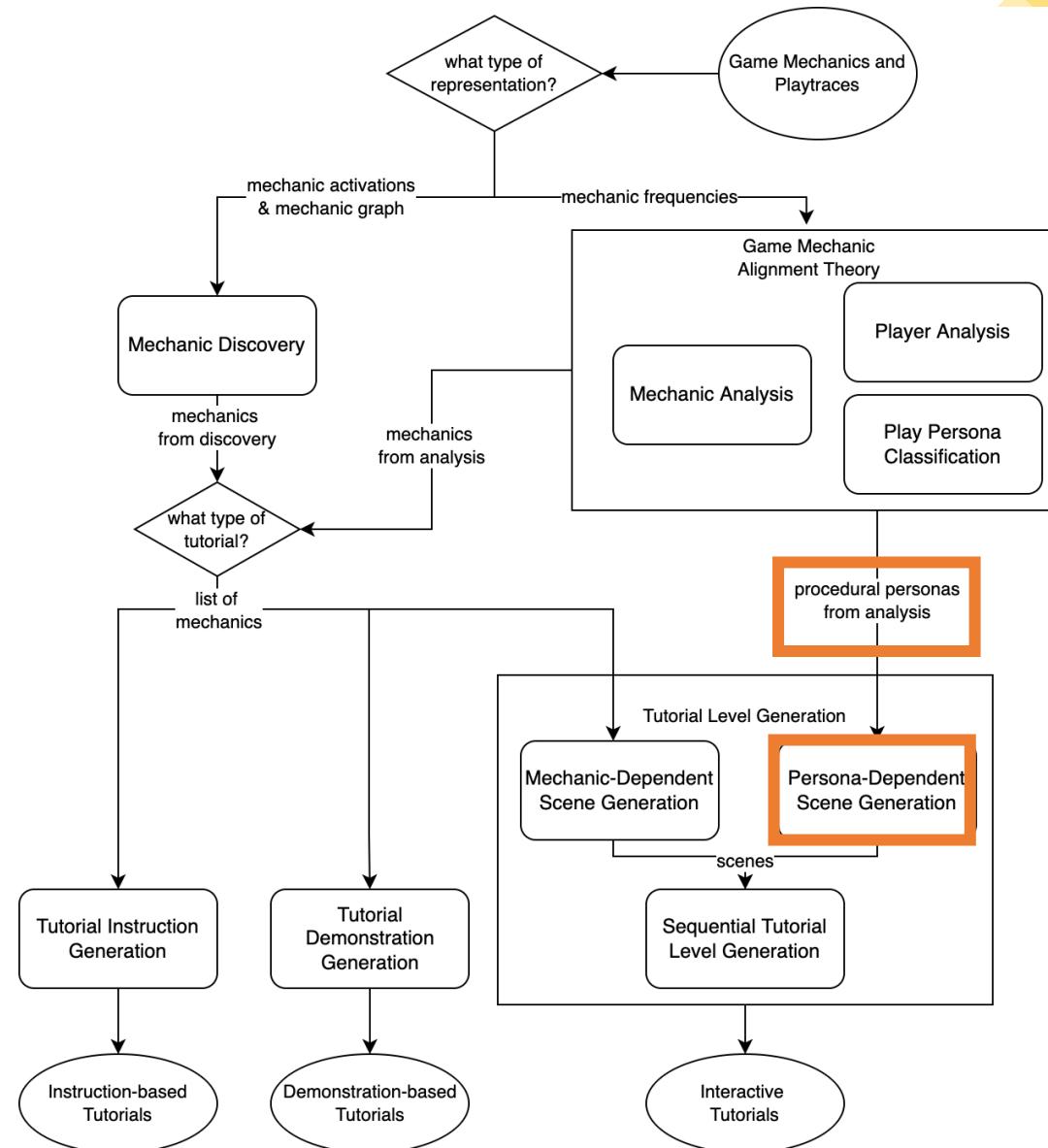
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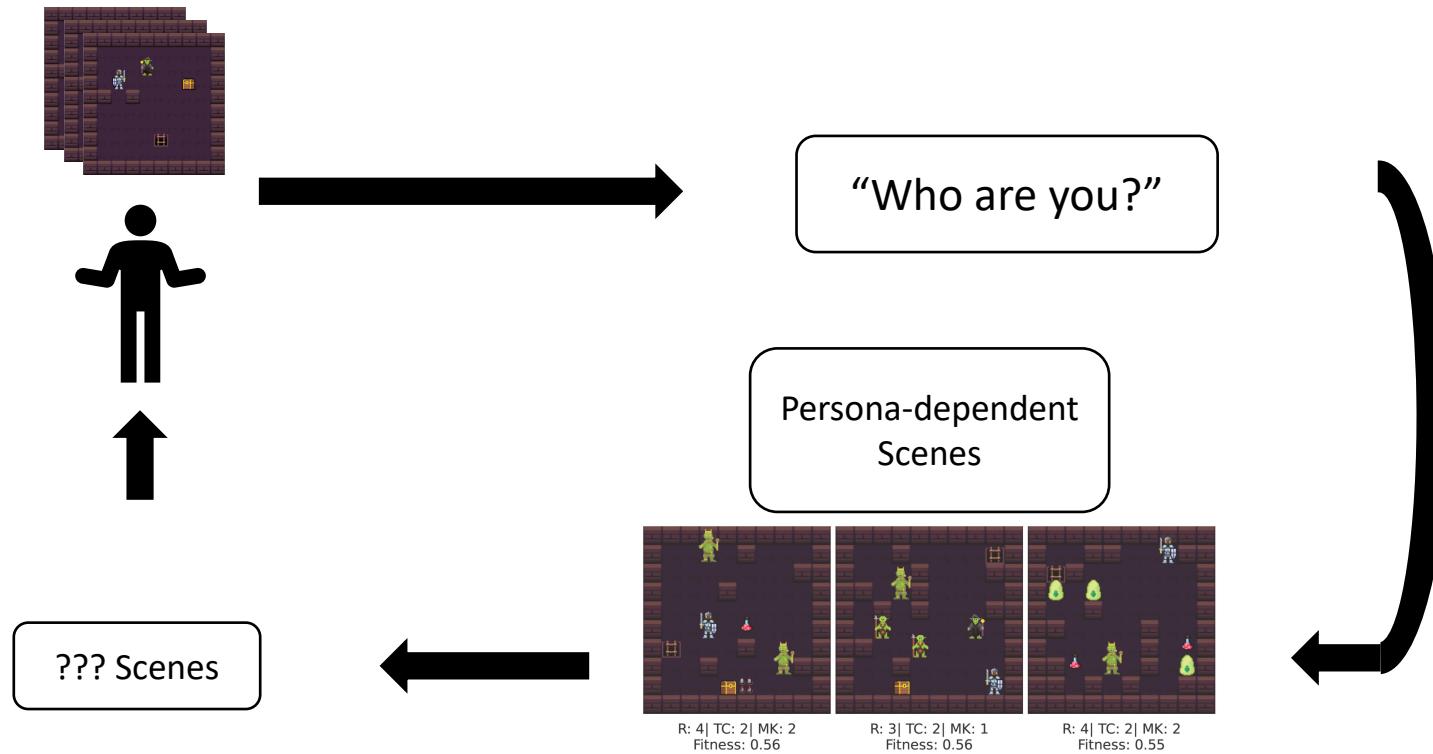
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A Persona-dependent Pipeline



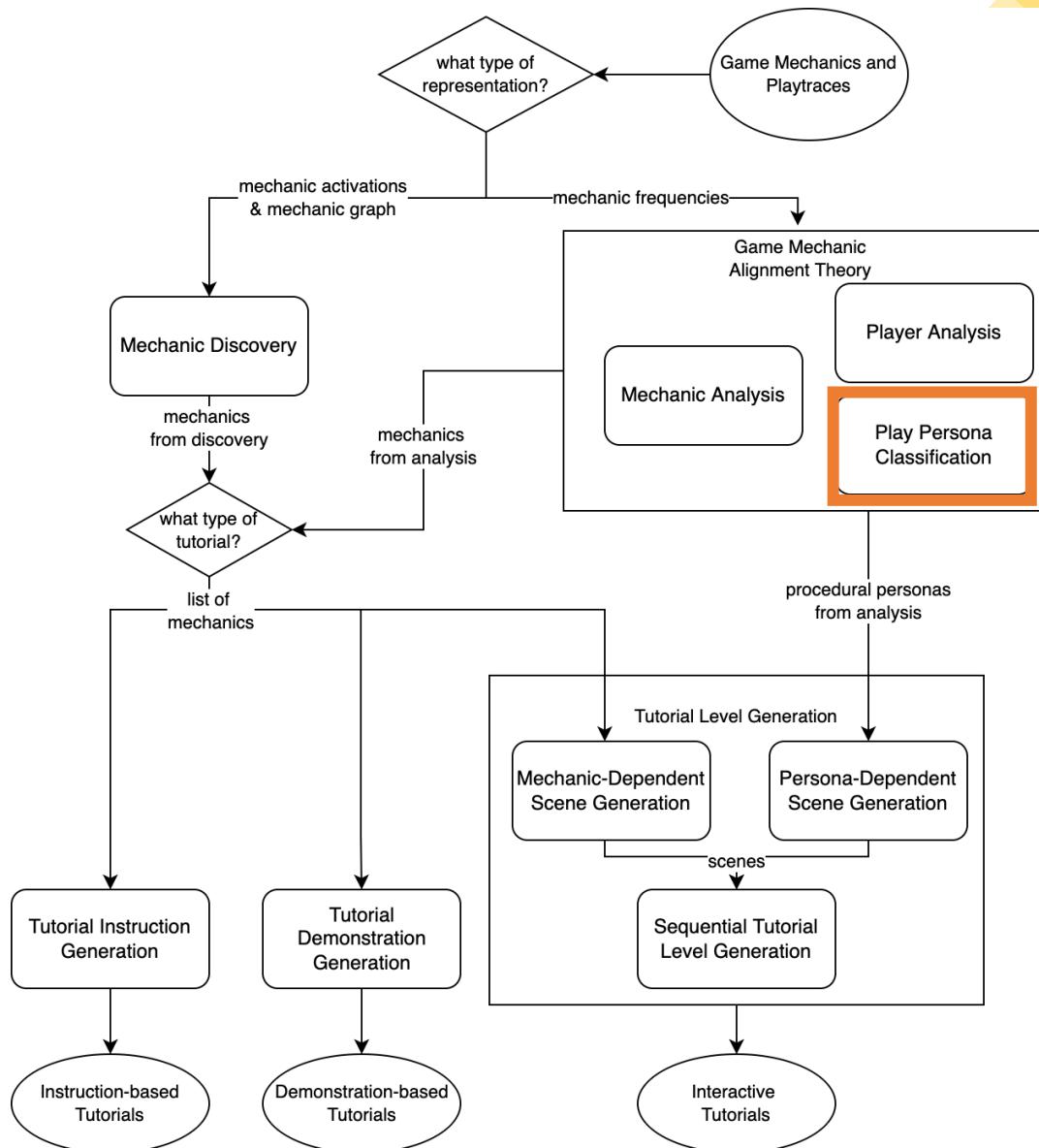
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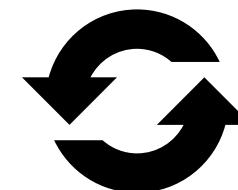
Play Persona Classification



Training on the User Study (SVM)

EnemyKill	TakeTurn	UsePortal	CollectTreasure	CollectPotion	JavelinThrow	Label
4	45	2	3	0	3	MK
1	24	2	0	1	0	R
6	40	0	1	3	5	MK

	Count
No Label	136
R	243
TC	92
MK	3
R/TC	108
R/MK	69
TC/MK	34
R/TC/MK	173

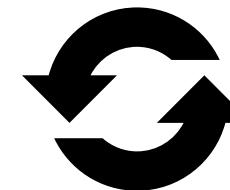


SVM

Training on the User Study (LSTM)



	Count
No Label	136
R	243
TC	92
MK	3
R/TC	108
R/MK	69
TC/MK	34
R/TC/MK	173



Model	Training	Validation	Testing
LSTM	0.837 ± 0.03	0.784 ± 0.067	0.726 ± 0.029
SVM	0.777	0.694	0.700

Classification Pipeline

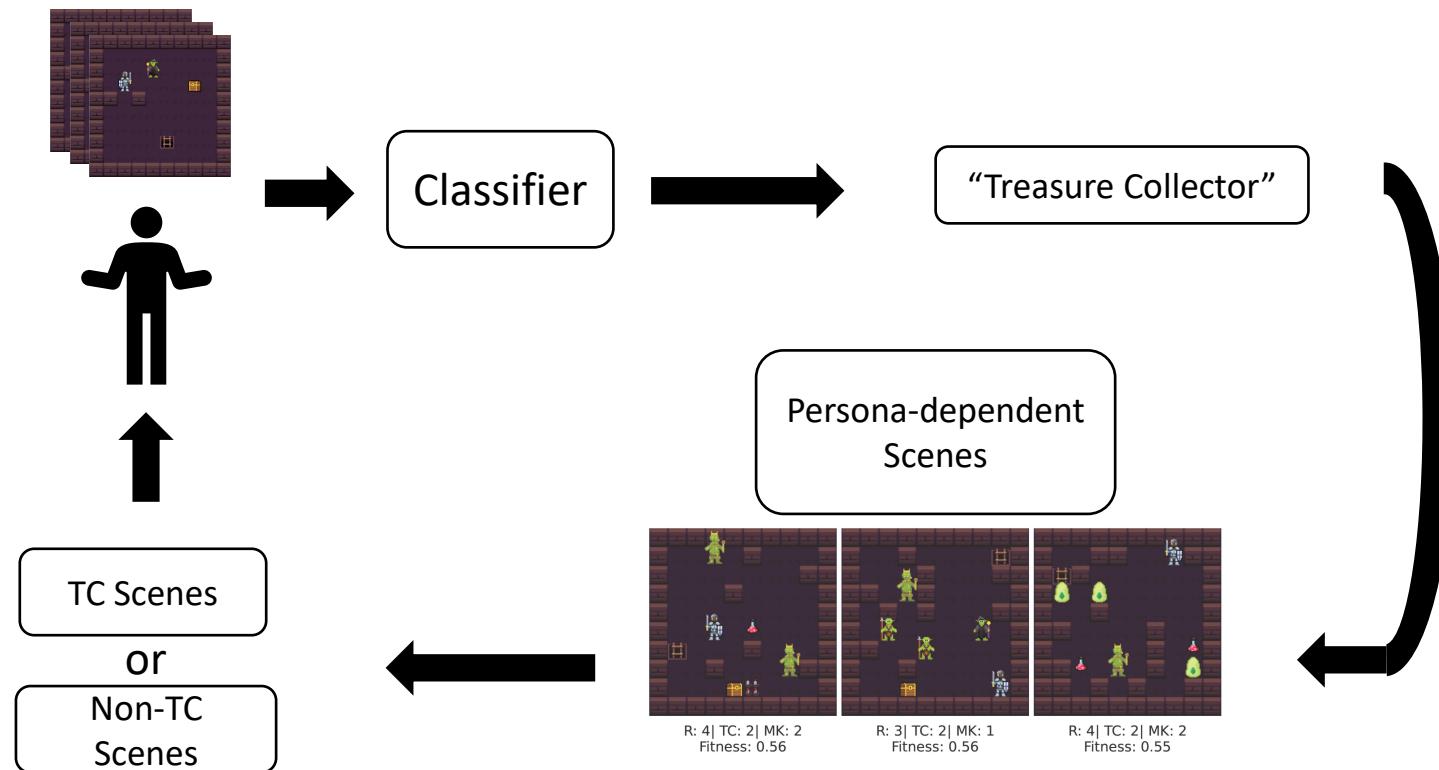
- LSTM – sequential game states
- SVM – mechanic frequency vectors

Candy Crush!

- 13 million daily players
- @ 30 seconds a trace
 - ~541.6k traces an hour
 - 4,513 every 30 seconds
- Labeling takes time!
- Game states > Int vectors



A Persona-dependent Pipeline



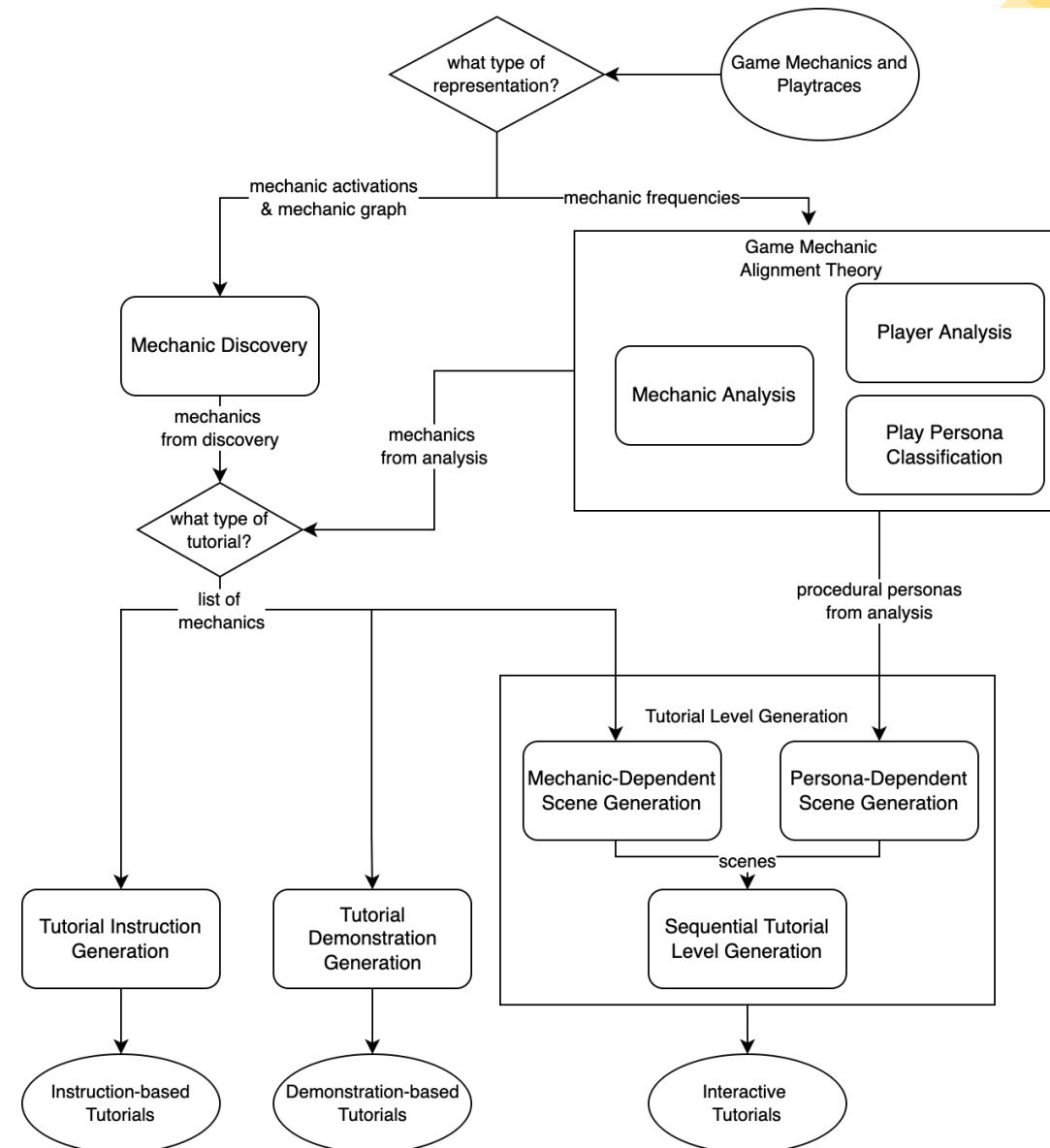
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Thesis Statement



“We can automatically generate tutorials and tutorial levels for video games using mechanics and play personas.”

Next Steps - Mechanics

Mechanic graphs
from video or other
means?

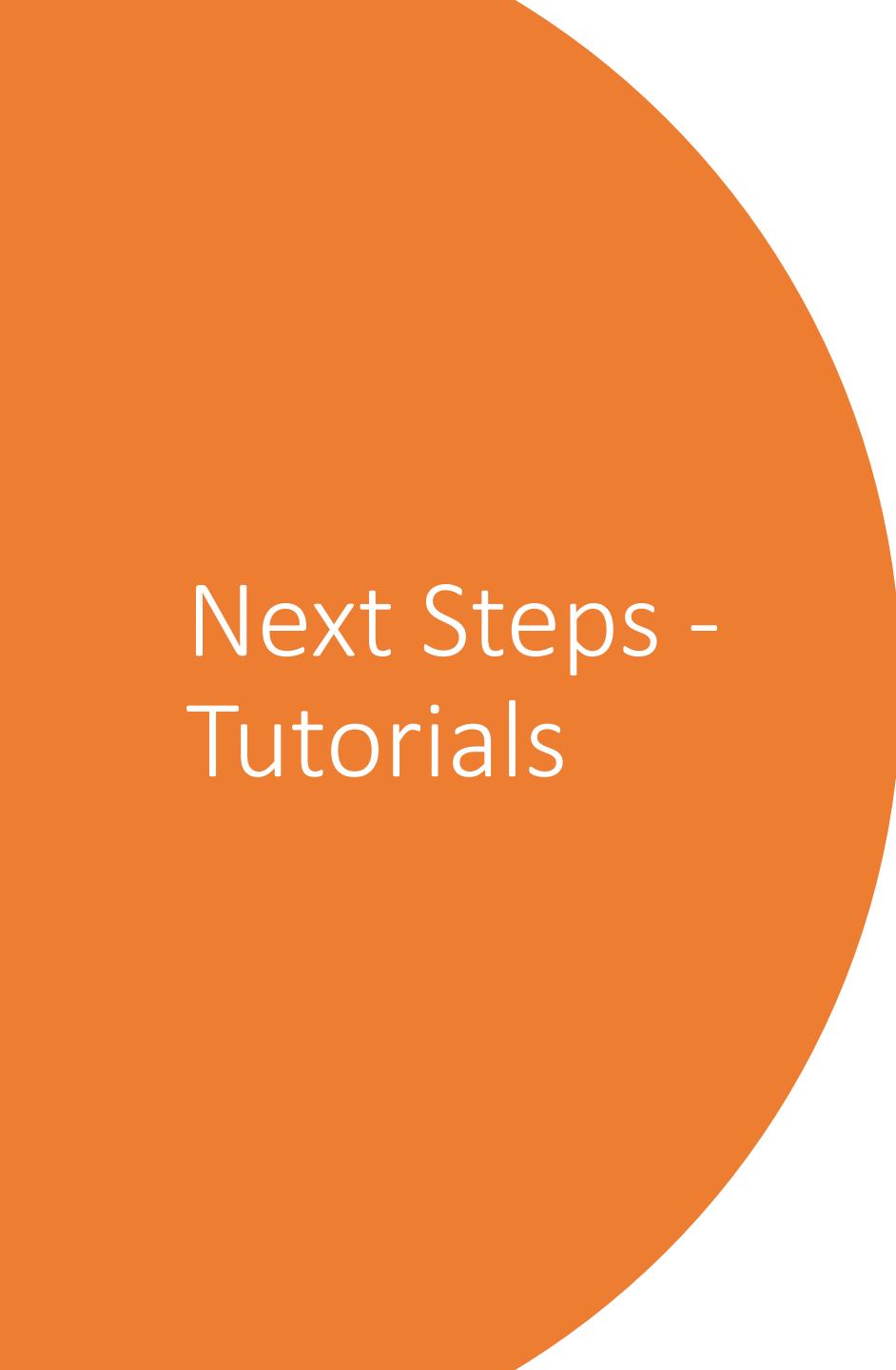
Separate player
mistakes/accidents
from intent?

A large orange circle is positioned on the left side of the slide, overlapping the white background.

Next Steps -
Personas

No procedural
personas?

Better ways to
classify playstyle?

A large orange circle is positioned on the left side of the slide, overlapping the white background.

Next Steps -
Tutorials

Automated,
adaptive level
curriculums?

More complex
games?

Final Thoughts

- Math, Science, Language...
- Personalized education



Questions?

