GDC

Advanced Real-Time Hierarchical Task Networks A New Approach

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Tomohiro Mori researched about CharacterAI and Animation in Future University Hakodate. He joined SquareEnix in 2019.

He is researching AI and Animation
-Full Procedural Animation
-Character AI using Hierarchical Task Network

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Kousuke Namiki has been involved in the game industry since 2008, and joined SquareEnix in 2012.

He worked in the development of titles such as
- FINAL FANTASY XV
- KINGDOM HEARTS III
- FINAL FANTASY VII REMAKE

as Game AI engineer and QA automation AI engineer.

Currently, he is engaged in research and development of next-generation AI system in Advanced Technology Division.

Today's Game AI and HTN

Introduction

Choices of Game AI

- Candidates of Game AI Systems
  - Finite State Machine
  - Behavior Tree
  - GOAP
  - Hierarchical Task Network (HTN)

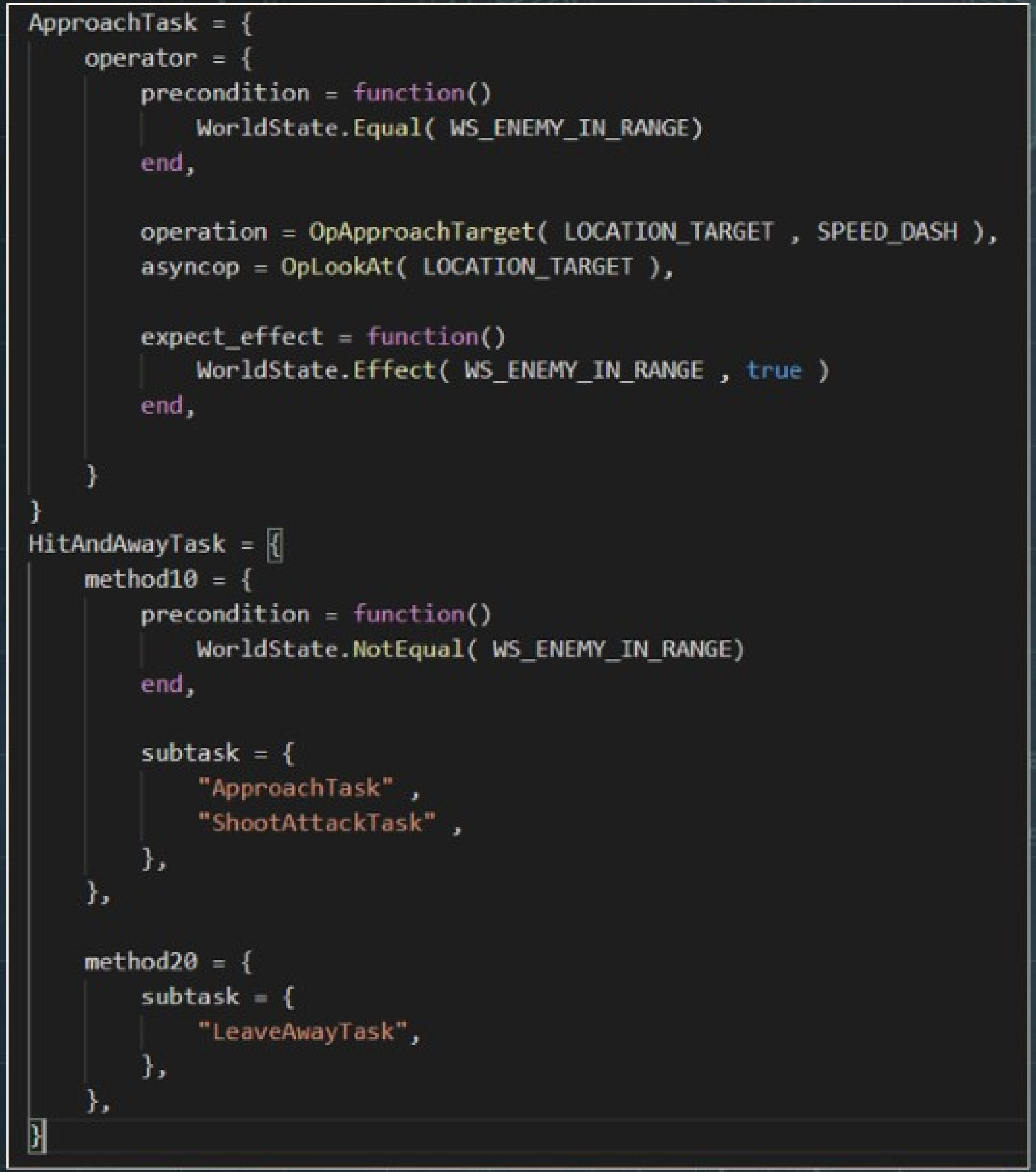
- Recent Game AI has Excelled in immediate response.
- Long-term behavior is a major challenge today.

HTN Introduction

- What is HTN ?
  - Traditional planning method
  - Planning in a static domain
    - e.g. Delivery Optimization in Logistics

- Expectations
  - Predict future situations
  - Take deliberate action

An Example of HTN



```
ApproachTask = {
    operator = {
        precondition = function()
            WorldState.Equal( WS_ENEMY_IN_RANGE)
        end,

        operation = OpApproachTarget( LOCATION_TARGET , SPEED_DASH ),
        asyncop = OpLookAt( LOCATION_TARGET ),

        expect_effect = function()
            WorldState.Effect( WS_ENEMY_IN_RANGE , true )
        end,

    }
}
HitAndAwayTask = {
    method10 = {
        precondition = function()
            WorldState.NotEqual( WS_ENEMY_IN_RANGE)
        end,

        subtask = {
            "ApproachTask" ,
            "ShootAttackTask" ,
        },
    },

    method20 = {
        subtask = {
            "LeaveAwayTask",
        },
    },
}
```

- There are two types of task in HTN.
    - Primitive
    - Compound

- Decompose
    - Break down a Compound Task into Multiple Tasks

- Hierarchical Planning
    - Break down large problems into sub-problems

HTN in Games

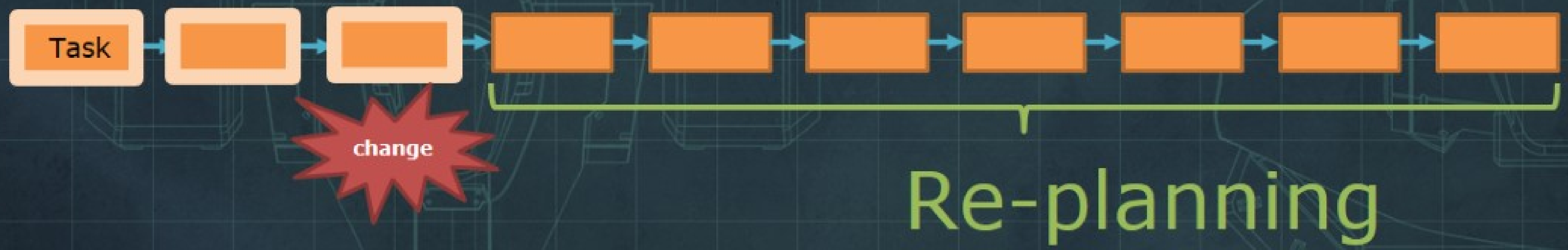
- HTN excels at planning for a static environment
- Console market has seen a rise in real-time games
- HTN is not designed for dynamic environments
- Player behavior is unpredictable to HTN

The Problem of Uncertainty in HTN

- In HTN, after the planning phase is over, tasks are arranged in a chain and executed in sequence.

- once a task chain is created, HTN can't modify that. if the environment changes, the existing plan is discarded and new plan is recreated by re-planning.

- The more frequent the re-planning, the less able the AI will be to think long-term, and the more it will turn into a reactive AI with a narrow view.



Plans are nothing

Planning is everything

Dwight D. Eisenhower

Next Gen HTN

ART-HTN

Our Motivation

- Even though various situations change in real time, we want to achieve more long-term behavior with planning.

- To take advantage of planning, we want to minimize the number of re-planning as much as possible

- Instead of symbolic planning, we want to make planning more relevant to the game situation by using simulator

Our Approach : ART-HTN

1. ## Multi Scenario Plan

   Our planner should have multiple scenarios in order to handle uncertain situation change.

2. ## Simulation Planner

   A game simulation would be more appropriate than symbolic planner.
   better planner might reduce amount of re-planning.

3. ## Executor - Planner Role Separation

   By giving more authority to the executor of the plan rather than the creator of the plan, we thought we could operate the plan flexibly.

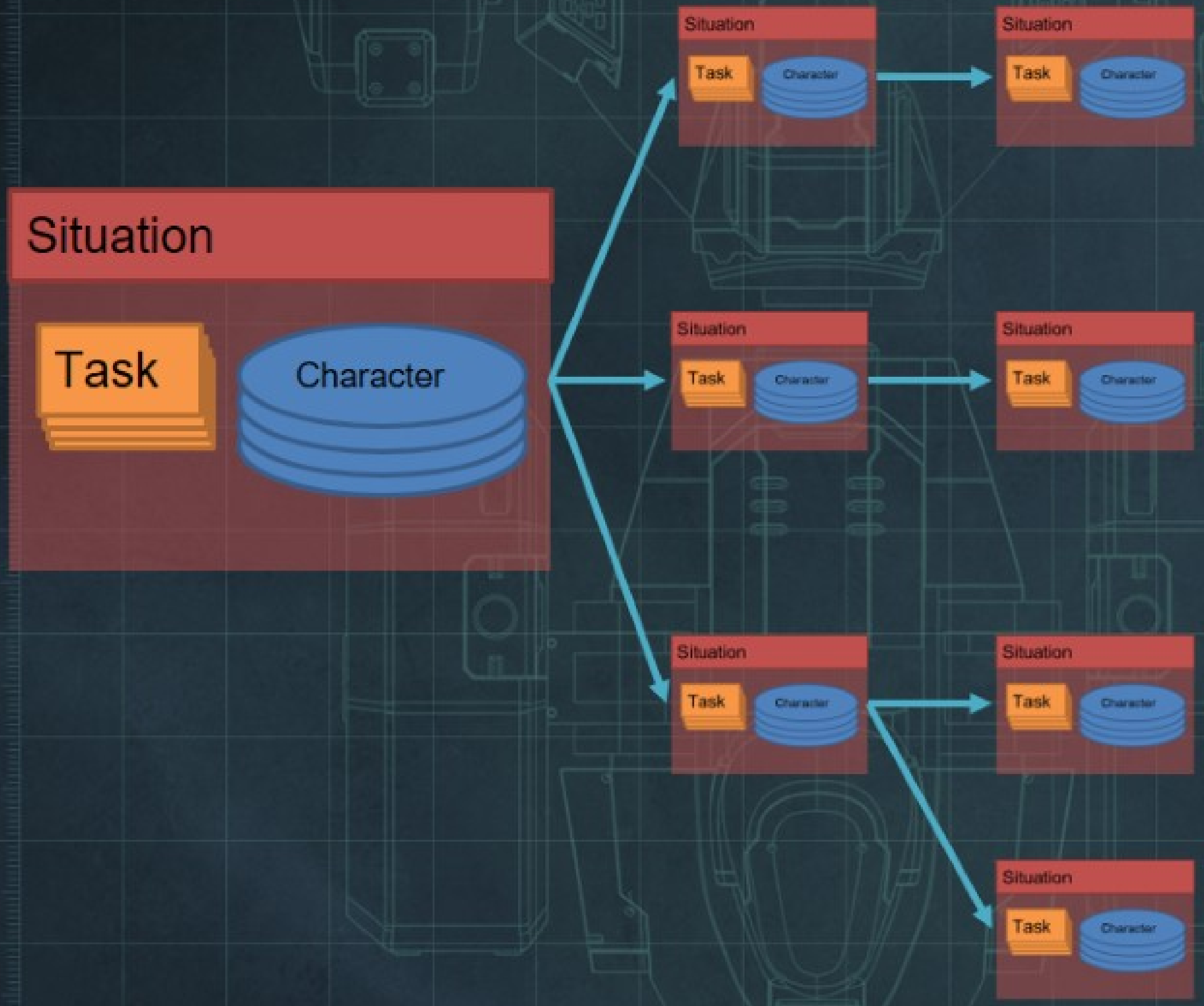
ART-HTN

1. Multi Scenario Plan

1. Multi Scenario Plan

- Reuse temporal states
  - Traditional Planner discard temporal states in search phase and returns only a final task chain of plan.
  - But temporal states can be used as Sub-Plans
- Our Multi Scenario Planner returns a plan with multiple branches. Planner leave branches in the middle state of the search whenever possible.

Situation-Task Network



- Multi Scenario Plan holds Tasks and Situations.

- Situation is a simplified model of game world, containing all simplified data in game world:
  - Character’s position
  - HP
  - Internal condition such as state-id of hostile AI agent.

- Situation has links to previous and next situations forming a graph.

- We call this graph the “ST-Network”

Variation of Tasks

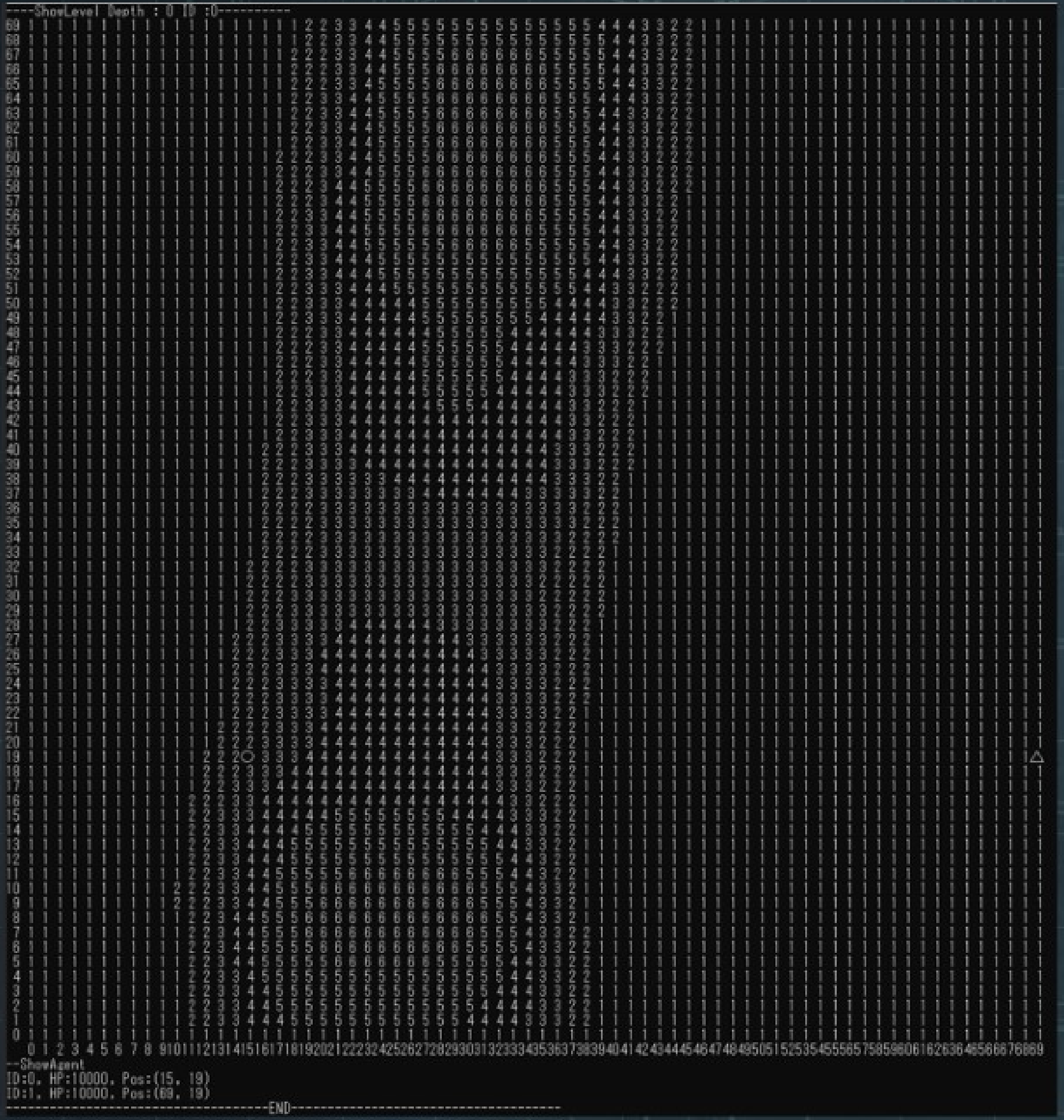
- Primitive Task
  - Simple action task which has precondition and simulate function.

- Composite Task
  - FSM-Task
    - To simulate opponent behavior, our planner can use FSM in planning phase
    - FSM can be used as a model of opponent behavior
  - Step-Task
    - Simple FSM, works like a Sequence Node of a Behavior Tree
    - Can have simple loops or small number of branches
    - Can describe directional actions with start and end states with

ART-HTN

2. Simulation Planner

2. Simulation Planner



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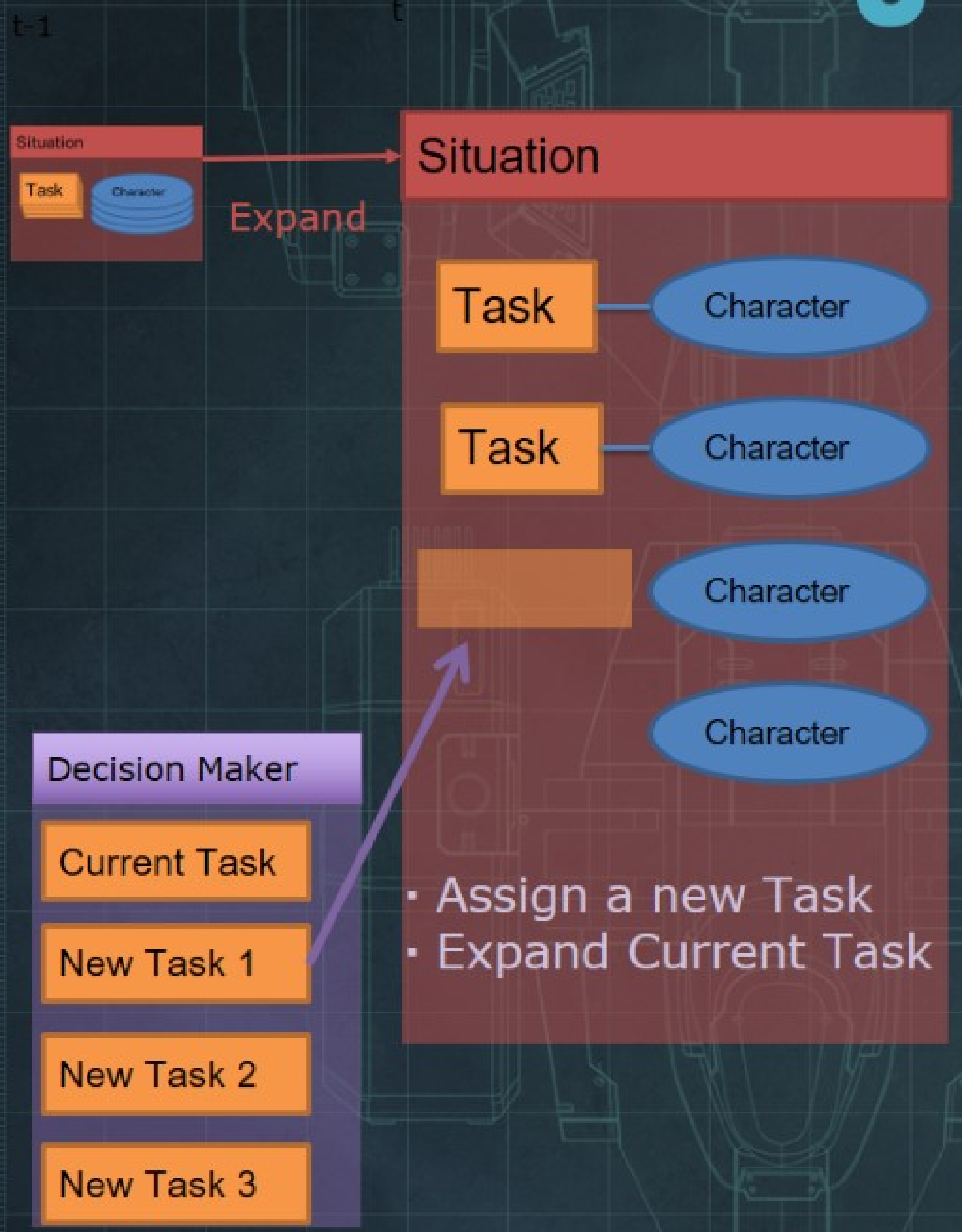
Simulation Planner Output

- ST-Network Generation
- Terminal Situation-Node Expansion
- Enemy-based Branch Generation

Task Assigning



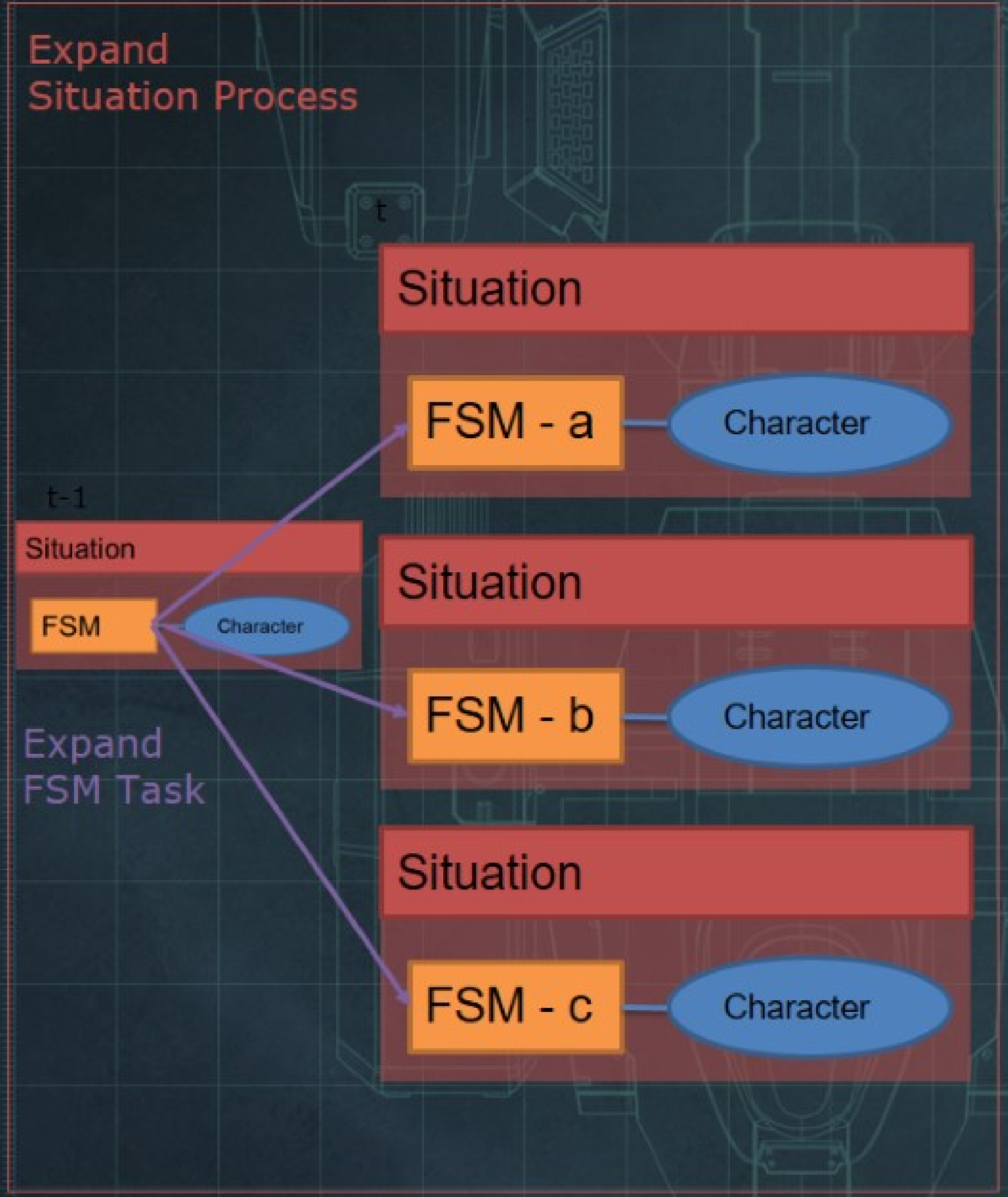
- Assign a new Task
- Expand Current Task

- To Expand Terminal Situation Node , Decision Makers choose a task for every character.

- Decision Maker can assign new Primitive-Task or Composite Task when the precondition matches to the situation.

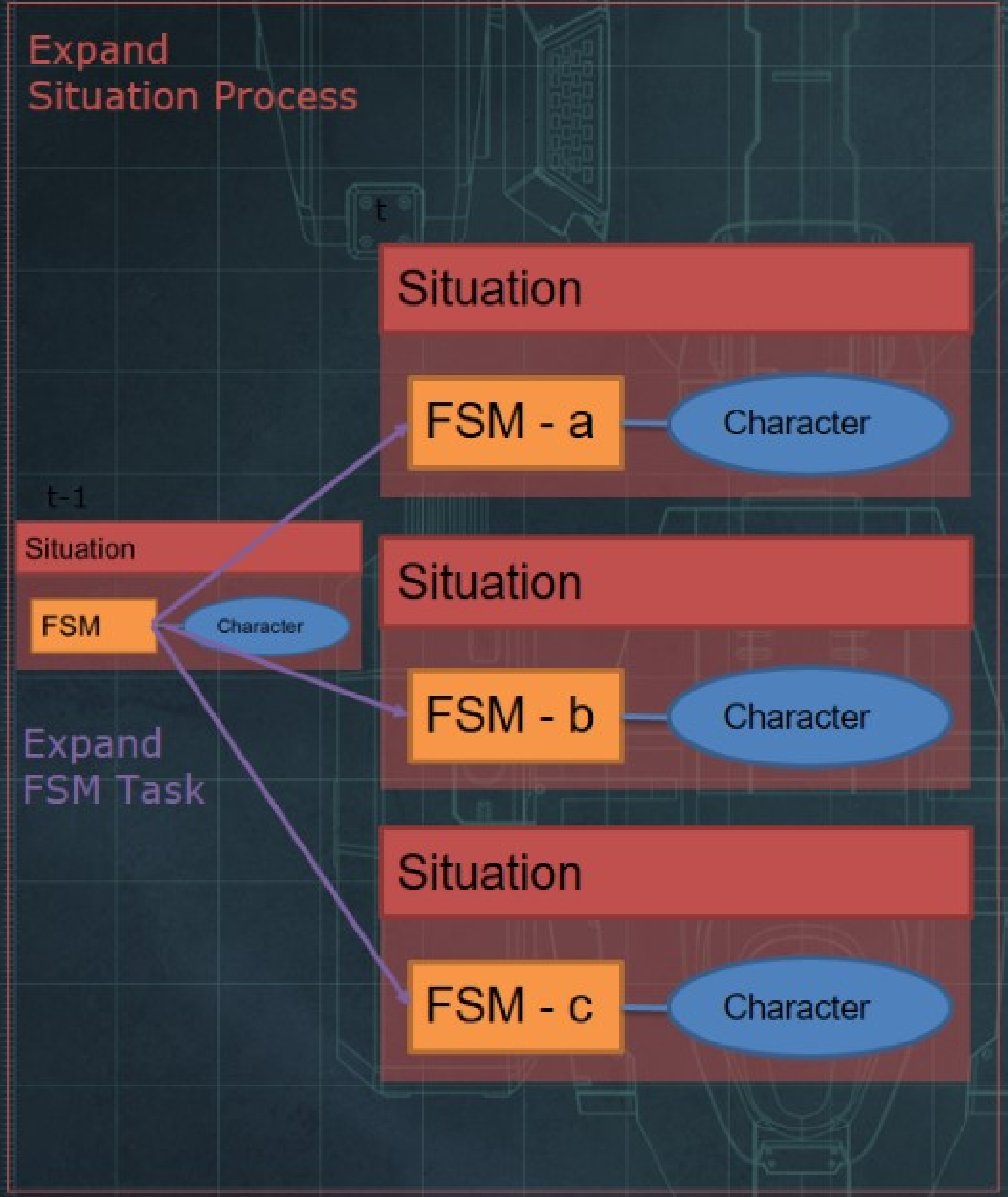
- Decision Maker can Expand Current Composite Task when the node allows.

Expand Composite Task

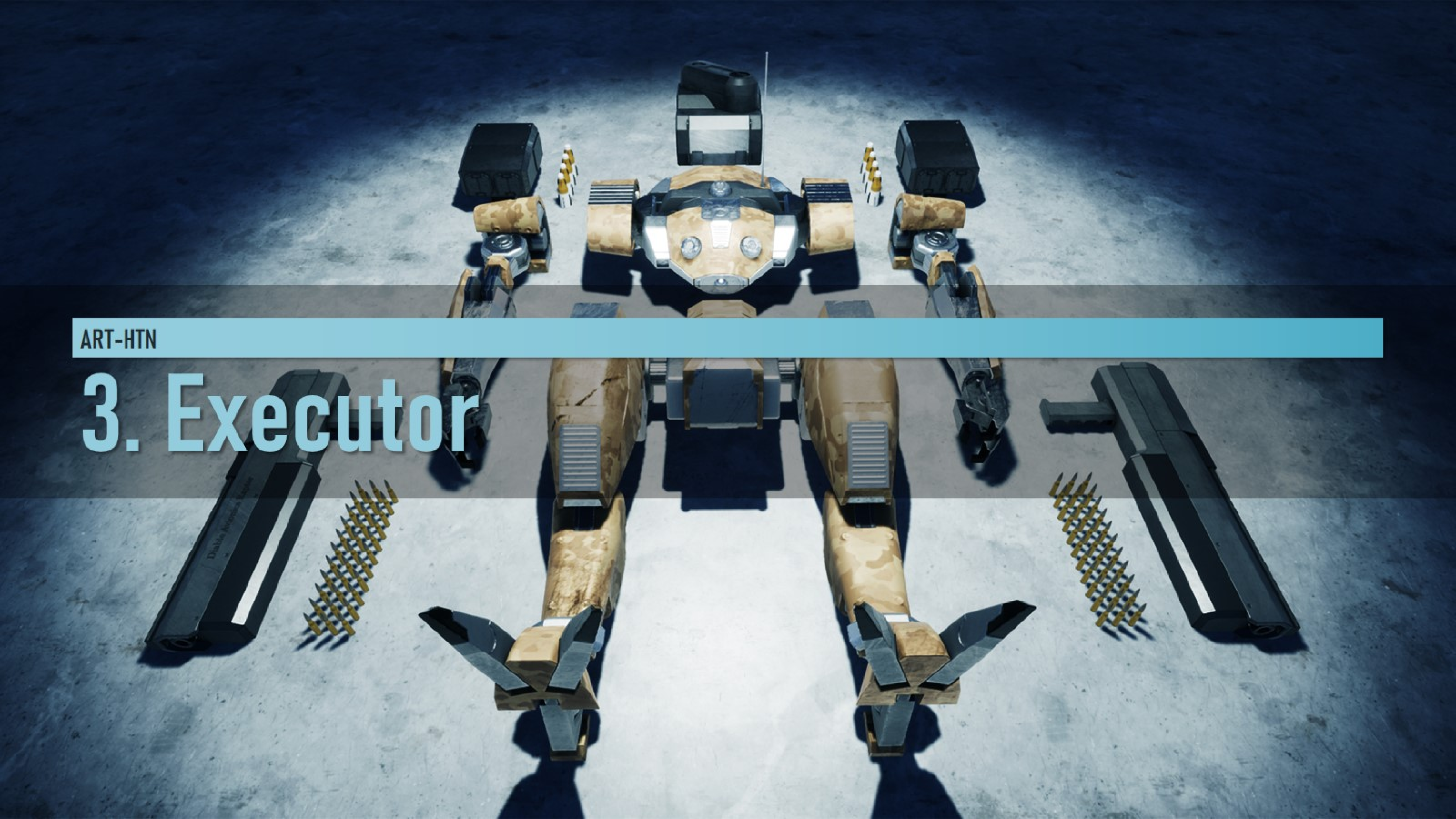


- Examples of Expansion of Composite Task
  - When FSM has transition to state a,b,c.
  - The FSM task can be expanded to a,b,c, copied instance.
  - All data in FSM-Task copied before the task execute state transition to make a,b,c versions of task instance.

Expand Composite Task



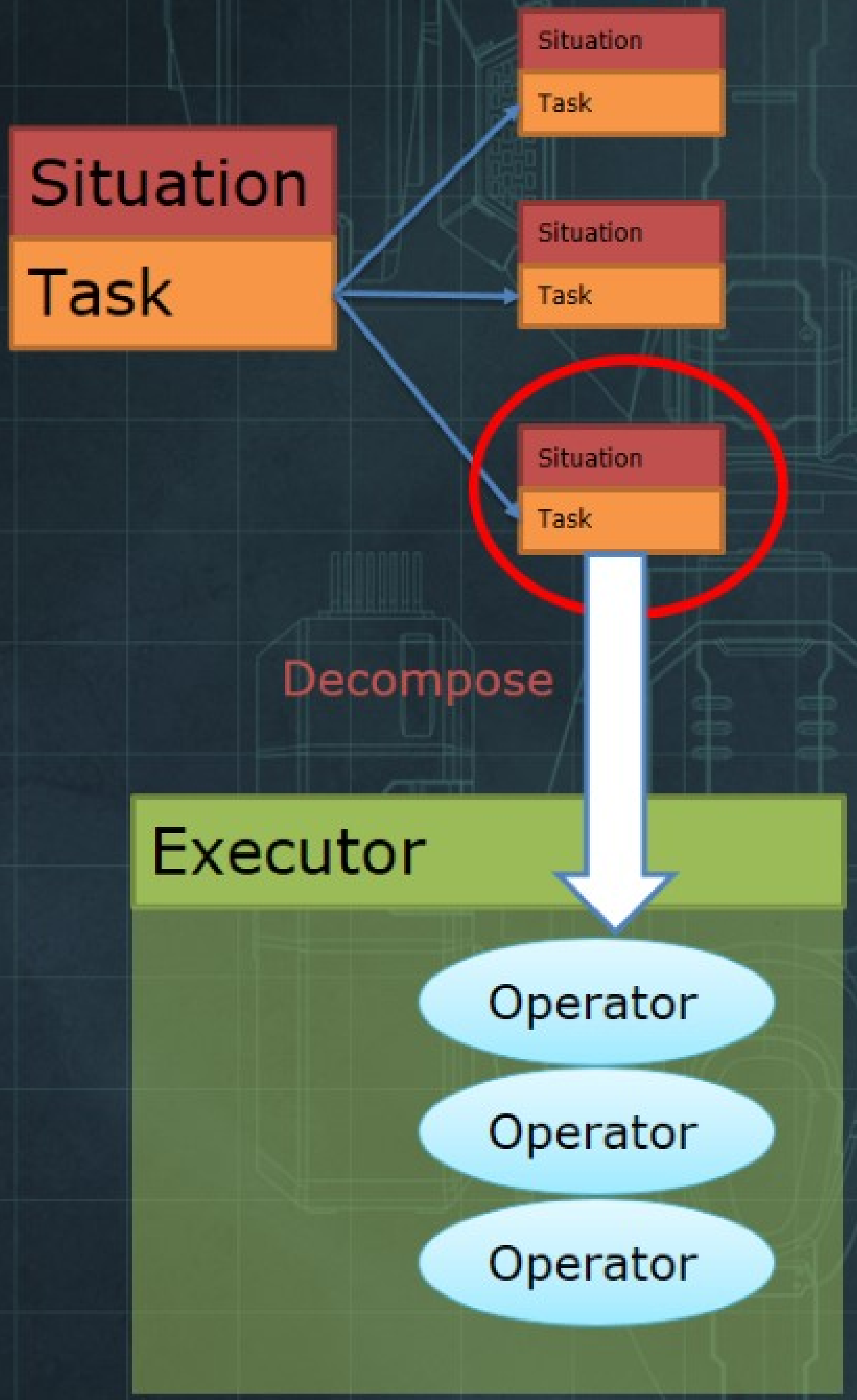
- Every agent’s decision-maker can conduct such process. So total amount of Situation Nodes tend to become huge.
- To Reduce ST-Network size, expand function receive threshold.
    - The task can be expanded only when the random number exceeds this threshold.



ART-HTN

3. Executor

Decomposition of Task



- ST-Networks choose best task to use
- Tasks are only data, cannot be executed as is
- Executor Process
  - Select High evaluation Task
  - Decompose the selected Task into Operators
  - Execute the Operators in order

Planning is nothing

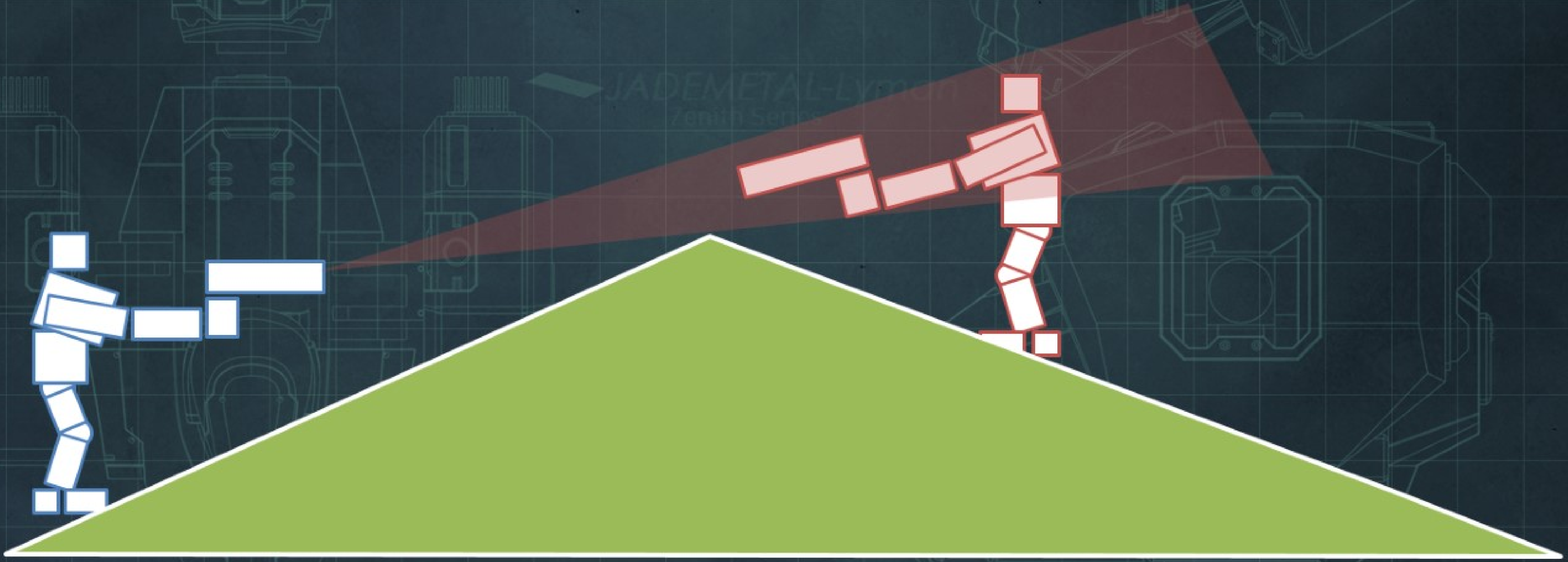
Execution is everything

ART-HTN

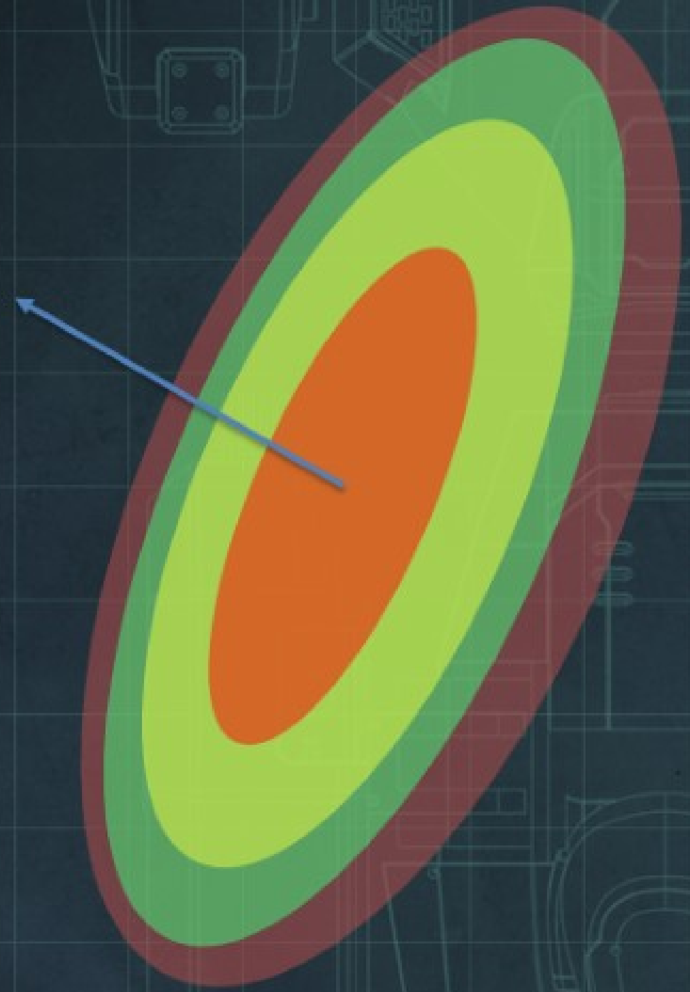
Example Demo

Example Demo

Ridge Shooting



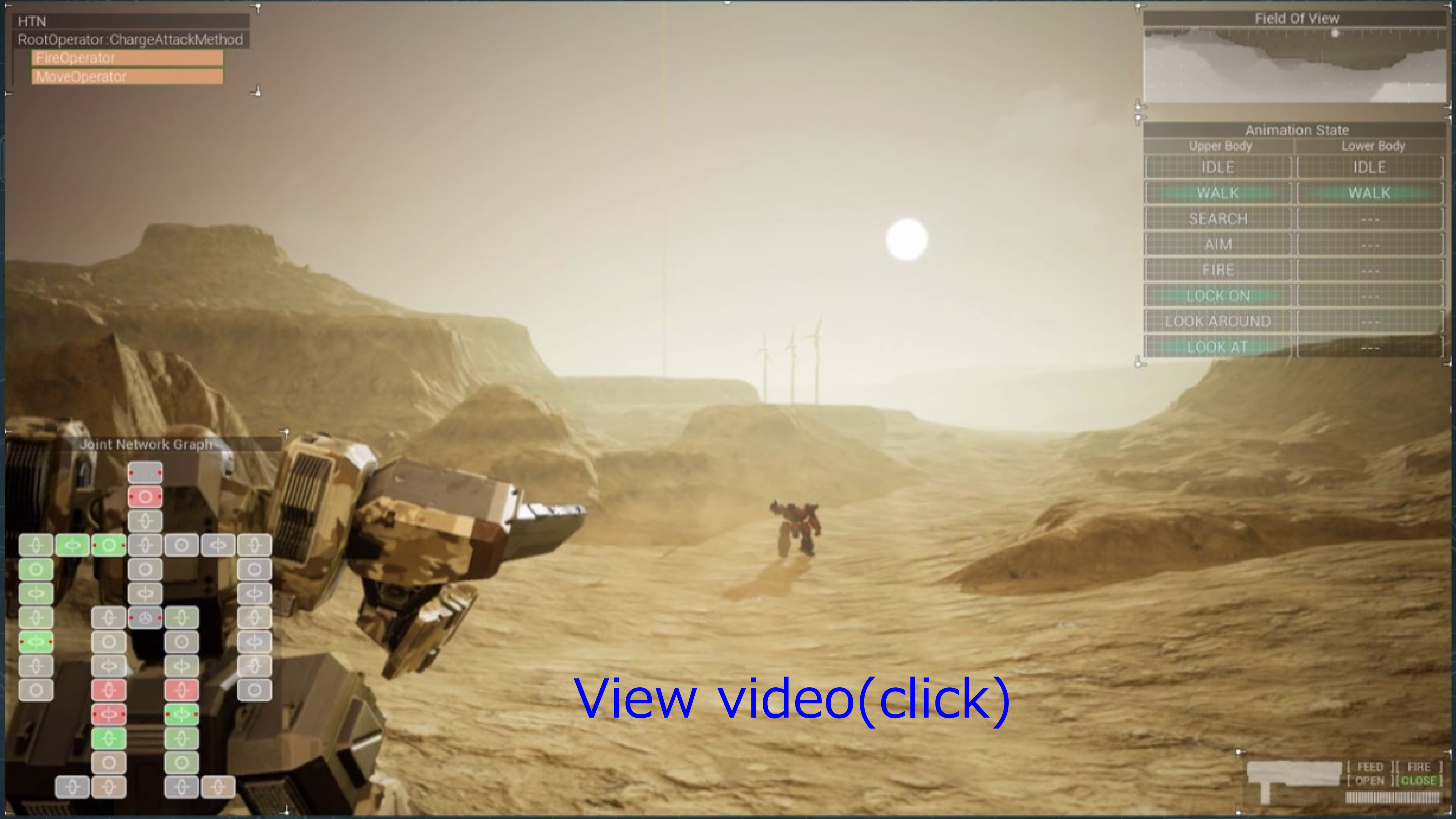
Hill detection Algorithm



- Detect contour lines on the terrain
- Find orientation and distribution of hills by PCA
- Rough granularity and Fast algorithm for simulation

Example Demo

Without Ridge Shooting



HTN
RootOperator:ChargeAttackMethod
FireOperator
MoveOperator

Field Of View

Animation State

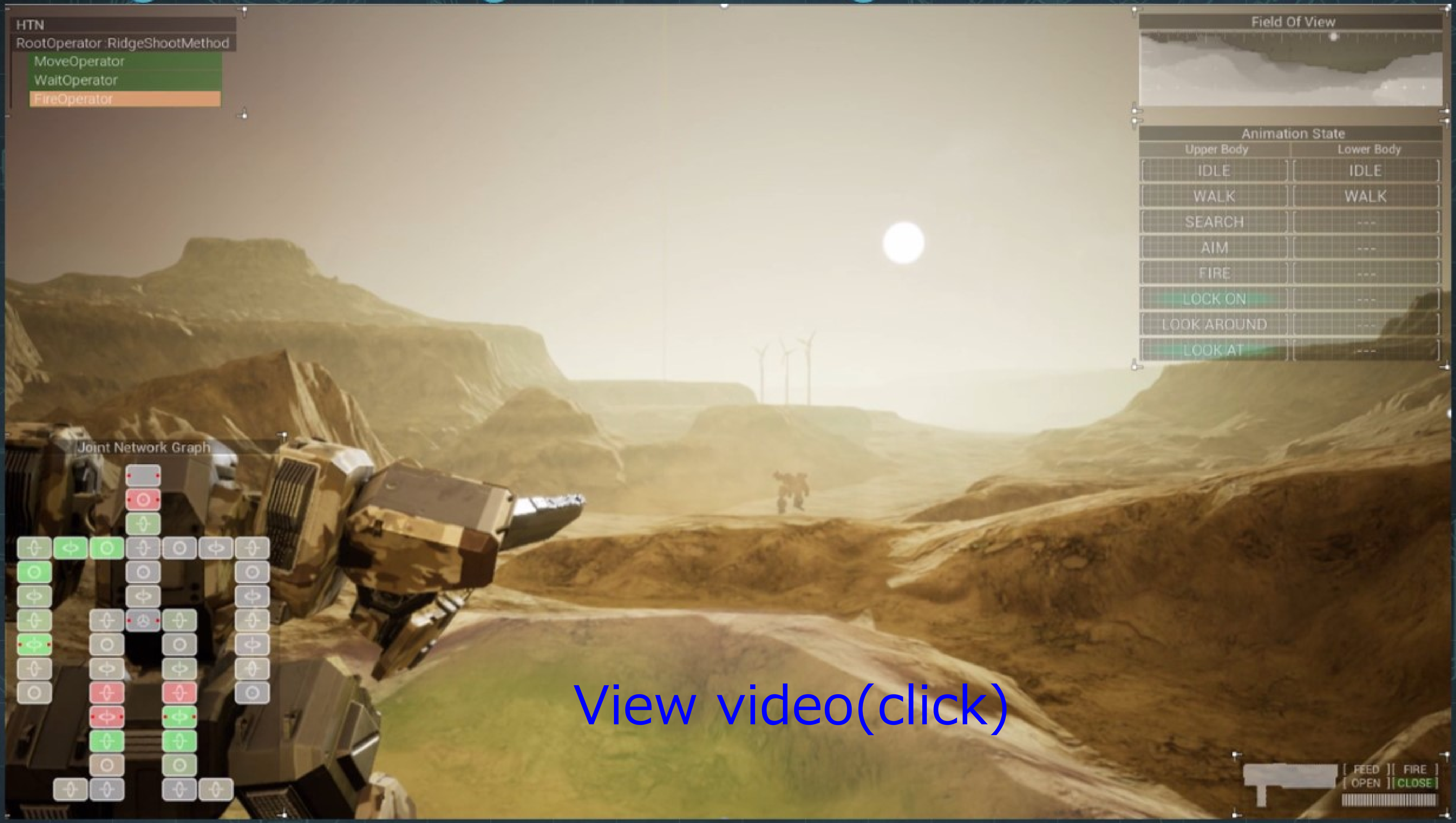
Upper Body	Lower Body
IDLE	IDLE
WALK	WALK
SEARCH	---
AIM	---
FIRE	---
LOCK ON	---
LOOK AROUND	---
LOOK AT	---

Joint Network Graph

View video(click)

Example Demo

Winning with Ridge Shooting



```
HTN
RootOperator:RidgeShootMethod
    MoveOperator
    WaitOperator
    FireOperator
```

Field Of View

Animation State

Upper Body	Lower Body
IDLE	IDLE
WALK	WALK
SEARCH	---
AIM	---
FIRE	---
LOCK ON	---
LOOK AROUND	---
LOOK AT	---

View video(click)

ART-HTN

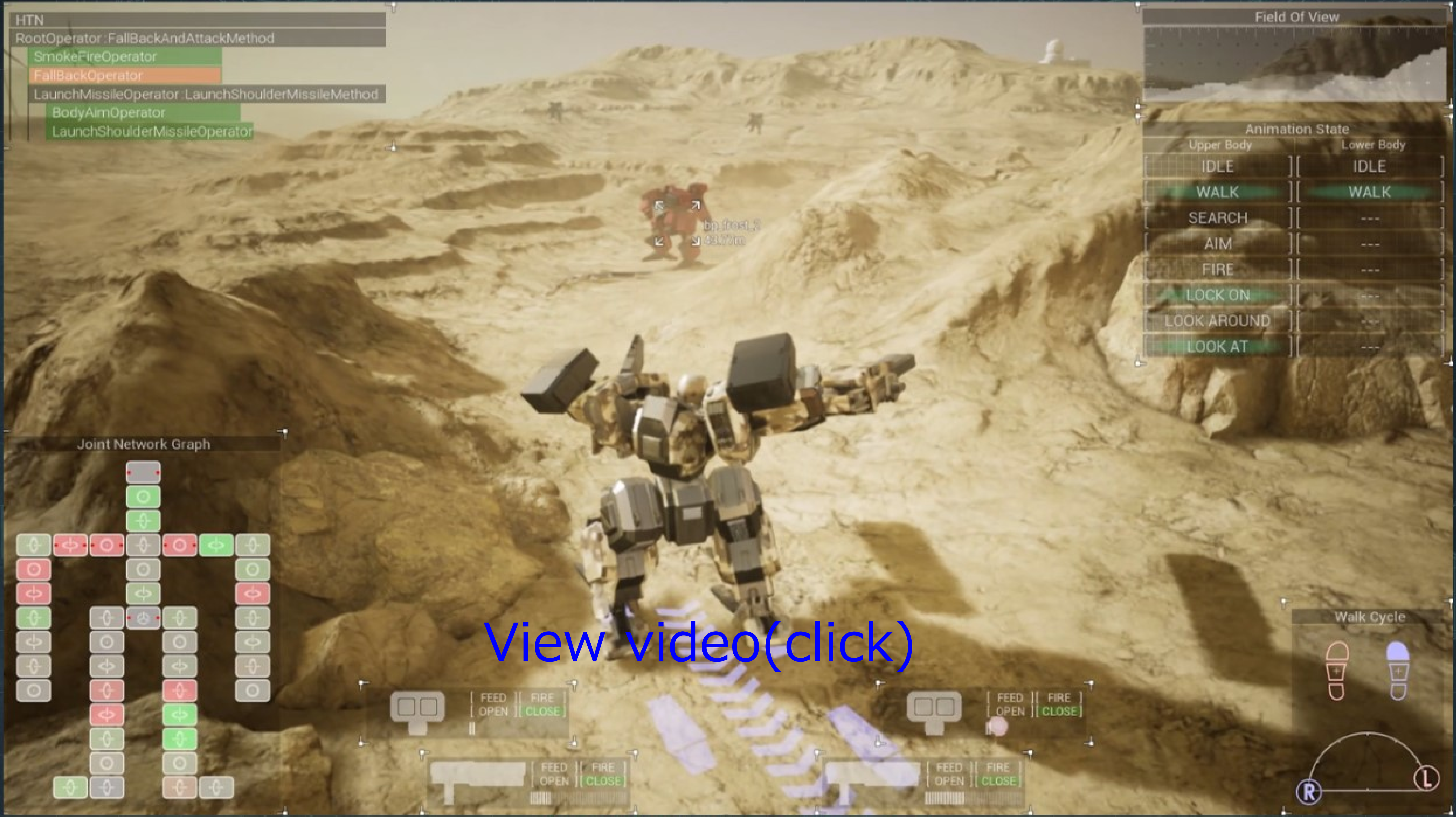
Final Demo

Reconnaissance-in-Force

- Eliminate weak targets while doing recon
- If a high-risk situation is encountered, attempt a retreat using a smoke screen
- Use powerful weapons to destroy enemies or make them give up the chase.

Final Demo

Reconnaissance-in-Force



```
HTN
RootOperator : FallBackAndAttackMethod
    SmokeFireOperator
    FallBackOperator
    LaunchMissileOperator : LaunchShoulderMissileMethod
        BodyAimOperator
        LaunchShoulderMissileOperator
```

Animation State

Upper Body	Lower Body
IDLE	IDLE
WALK	WALK
SEARCH	---
AIM	---
FIRE	---
LOCK ON	---
LOOK AROUND	---
LOOK AT	---

View video(click)

Summary

- In order to achieve long-term behavior in dynamic environment, HTN system should be improved.

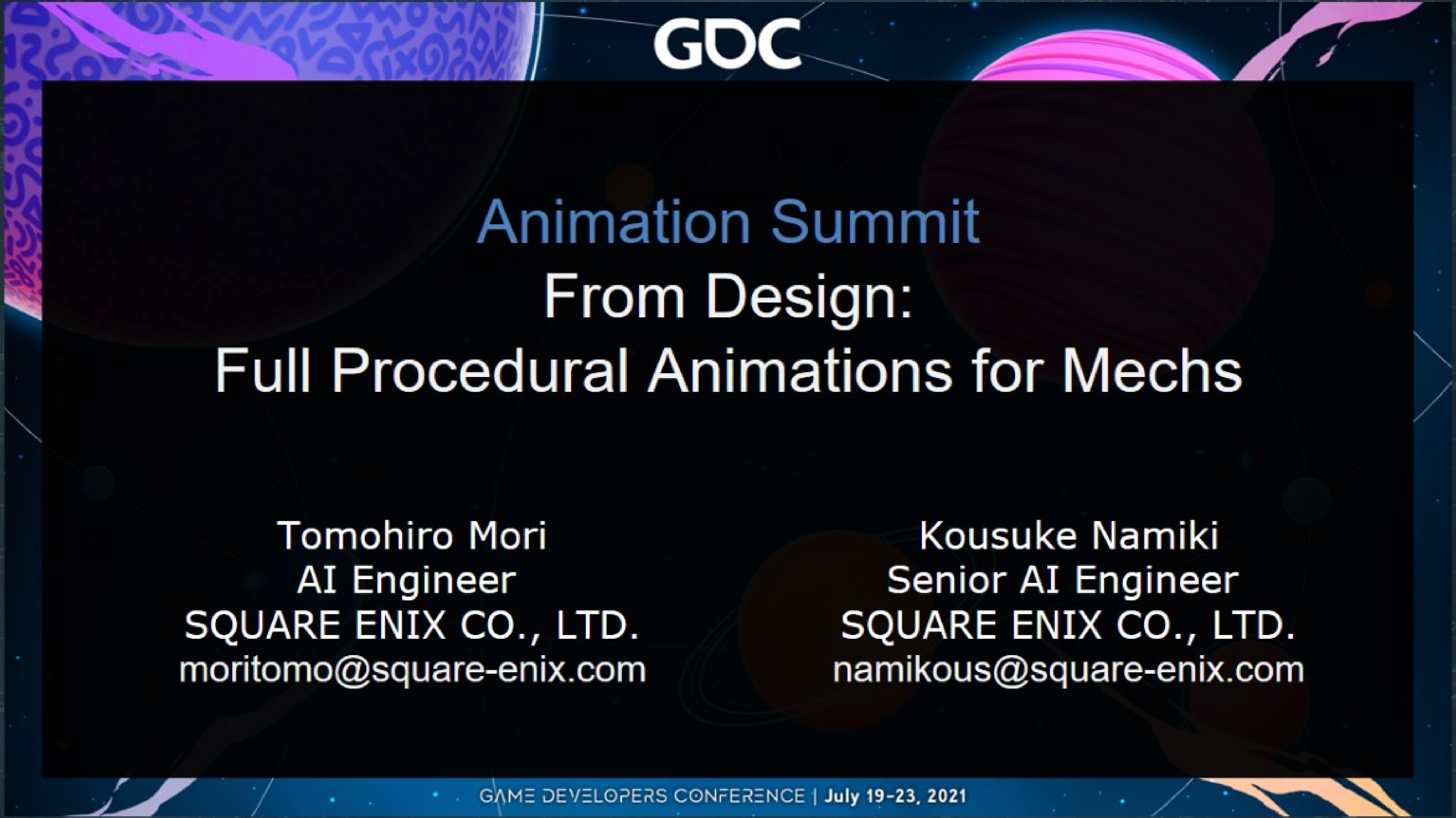
- We present “ART-HTN” which consists of 3 features.
    - Multi Scenario Plan
    - Simulation Planner
    - Executor

- We verified that on runtime demo with dynamic environment.

Thank you for watching!

Related Session

Monday, July 19 3:20pm - 3:50pm



GDC

Animation Summit

From Design:
Full Procedural Animations for Mechs

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Advanced Real-Time Hierarchical Task Networks
A New Approach

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