Modular Design and Coordination of Computer-Controlled Characters in Games

Thesis Defense – University of Antwerp

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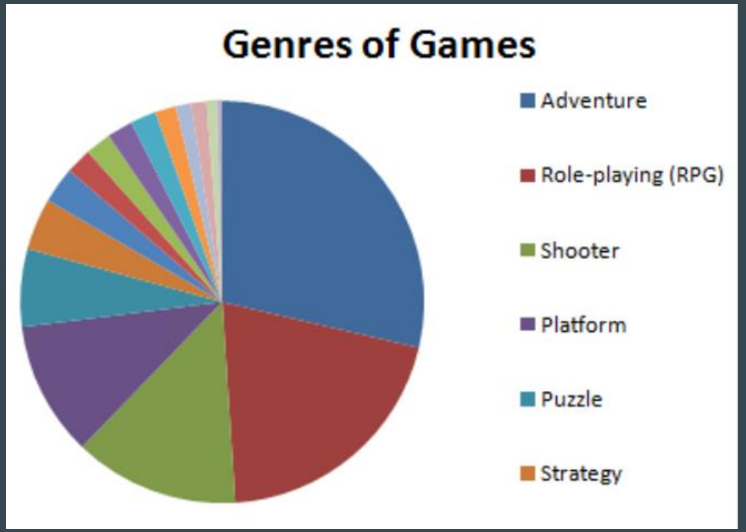
Motivation

- The need for believable NPCs
- Popular game genres
- Team-based game
- Autonomy and Coordination

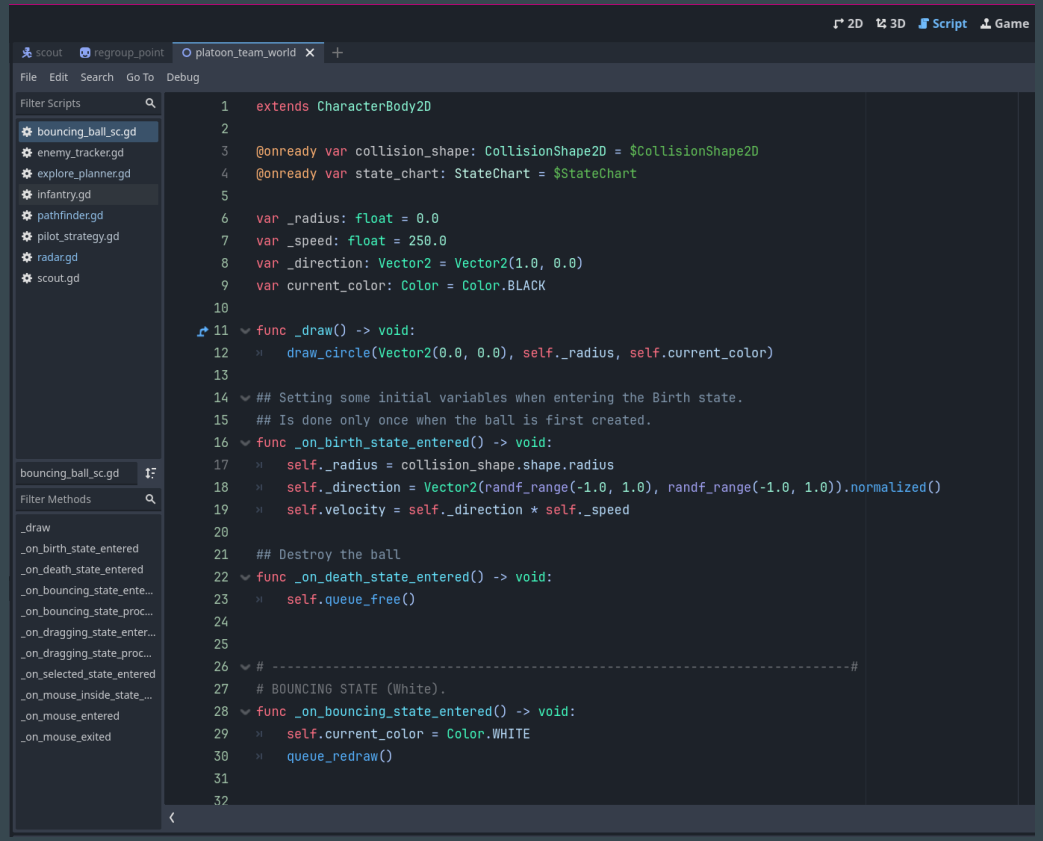


[1]

[1] A. A. Qaffas, “An operational study of video games’ genres,” International Journal of Interactive Mobile Technologies (iJIM), vol. 14, no. 15, pp. 175–194, 2020.

The Godot engine

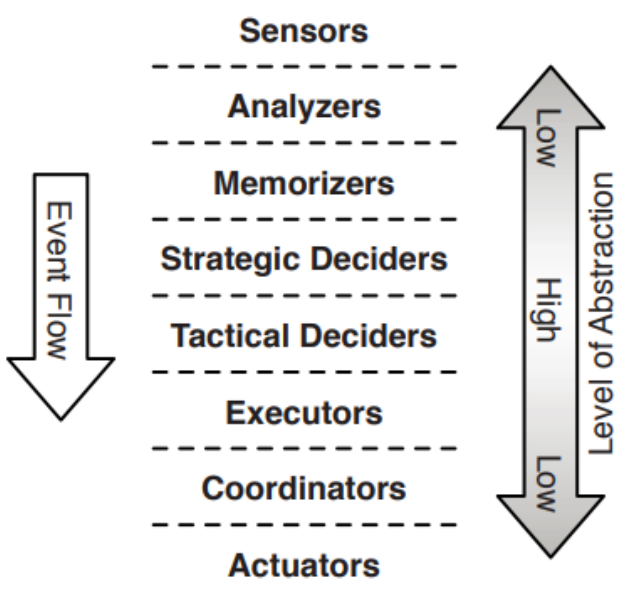
- Nodes
- Scenes
- SceneTree
- Behavior through code
  - GDScript




Scene Project Debug Editor Help
2D 3D Script Game AssetLib
PlatoonTeamWorld
TileMapLayer
Bounds
area
Camera2D
Infantry
Infantry2
AllyPoint
InfantryEnemy
InfantryEnemy2
EnemyPoint
FileSystem
BouncingBalls
examples
godot_state_charts_examples
Platooning
Memorizers
Scenarios
platoon_leader_world.gd
platoon_leader_world.tscn
platoon_scout_world.gd
platoon_scout_world.tscn
platoon_team_world.gd
platoon_team_world.tscn
Sensors
StrategicDeciders
TacticalDeciders
communicator.gd
communicator.tscn
Output Debugger (1) Audio Animation Shader Editor TileSet

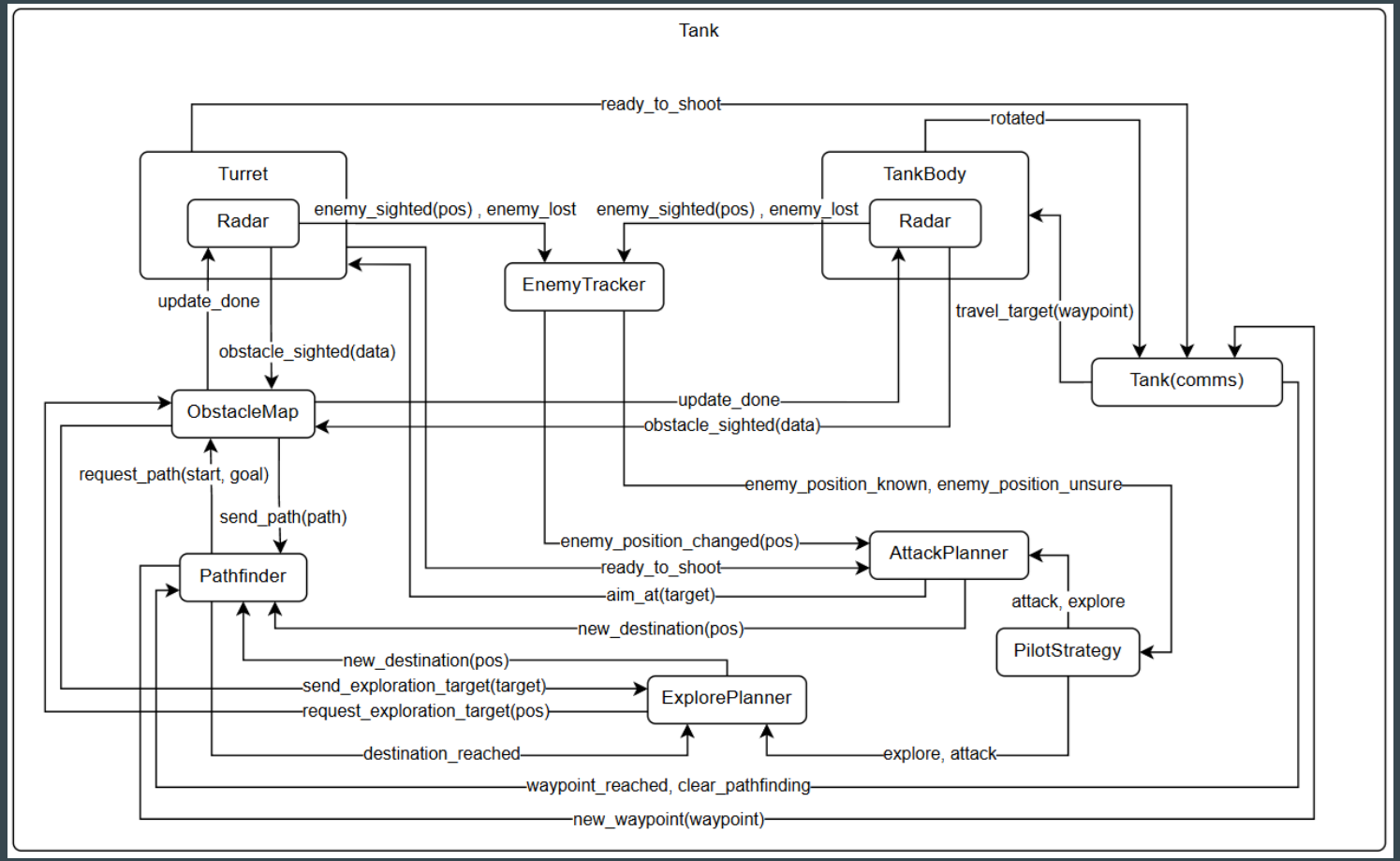
Modular Design

- Understandability
- Reusability
- Godot's modularity
- Appropriate formalism
- Inspiration for approach
  - Model-based design of computer-controlled game character behavior [2]
  - Reusable components for artificial intelligence in computer games [3]



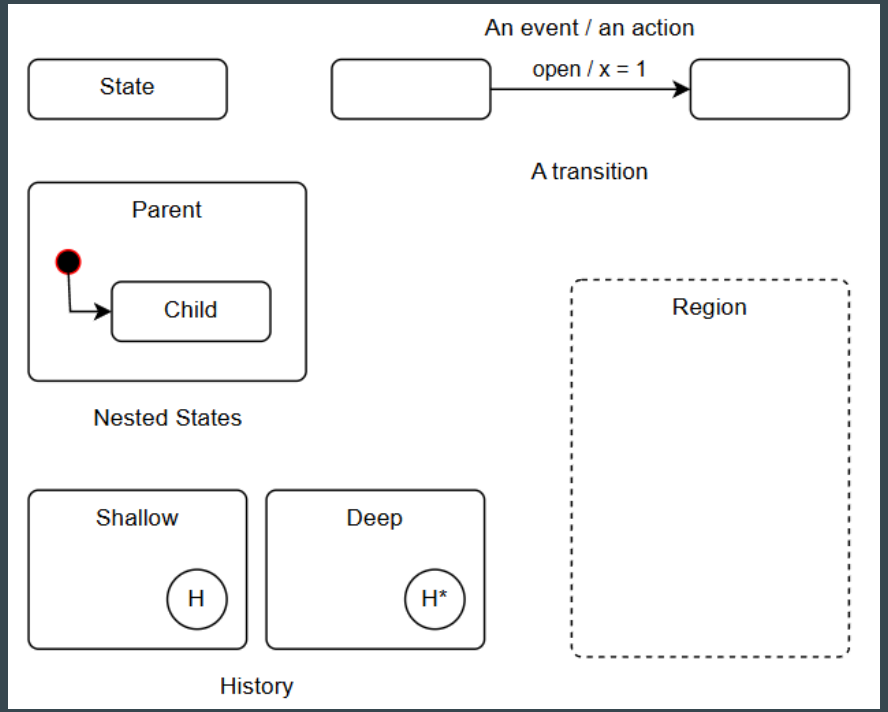
[2]

[2] J. Kienzle, A. Denault, and H. Vangheluwe, "Model-based design of computer-controlled game character behavior," MoDELS 2007, LNCS 4735, pp. 650—665, 2007.
[3] C. Dragert, J. Kienzle, and C. Verbrugge, "Reusable components for artificial intelligence in computer games," GAS, pp. 35–41, 2012.


Tank
ready_to_shoot
rotated
Turret
Radar
enemy_sighted(pos) , enemy_lost
enemy_sighted(pos) , enemy_lost
TankBody
Radar
EnemyTracker
update_done
obstacle_sighted(data)
travel_target(waypoint)
Tank(comms)
ObstacleMap
update_done
obstacle_sighted(data)
request_path(start, goal)
send_path(path)
enemy_position_known, enemy_position_unsure
enemy_position_changed(pos)
AttackPlanner
Pathfinder
ready_to_shoot
aim_at(target)
attack, explore
new_destination(pos)
PilotStrategy
new_destination(pos)
send_exploration_target(target)
ExplorePlanner
request_exploration_target(pos)
destination_reached
explore, attack
waypoint_reached, clear_pathfinding
new_waypoint(waypoint)

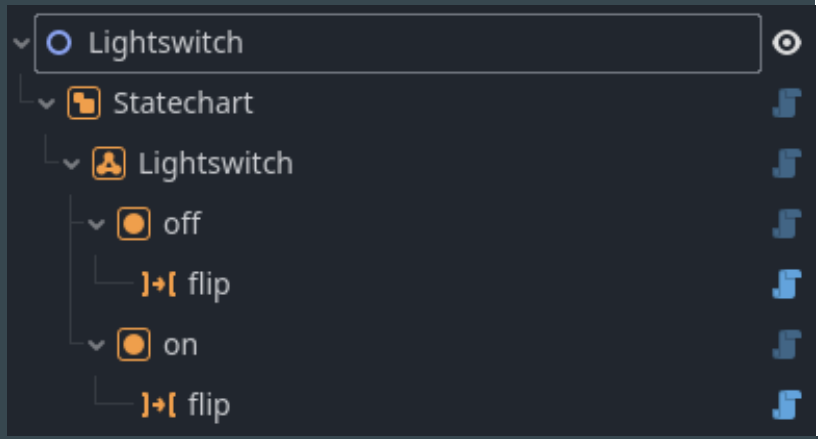
Statecharts

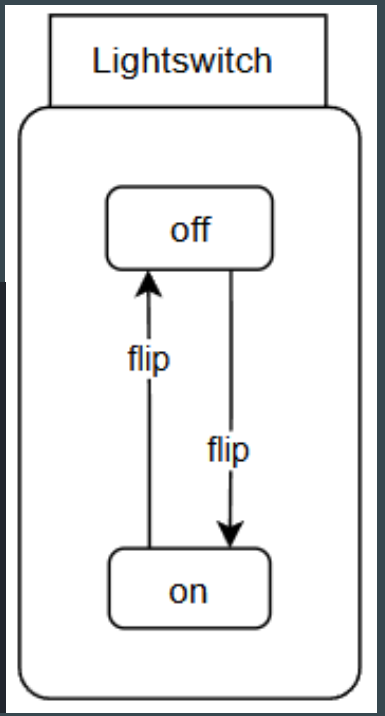
- Finite State Machines
- Hierarchy
- Concurrency
- Timed behavior
- History



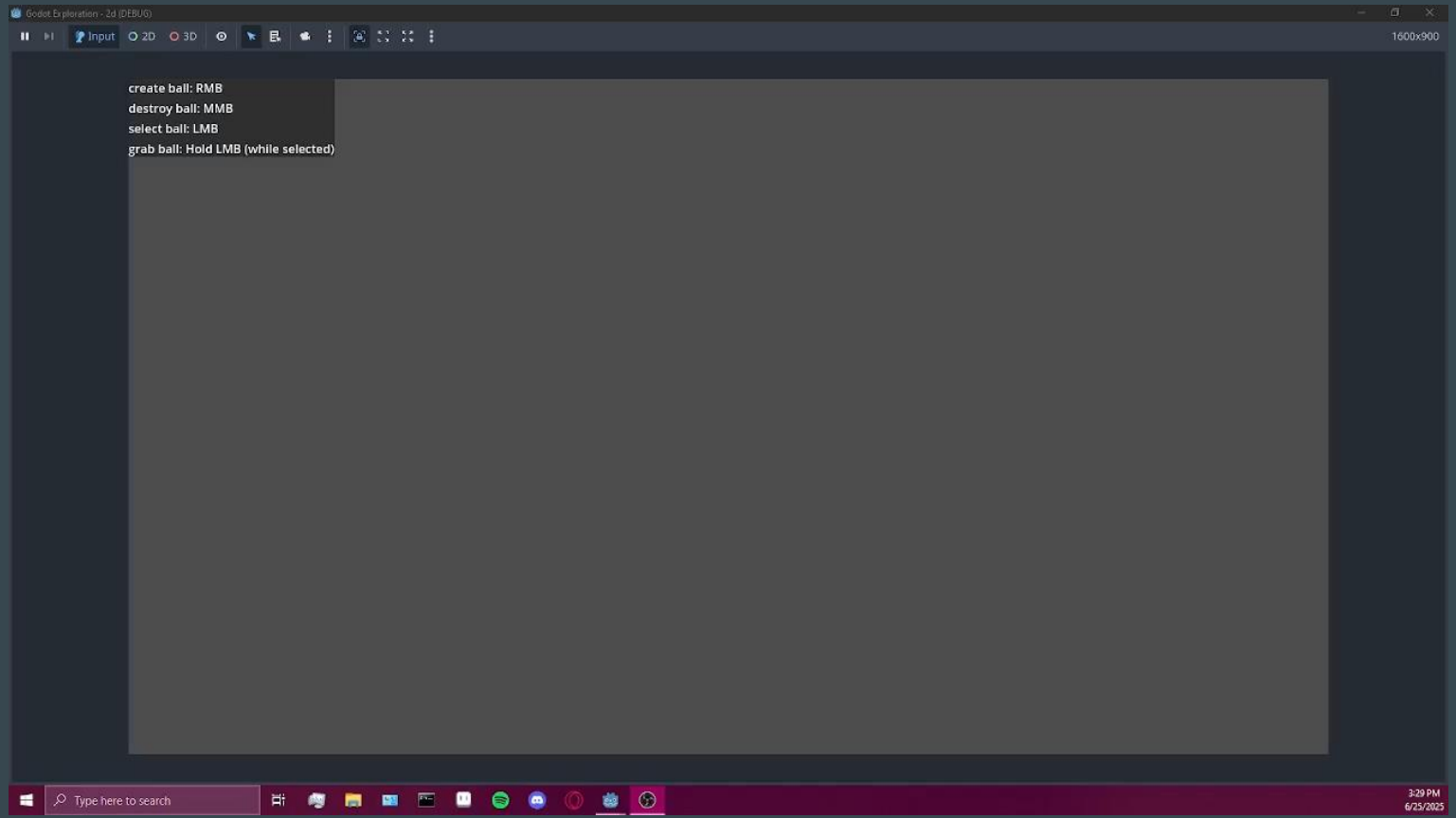
Statecharts in Godot

- Godot Statechart Extension
  - developed by Godot community developer





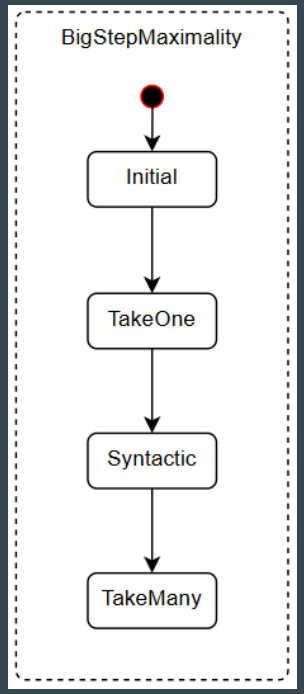
Bouncing Ball Demo

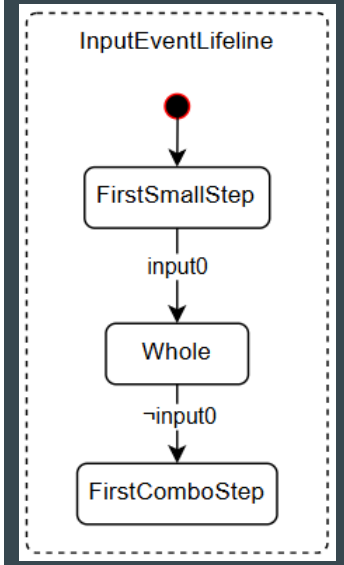


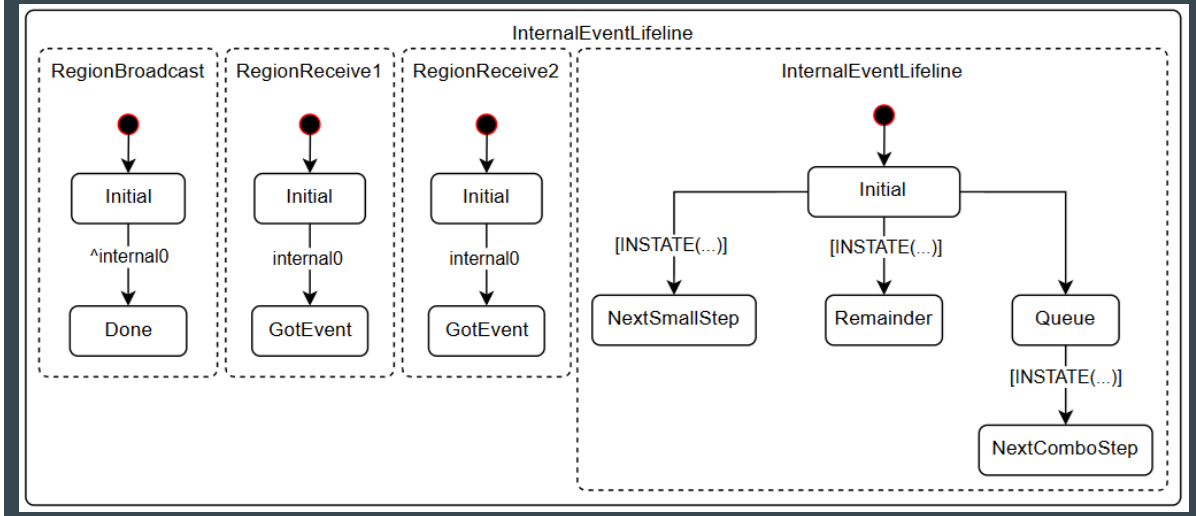
Semantic analysis

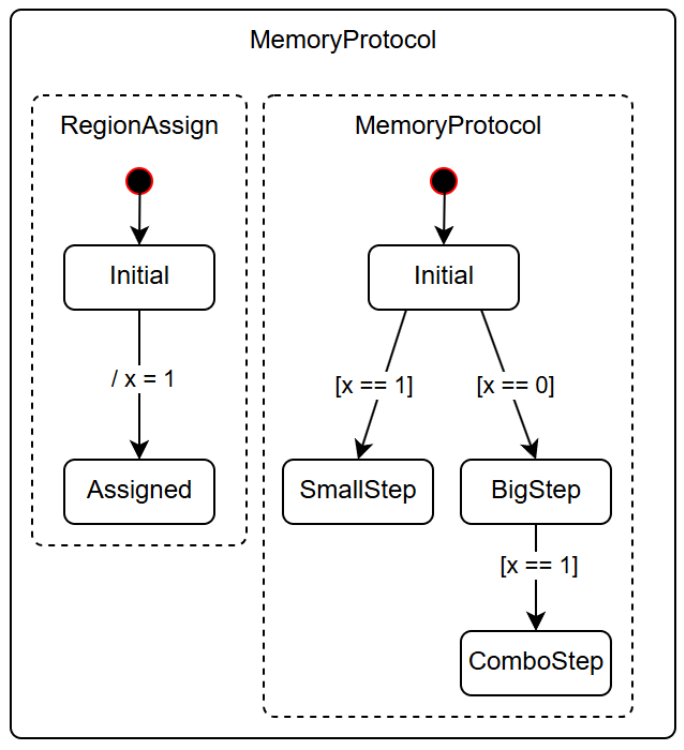
- Limited documentation
- Testing statechart [4]
  - Orthogonal regions testing different semantics
- Additional small tests

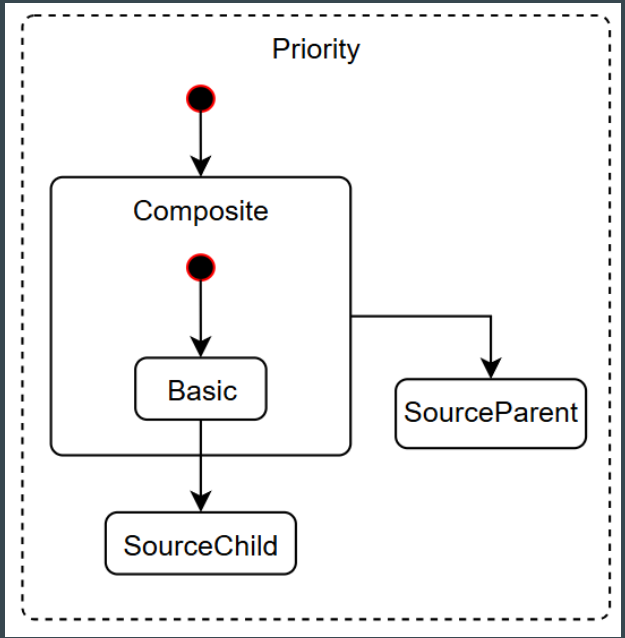
[4] J. Exelmans, S. V. Mierlo, and H. Vangheluwe, “A statecharts interpreter and compiler with semantic variability,” MODELS ’22: Proceedings of the 25th International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings, pp. 722–727, 2022.

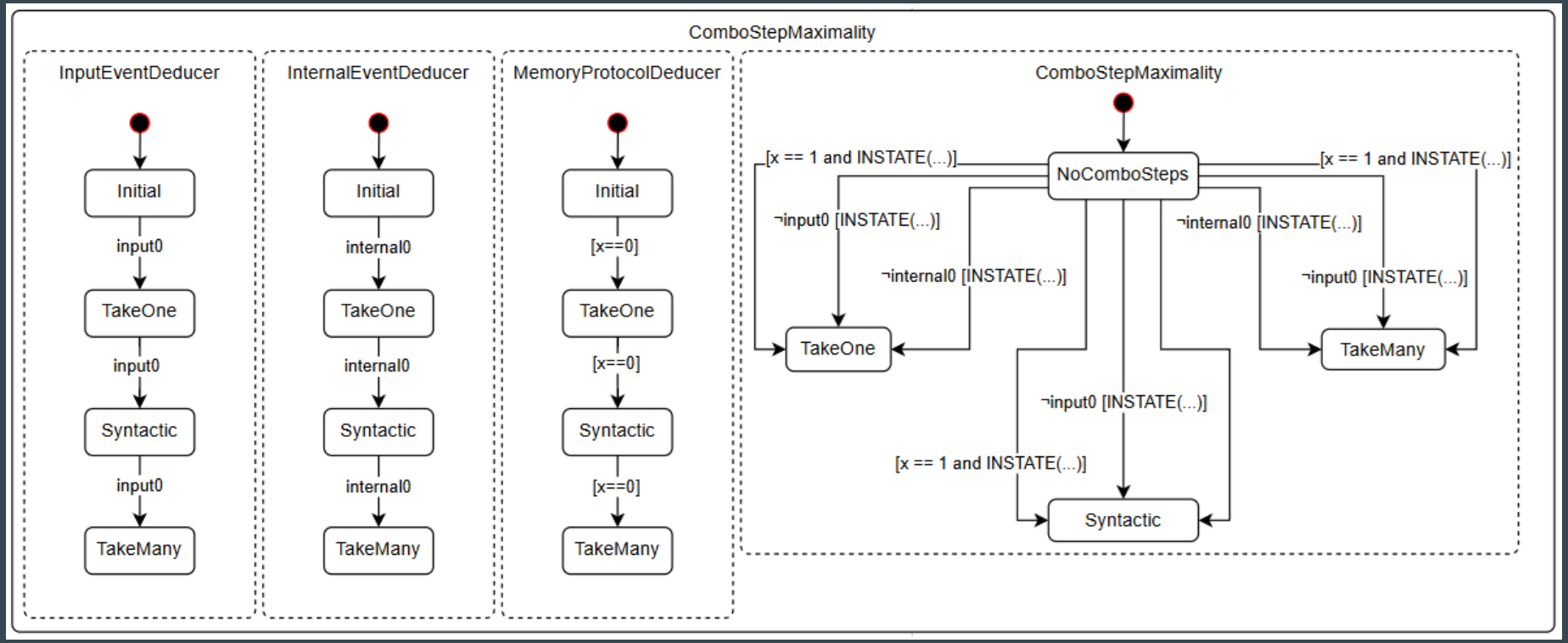

BigStepMaximality
Initial
TakeOne
Syntactic
TakeMany


InputEventLifeline
FirstSmallStep
input0
Whole
¬input0
FirstComboStep

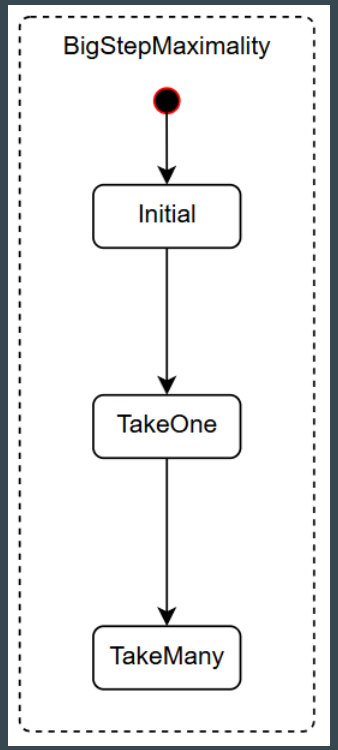

InternalEventLifeline
RegionBroadcast
Initial
^internal0
Done
RegionReceive1
Initial
internal0
GotEvent
RegionReceive2
Initial
internal0
GotEvent
InternalEventLifeline
Initial
[INSTATE(...)]
[INSTATE(...)]
NextSmallStep
Remainder
Queue
[INSTATE(...)]
NextComboStep

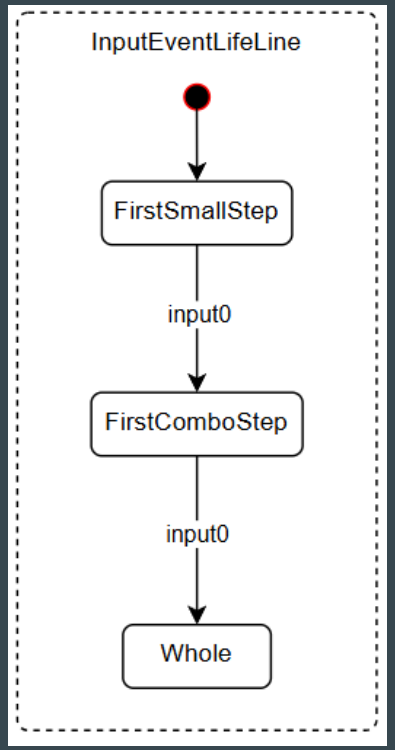

MemoryProtocol
RegionAssign
Initial
/ x = 1
Assigned
MemoryProtocol
Initial
[x == 1]
[x == 0]
SmallStep
BigStep
[x == 1]
ComboStep


Priority
Composite
Basic
SourceChild
SourceParent


ComboStepMaximality
InputEventDeducer
Initial
input0
TakeOne
input0
Syntactic
input0
TakeMany
InternalEventDeducer
Initial
internal0
TakeOne
internal0
Syntactic
internal0
TakeMany
MemoryProtocolDeducer
Initial
[x==0]
TakeOne
[x==0]
Syntactic
[x==0]
TakeMany
ComboStepMaximality
NoComboSteps
[x == 1 and INSTATE(...)]
[x == 1 and INSTATE(...)]
¬input0 [INSTATE(...)]
¬internal0 [INSTATE(...)]
¬internal0 [INSTATE(...)]
¬input0 [INSTATE(...)]
TakeOne
TakeMany
¬input0 [INSTATE(...)]
[x == 1 and INSTATE(...)]
Syntactic

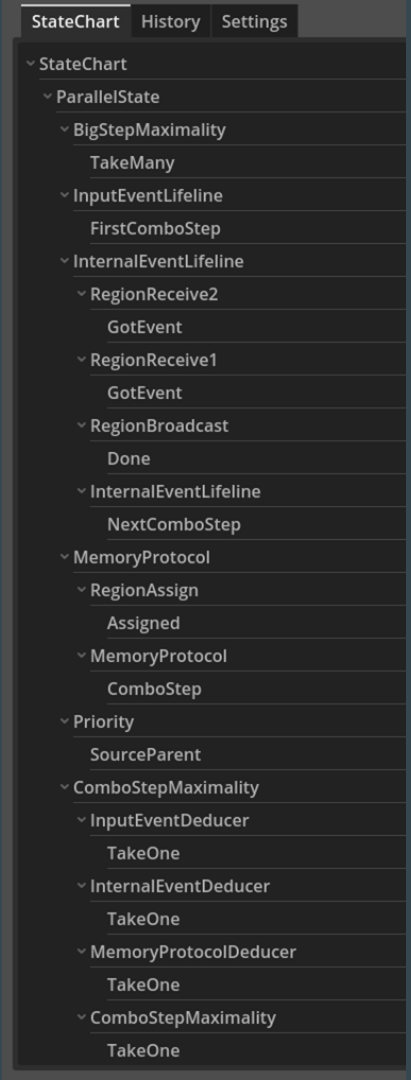
Alterations





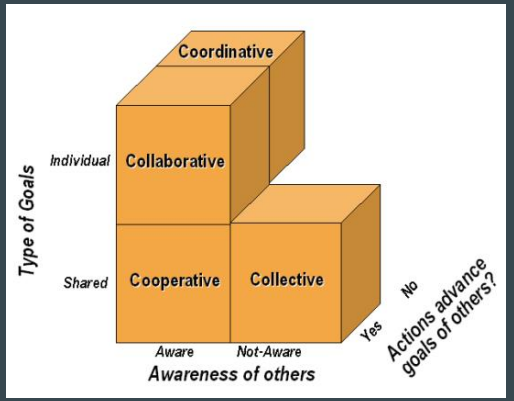
Semantic results

- Transition semantics
- Event lifetime
- Combo-Step

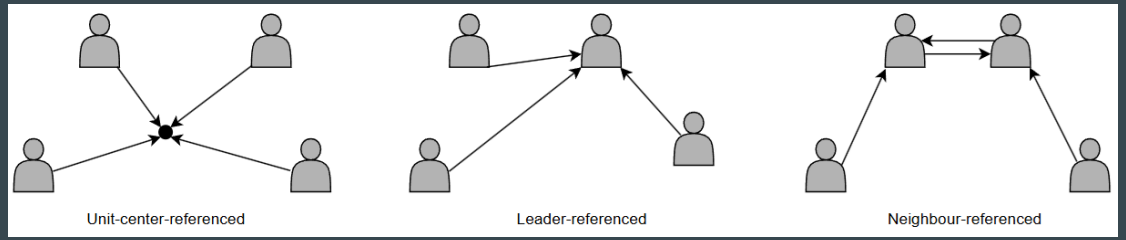


Coordination and Communication

- Distributed Intelligence [5]
- Formation Control [6]



[5]

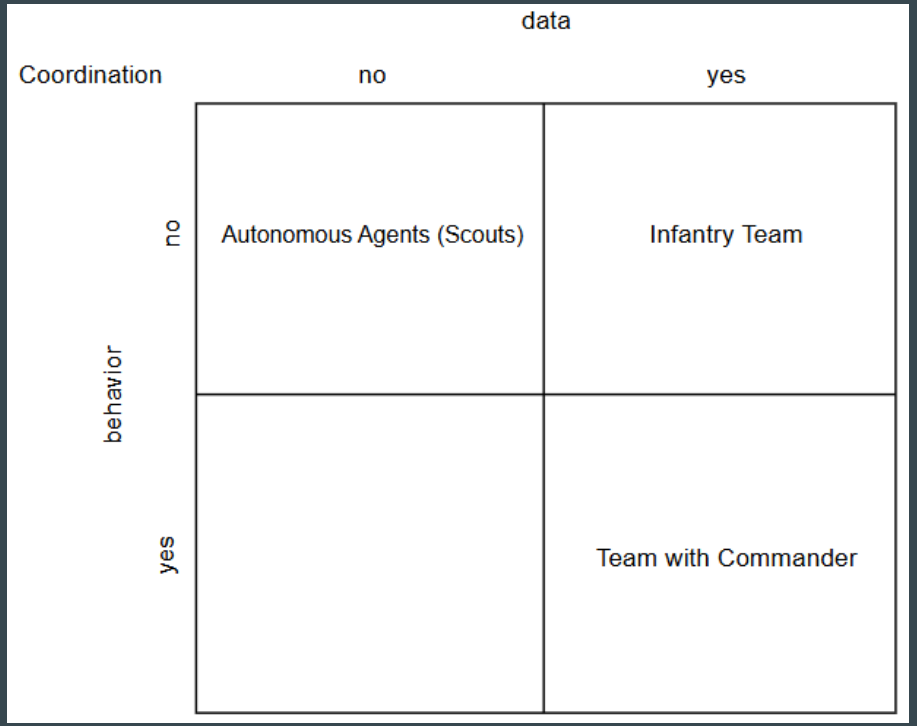


[6]

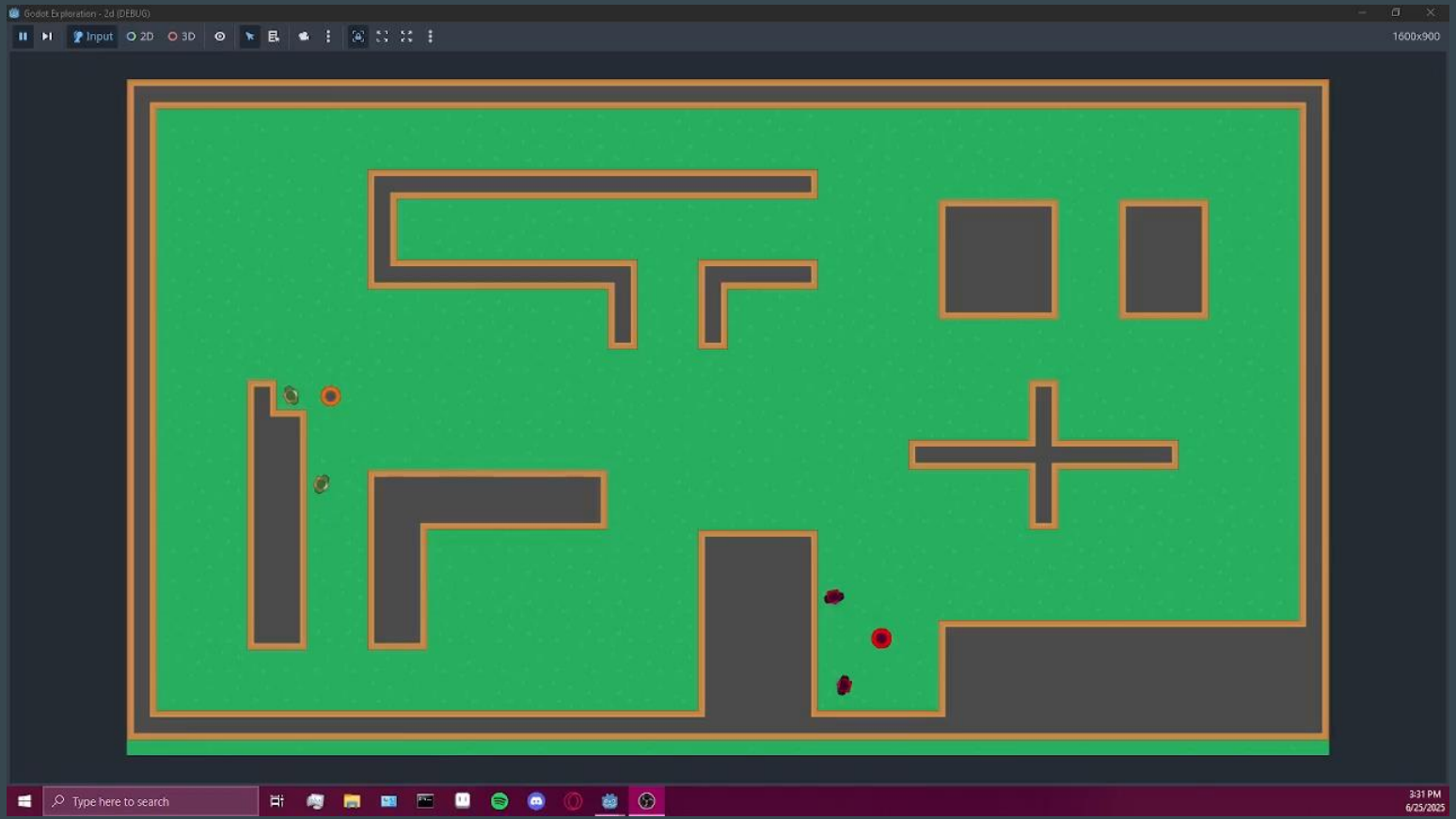
[5] L. E. Parker, “Distributed intelligence: Overview of the field and its application in multi-robot systems,” Association for the Advancement of Artificial Intelligence, 2007.
[6] T. Balch and R. C. Arkin, “Behavior-based formation control for multirobot teams,” IEEE Transactions on Robotics and Automation, vol. 14, no. 6, pp. 926–939, 1998.

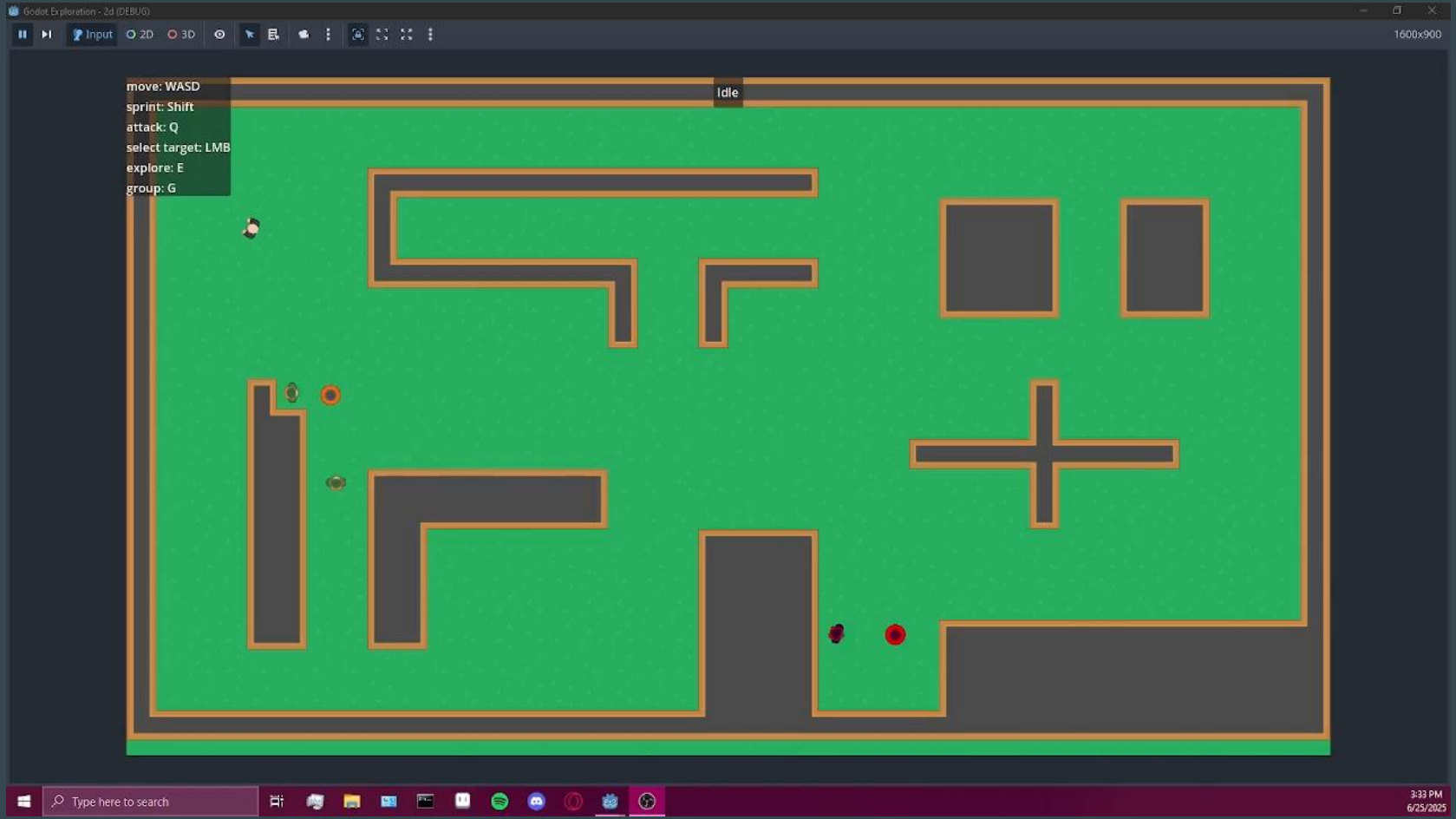
Practical Experiments

- Interaction
- Coordination and communication



Coordination Experiments Demos




Godot Exploration - 2d (DEBUG)
Input
2D
3D
1600x900
move: WASD
sprint: Shift
attack: Q
select target: LMB
explore: E
group: G
Idle
Type here to search
3:33 PM
6/25/2025

Conclusion

- Modular design
- Communicating objects
  - behavior modelled with Statecharts
- Non-player characters in a game

Contributions

- Semantic analysis
- Exploration of modular design in the Godot engine

Future Work

- Evaluation – parameterization
  - playability (include human player)
- Coordination
  - communication, formations, tactics
- Coordination problems
  - friendly fire