Game AI techniques from algorithmic approach to machine learning

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Kazuko Manabe
AI Engineer

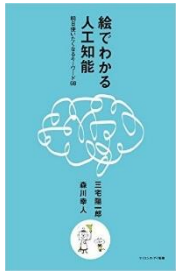
Youichiro Miyake Profile

Since 2004 , I have been developing game AI for many titles in AAA titles:

- *Chrome Hounds（Xbox360®）*
- *Demon's Souls（PS3®）*
- *Armored Core V（Xbox360®/PS3®）*
- *Final Fantasy XIV: A Realm Reborn*
- *Final Fantasy XV*
- *….*

AI for Game Titles

My books of AI



FINAL FANTASY XV Core AI Team in 2015

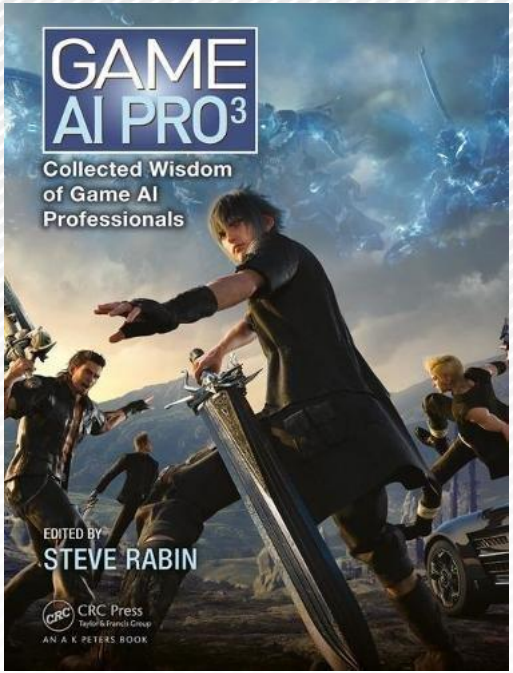
- SQUARE ENIX

I will explain FFXV AI team's total works implemented in the game.

- Youichiro Miyake

(AI Graph) Youji Shirakami 、Kazuya Shimokawa
(Monster AI & Learning) Kosuke Namiki, Tomoki Komatsu
(Animation) Noriyuki Imamura
(AI Navigation & Simulation) Fabien Gravot, Hendrik Skubch,
Ingimar Holm Gudmundsson, Matthew W. Johnson
(Buddy AI, Meta AI) Prasertvithyakarn Prasert, Tatsuhiro Joudan
(Data Logging) Shintaro Minamino
(AI Mode) Kosuke Takahashi

References



familiar with. Scripts are edited in Excel®, whose table oriented perspective lends itself well to rule-based scripting. Upon saving, a compiler translates the XML source to a binary loadable by the runtime. All identifiers used in the script, such as roles, predicates, and actions are translated to unique 32-bit identifiers by means of an id-server. In order to supply a debug UI with readable names again, a separate file with debug symbols is generated.

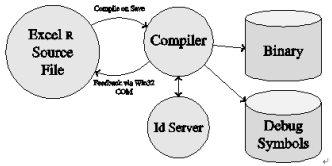


Figure 2 The build chain transforms textual scripts into an interpretable binary format.

▪ *5.1 Validation*

The mathematically grounded properties of STRIPS allow us to detect various scripting errors during compilation and supply feedback directly into the editor. Most notably, we can detect common problems such as:

- Unreachable states
- Unexecutable rules (specialization of rules of higher precedence)
- Usage of uninstantiated variables

However, Turing completeness of the scripting language prevents us from detecting all problems.

▪ **6 Extensions**

The concepts presented here were used heavily during production of FINAL FANTASY XV. Naturally, we made adjustments to the original system to accommodate unforeseen needs and situations.

- **Beyond Agents:** While actions of NPCs are easily representable in the language presented, achieving other effects, such as opening a shop UI or reacting to the player clicking an icon was not. Most of these issues relate to the communication with other game systems. We addressed this by wrapping these systems into proxy objects that participate in a script as if they were NPCs. Thus the shop itself becomes an NPC with available actions such as opening and closing specific shop pages. Moreover, these proxy objects push information about ongoing events in their domain into the blackboard. For example, the shop informs the script of what the player is buying or selling. The shopkeeper's reaction can then simply be driven using the blackboard.
- **Templating:** During development, we discovered sets of highly similar scripts being used throughout the game, such as scripts controlling different shopkeepers. The logic

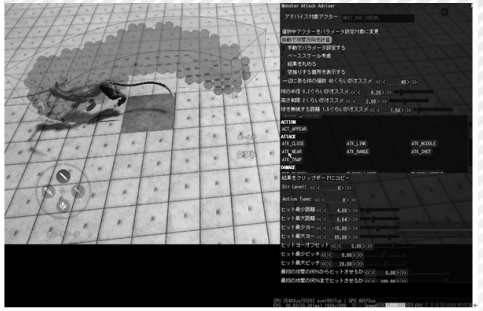


Figure 10 Attack motion analysis in simulation

▪ **8 Cooperation of Characters by Meta-AI**

Meta-AI (sometimes called AI Director) is an AI that keeps watching a game and dynamically changes the situation of the game by ordering characters [Miyake 2016a].

In FINAL FANTASY XV, the meta-AI arranges battle sequences. It always watches a battle situation and characters' behaviors. When a player or the buddies get into danger, the meta-AI will select one of the buddies who is most appropriate to go to help (for example, nearest and not attacking), and meta-AI gives the selected character an order to go help the character in danger(Figure 11). Buddies' decision-making always depends on the AI Graph. But when a buddy receives an order from meta-AI, it must stop its AI Graph and obey the meta-AI's order.

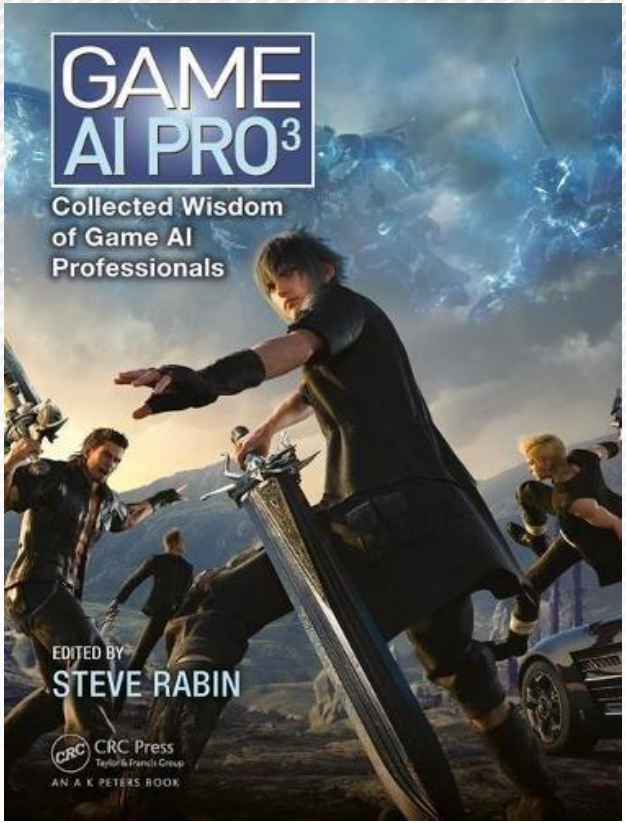
In a battle, the meta-AI can give four kinds of orders.

(a) Save a player or a buddy in danger.
(b) When a player is surrounded by enemies, allow a player to escape.
(c) Follow an escaping player.
(d) Obey the team tactics.

By using these orders, a meta-AI can tighten a battle flow, and controls a player's tension and relaxation.

GAME AI PRO 3 (2017/6)

SQUARE ENIX 5 articles in Game AI PRO 3



Predictive Animation Control Using Simulations and Fitted Models.
Ingimar Hólm Guðmundsson, Skubch Hendrik, Fabien Gravot and Yoichiro Miyake

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch

Logging Visualization in FINAL FANTASY XV
Matthew W. Johnson, Fabien Gravot, Shintaro Minamino, Ingimar Gudmundsson, Hendrik Skubch, and Miyake Youichiro

Guide to Effective Autogenerated Spatial Queries
Eric Johnson

A Character Decision-Making System for FINAL FANTASY XV by combining Behavior Trees and State Machines
Youichiro Miyake, Youji Shirakami, Shimokawa Kazuya, Kousuke Namiki, Tomoki, Komatsu, Tatsuhiro Joudan, Prasertvithyakarn Prasert, Takanori Yokoyama

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Lecture slides

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- http://www.jp.square-enix.com/tech/library/pdf/2015cedec_FFXV_AI_English_part2.pdf

- Hendrik Skubch, Not Just Planning: STRIPs for Ambient NPC Interactions in Final Fantasy XV (nucl.ai 2015)
- https://archives.nucl.ai/recording/not-just-planning-strips-for-ambient-npc-interactions-in-final-fantasy-xv/

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Articles in Books

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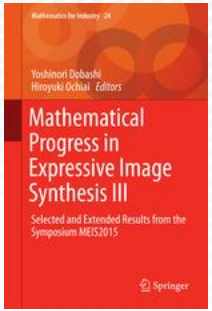
  Handbook of Digital Games and Entertainment Technologies, Pages 253-292
  http://www.springer.com/jp/book/9789814560498



- Youichiro Miyake, A Multilayered Model for Artificial Intelligence of Game Characters as Agent Architecture
  Mathematical Progress in Expressive Image Synthesis III, Pages 57-60
  http://www.springer.com/jp/book/9789811010750

Digital Game AI

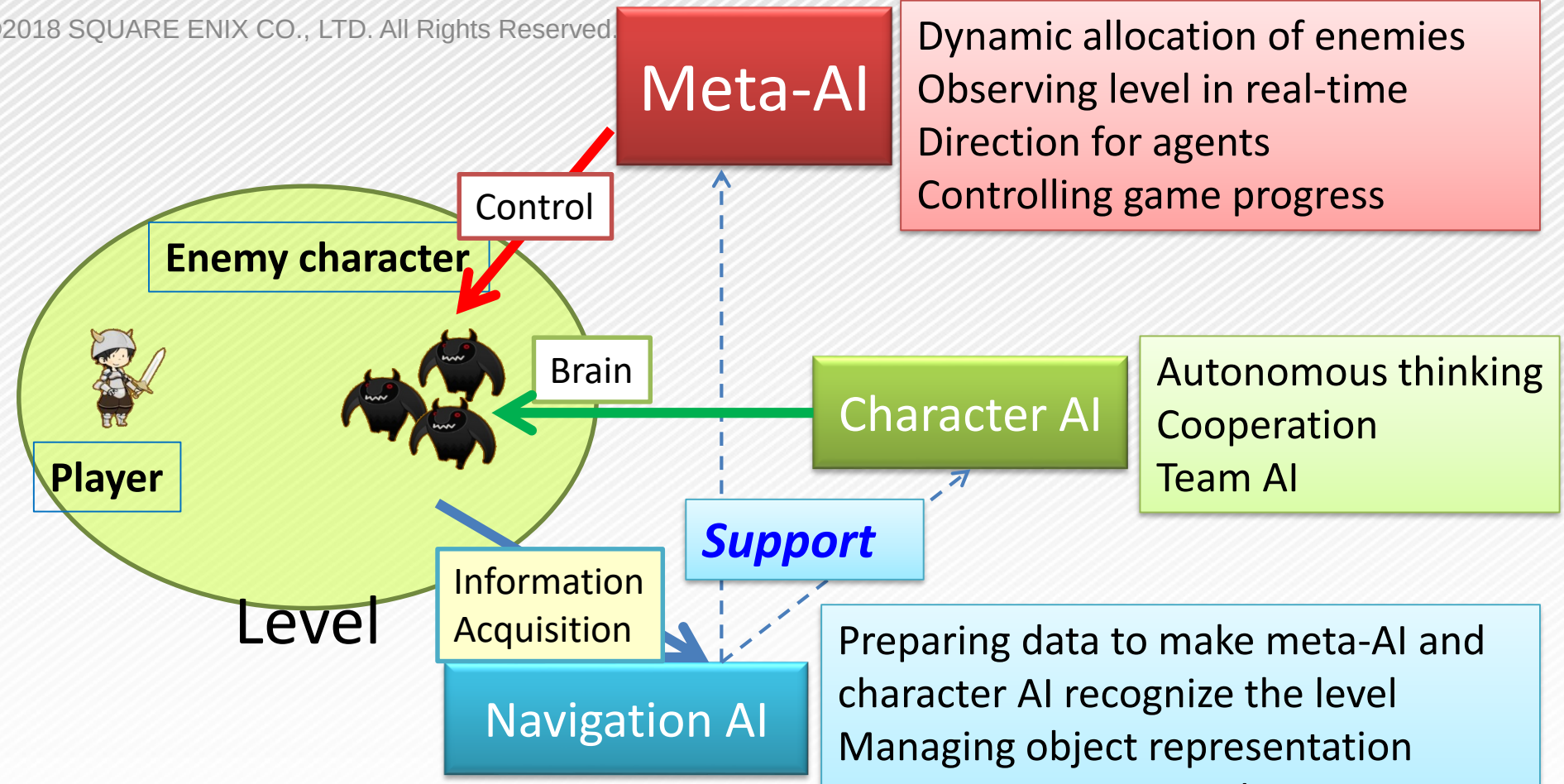
Contents

This slide has many movies that can be replayed by pushing a button ▶

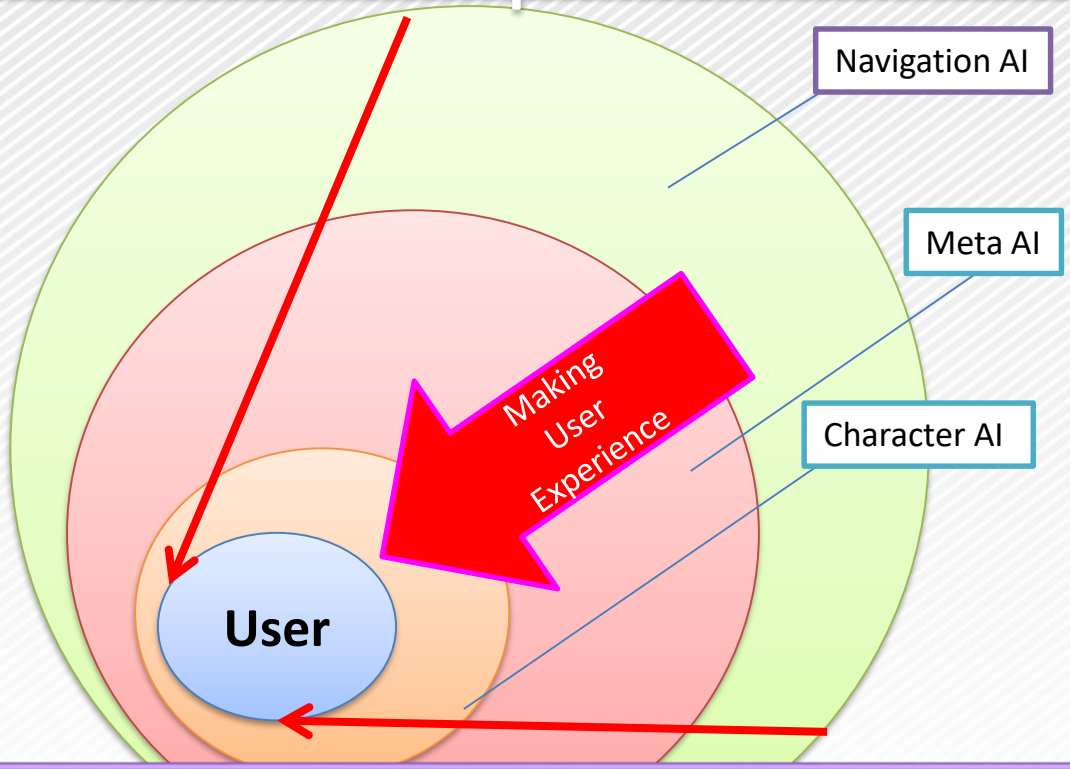
Chapter 2

INTORDUCTION

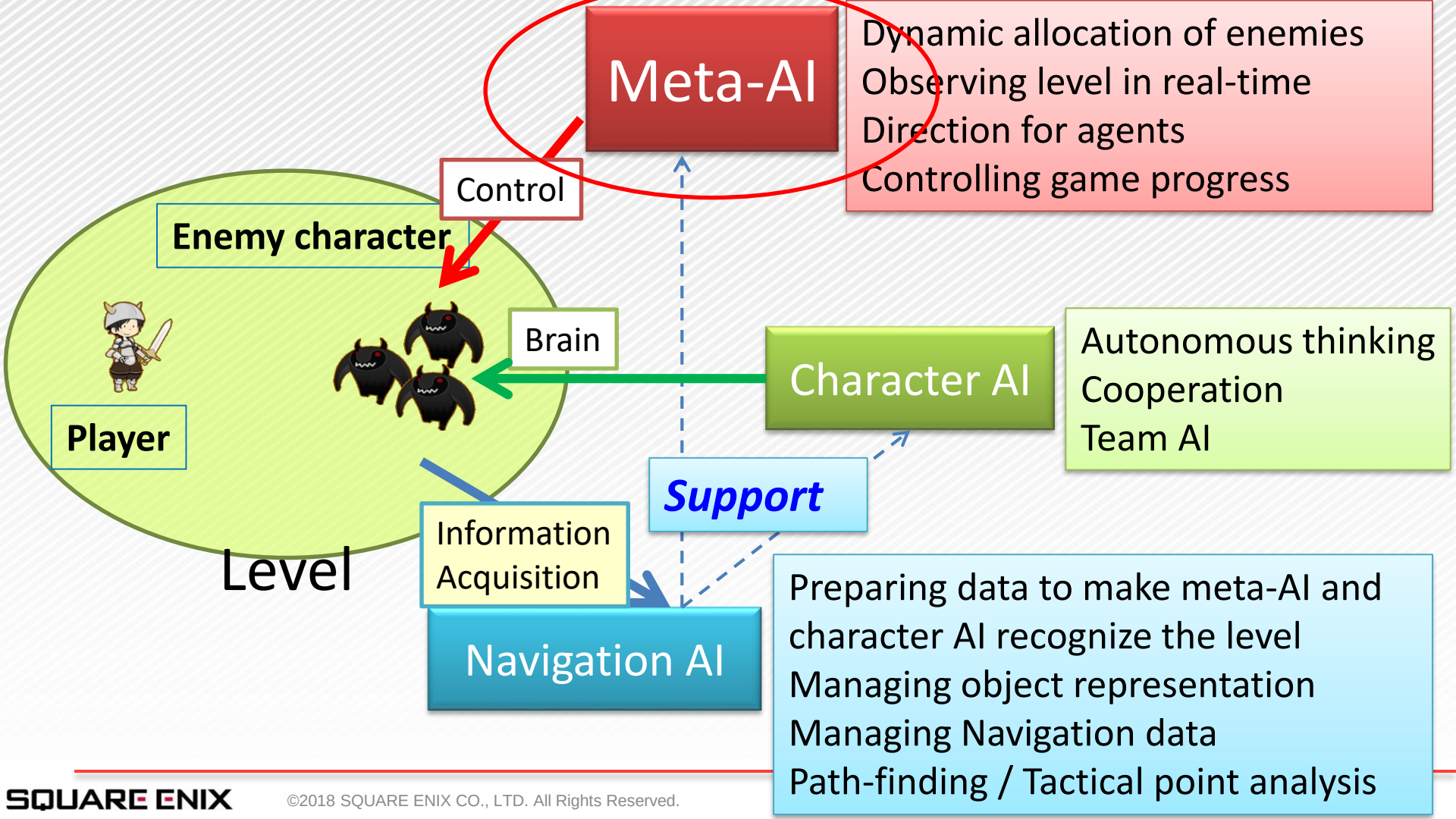
GAME AI OVERVIEW



User Experience



The combination of “Navigation AI” ”Meta AI”” Character AI” makes user experience.

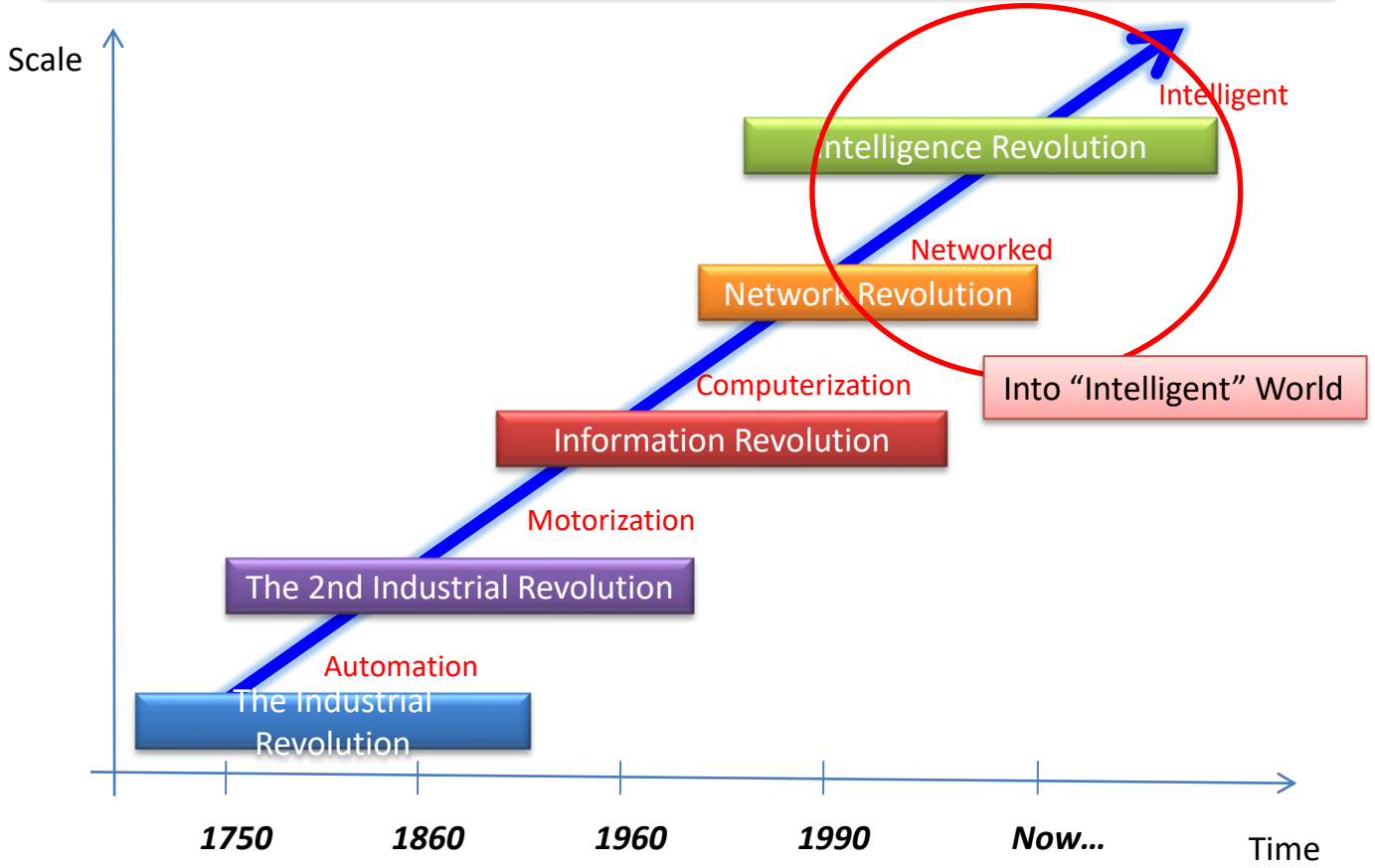


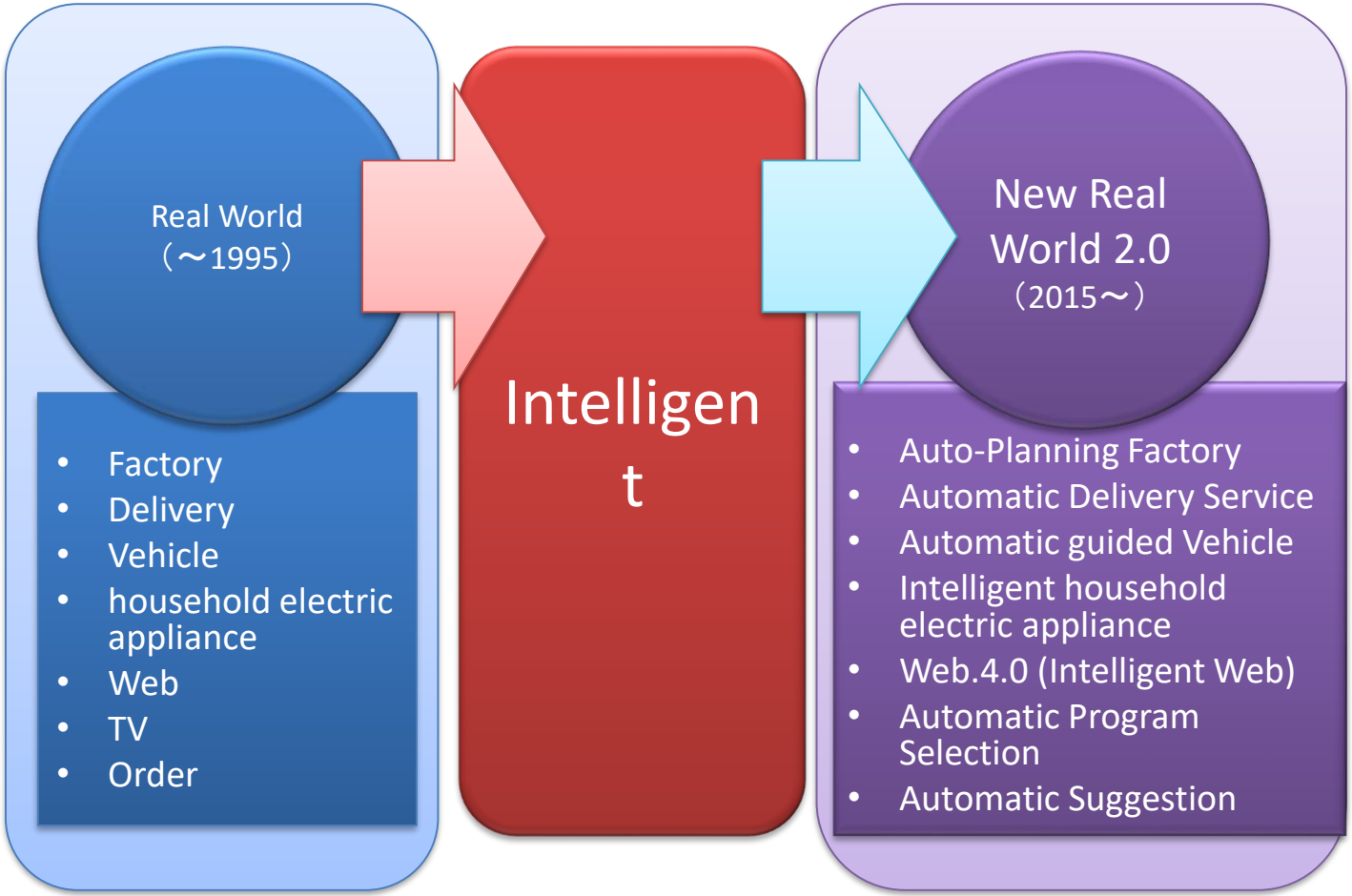
Introduction

1.1

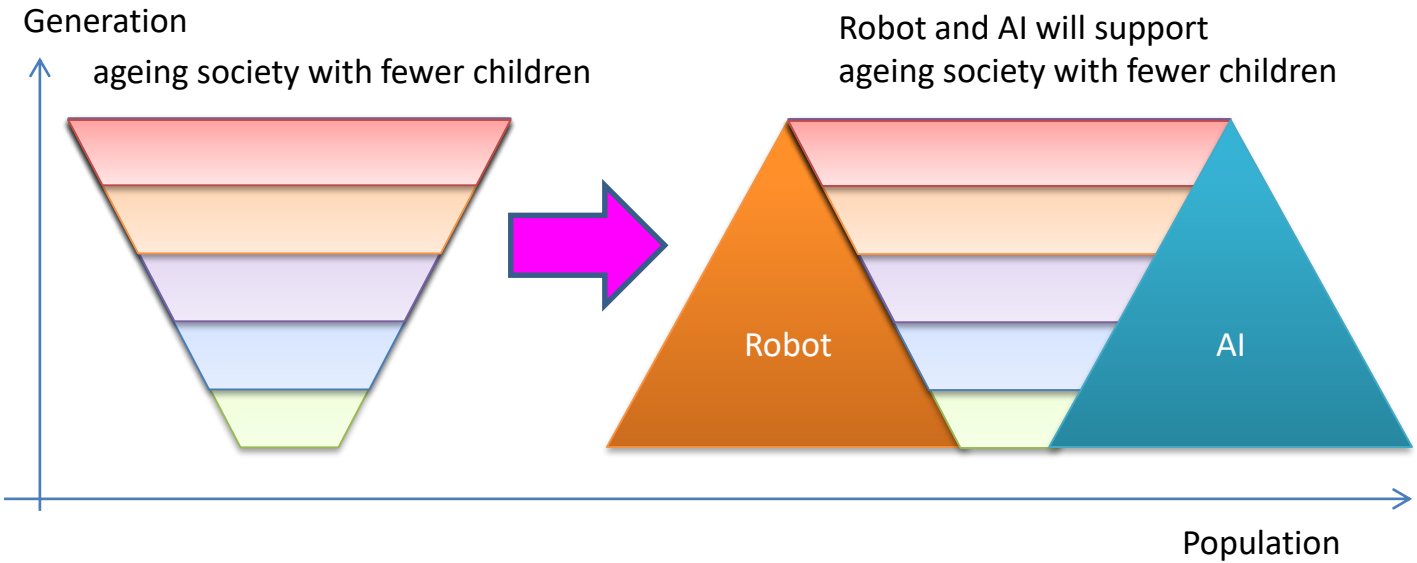
OVERVIEW

Technological Innovation

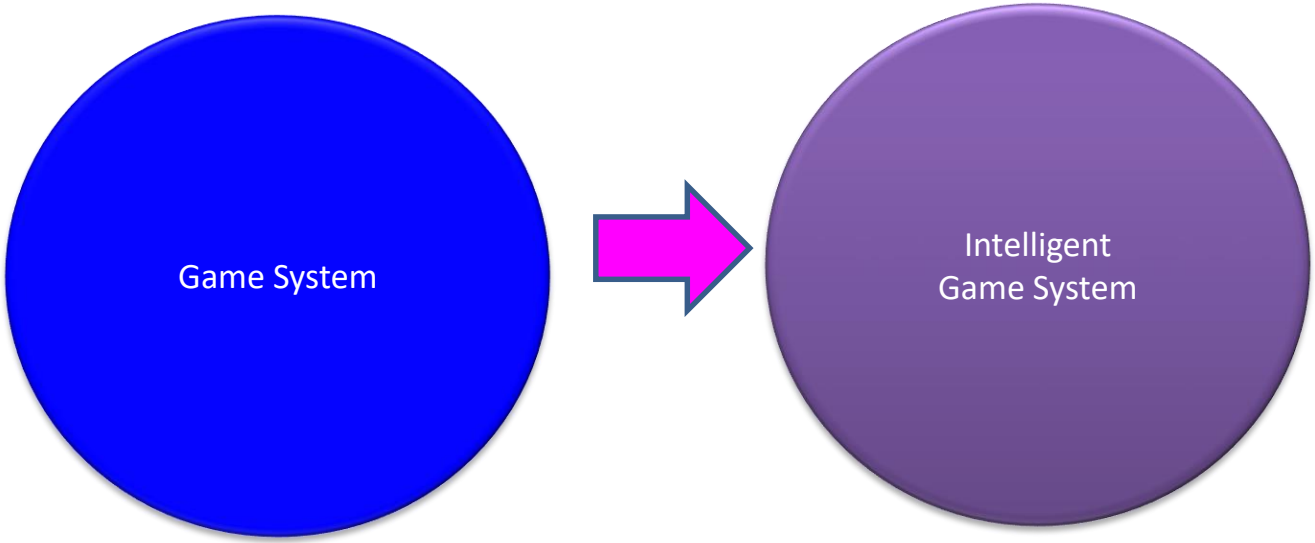




Society and AI



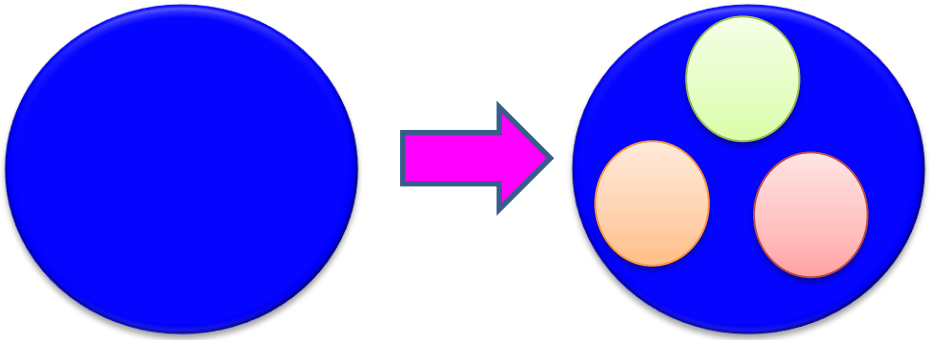
Intelligent Game System



Digital Games have also become intelligent.
So, what is an “Intelligent Game System” ?

What is digital game ?

- Interactive Digital Space
- The space becomes structured
- AI becomes a module



The System of digital game AI

- Role of AI in digital game becomes clear.
- There are three roles of AI.

Meta AI

AI to control a whole game system

Character AI

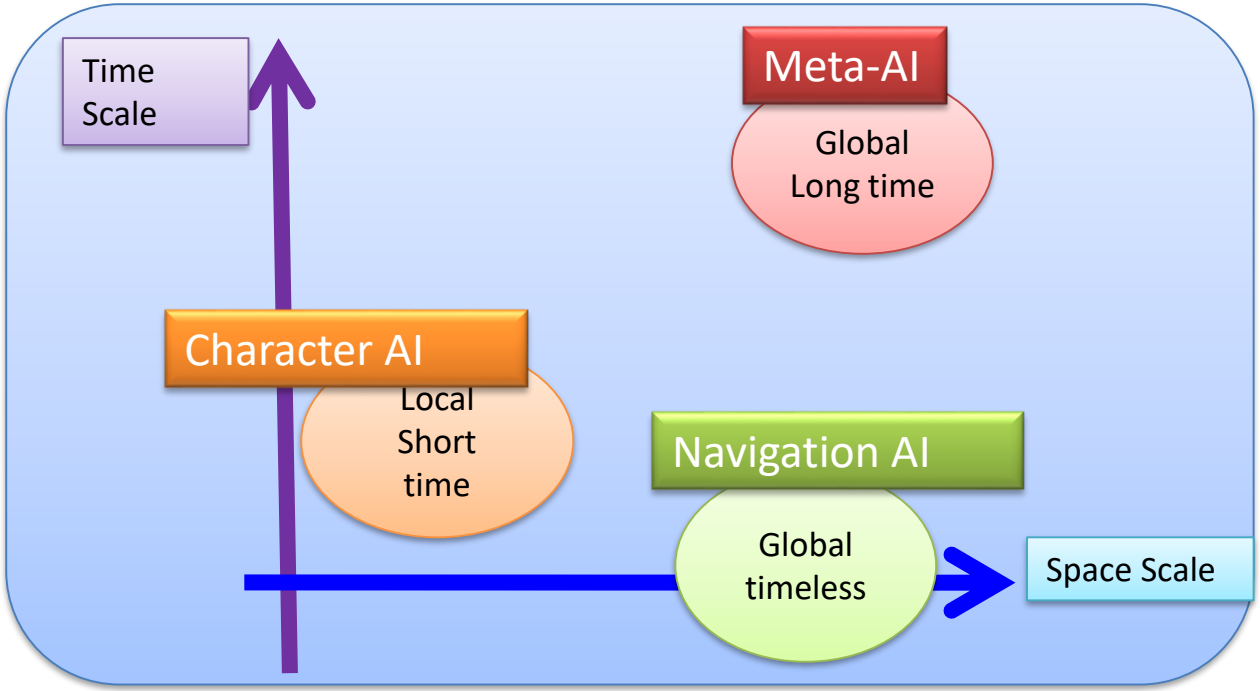
AI of character (Character's Brain)

Navigation AI

AI to recognize an environment in game by analyzing a level, terrain, and space.

Two Axis to categorize AI

- The problem of “What is AI” is a very difficult problem.
- We had better search what problem an AI is seeking to resolve.



Different AI, different role

Meta-AI

Meta AI keeps watching a game situation and dynamically controls game balance, intention of game player, and game dynamics.

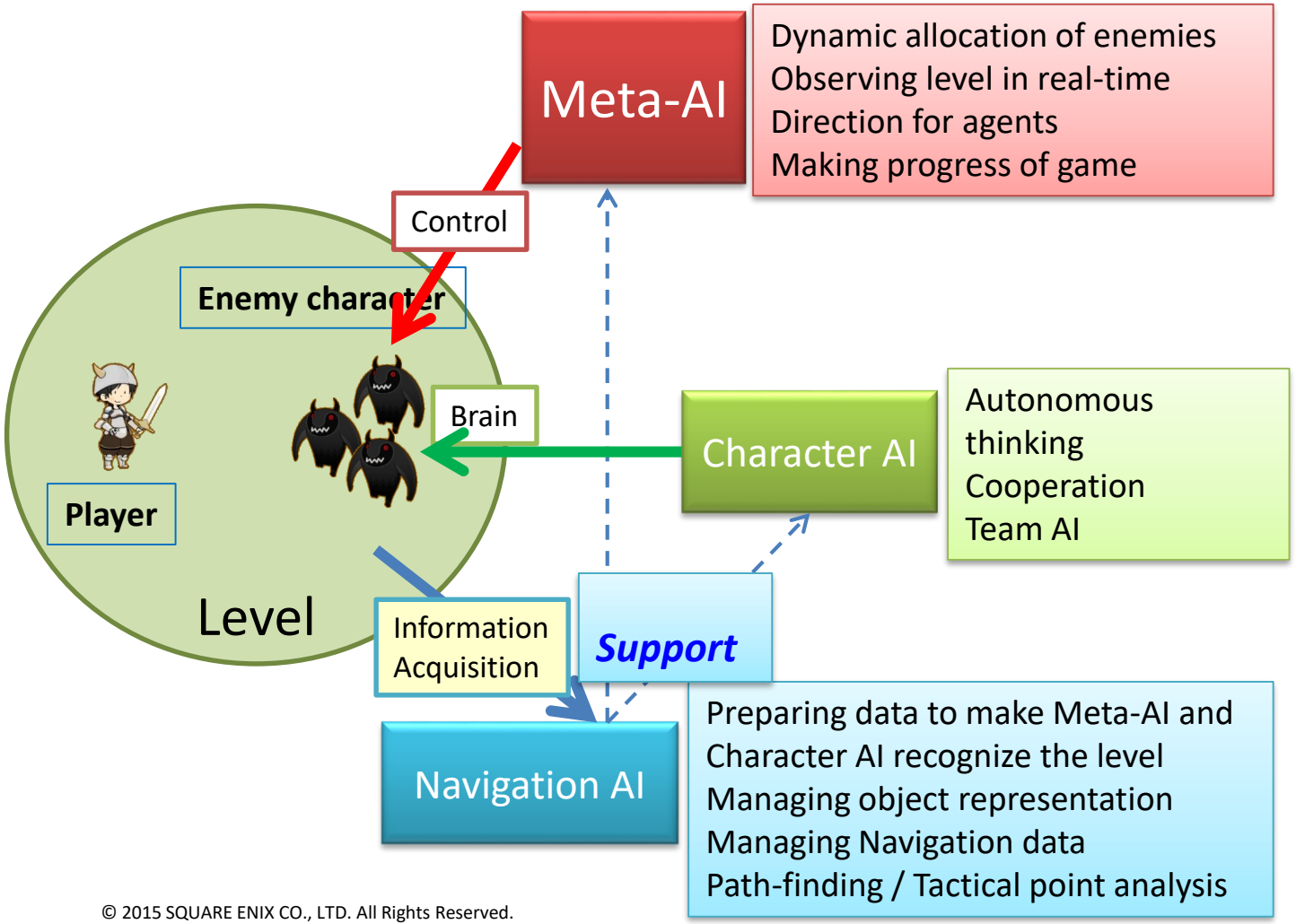
Character AI

Character AI is a character's brain, which recognizes the local environment around the character, and executes its action and motion in a limited time.

Navigation AI

Navigation AI analyzes the terrain and level design and abstracts space features which are used to adapt a character's action to the environment.

AI who has a role is called "Agent". Especially, in digital game, character AI is called "Agent".

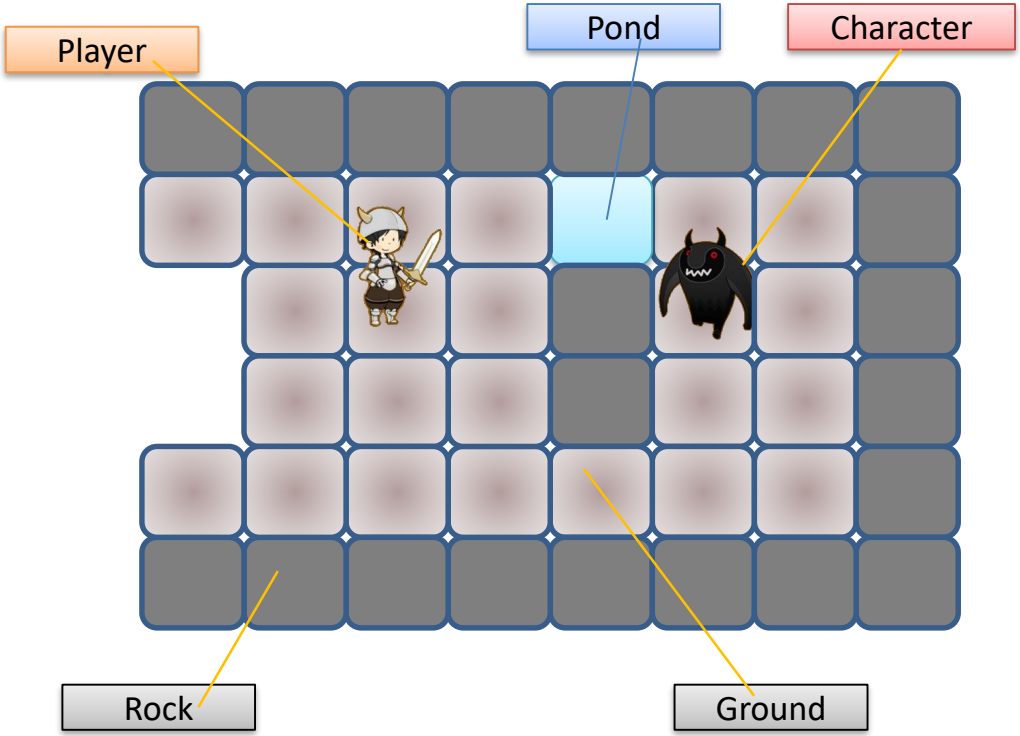


1.2

LET’S SEE AN EXAMPLE.

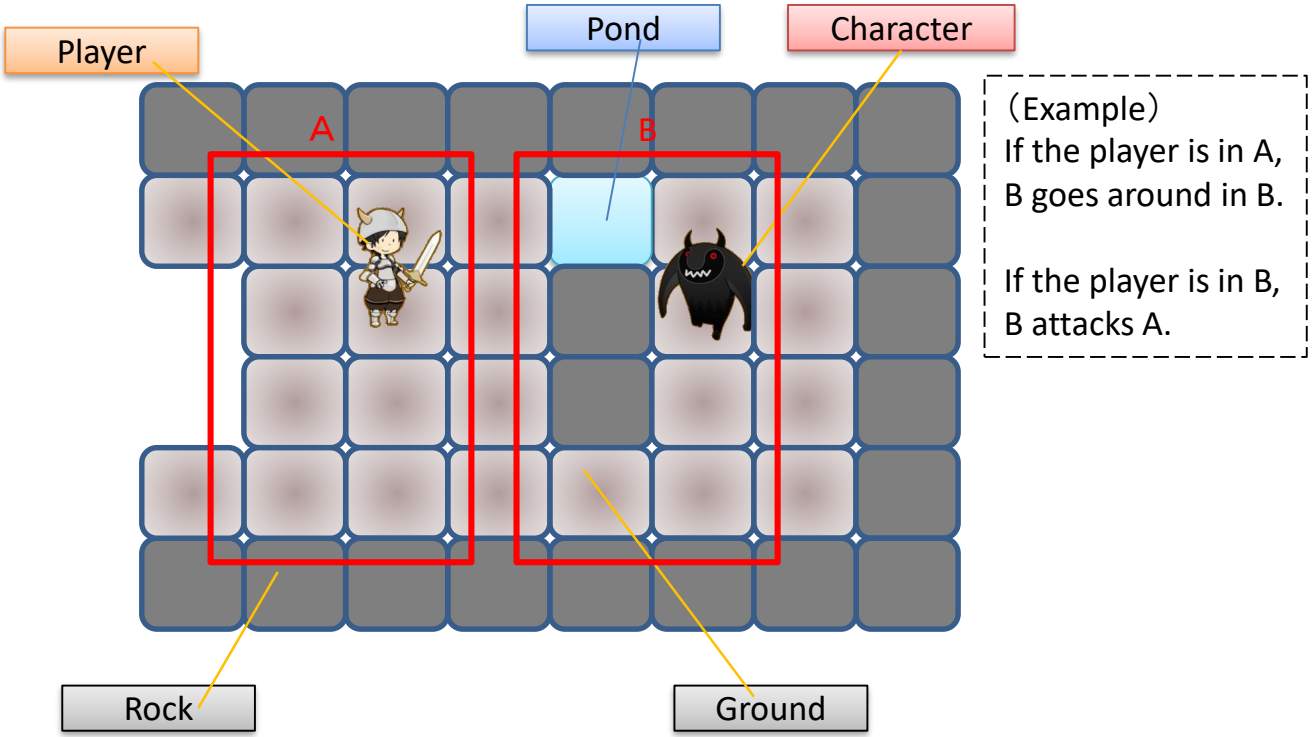
How to design AI ?

For example, how to design AI in this situation ?



How to design AI ?

For example, how to design AI in this situation ?

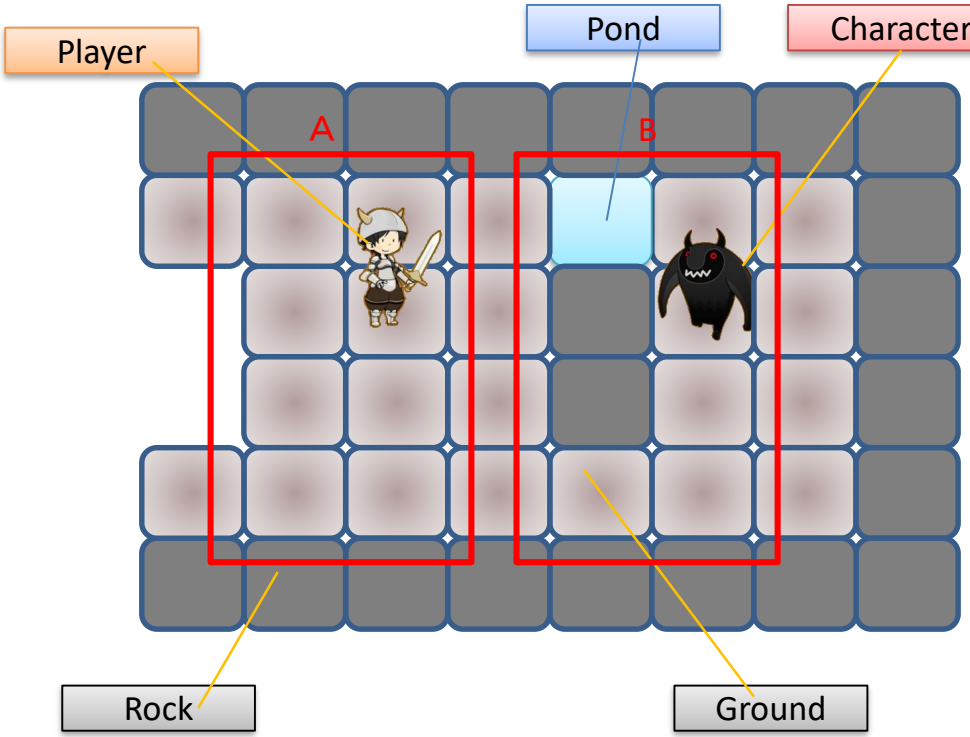


（Example）
If the player is in A,
B goes around in B.

If the player is in B,
B attacks A.

How to design AI ?

For example, how to design AI in this situation ?



（Example）
If the player is in A,
B goes around in B.

If the player is in B,
B attack A.

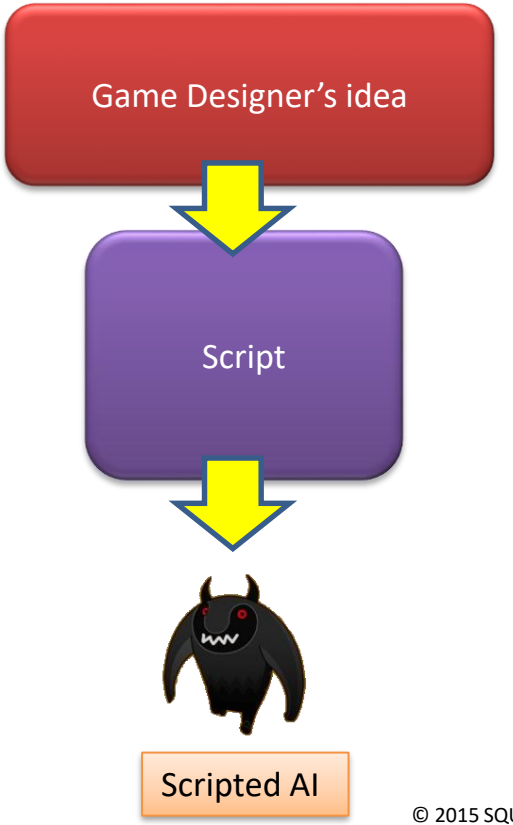
But this statement is not the AI's idea.

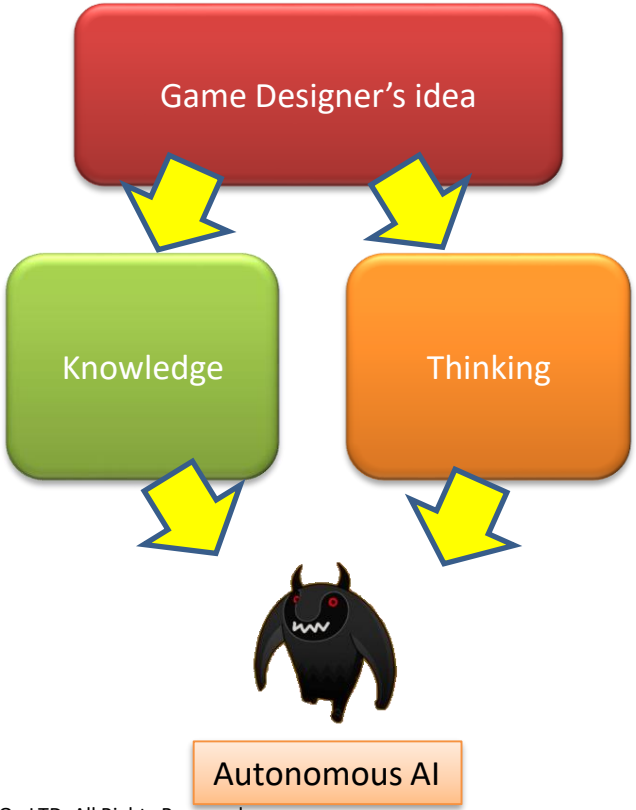
A game designer writes these ideas.

= They are orders to AI.

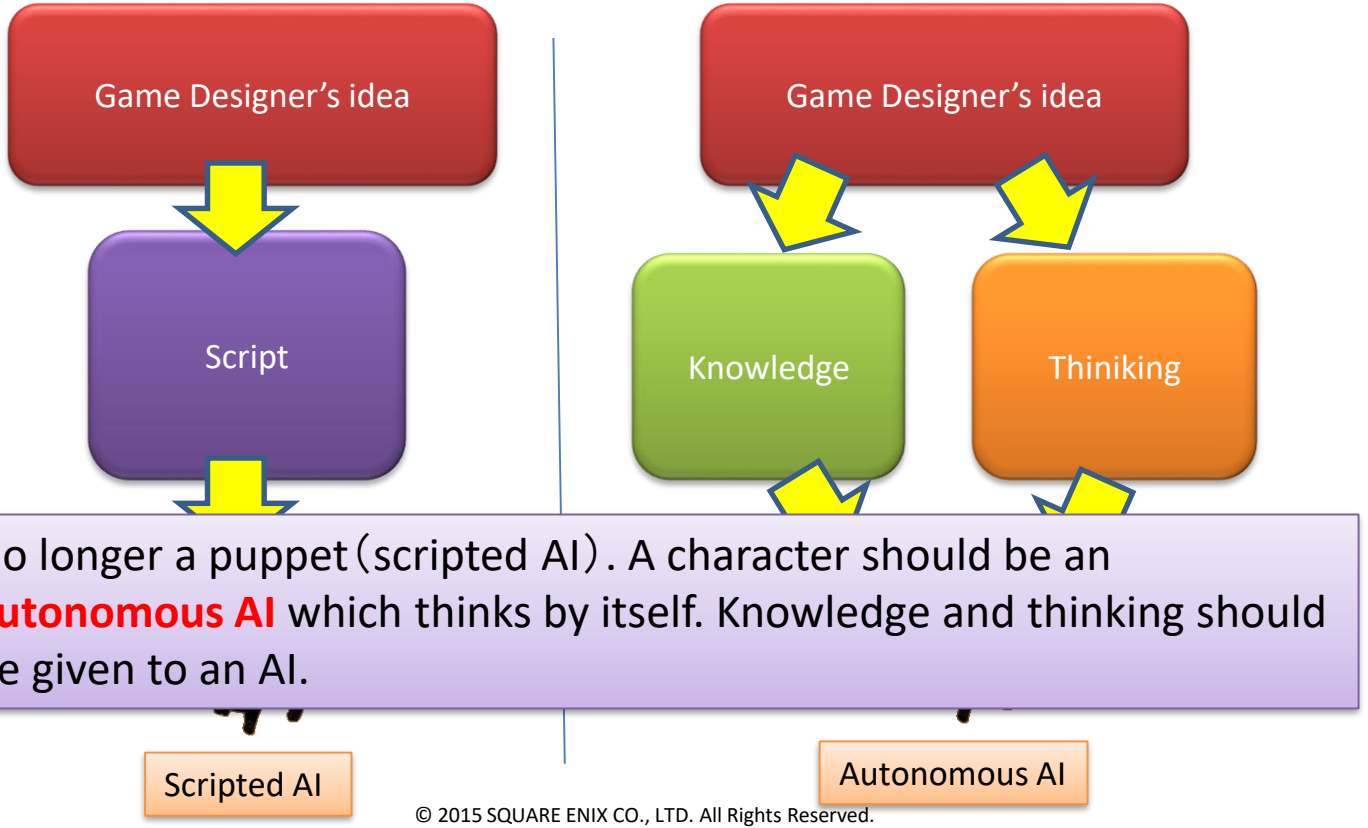
Classical AI = Scripted AI

From Scripted AI to Autonomous AI

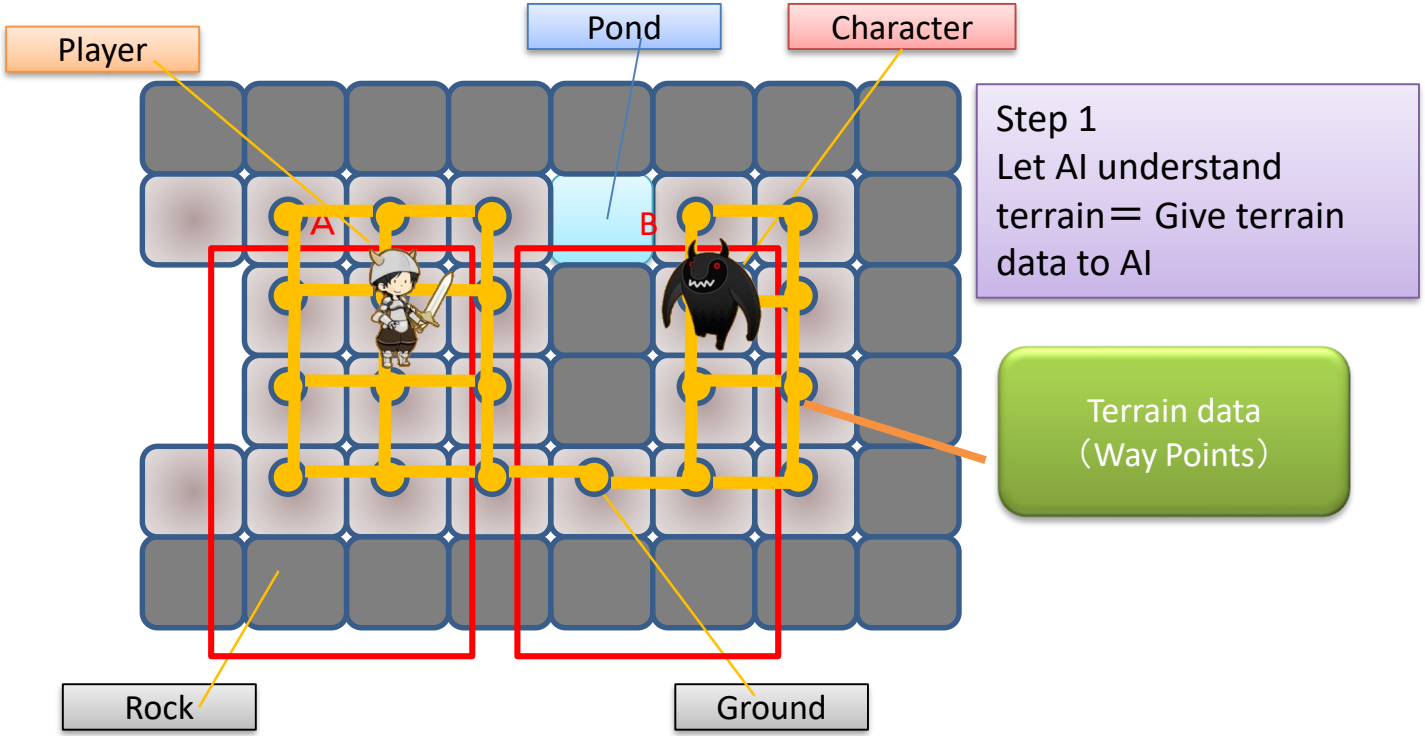




From Scripted AI to Autonomous AI



How to design AI ?

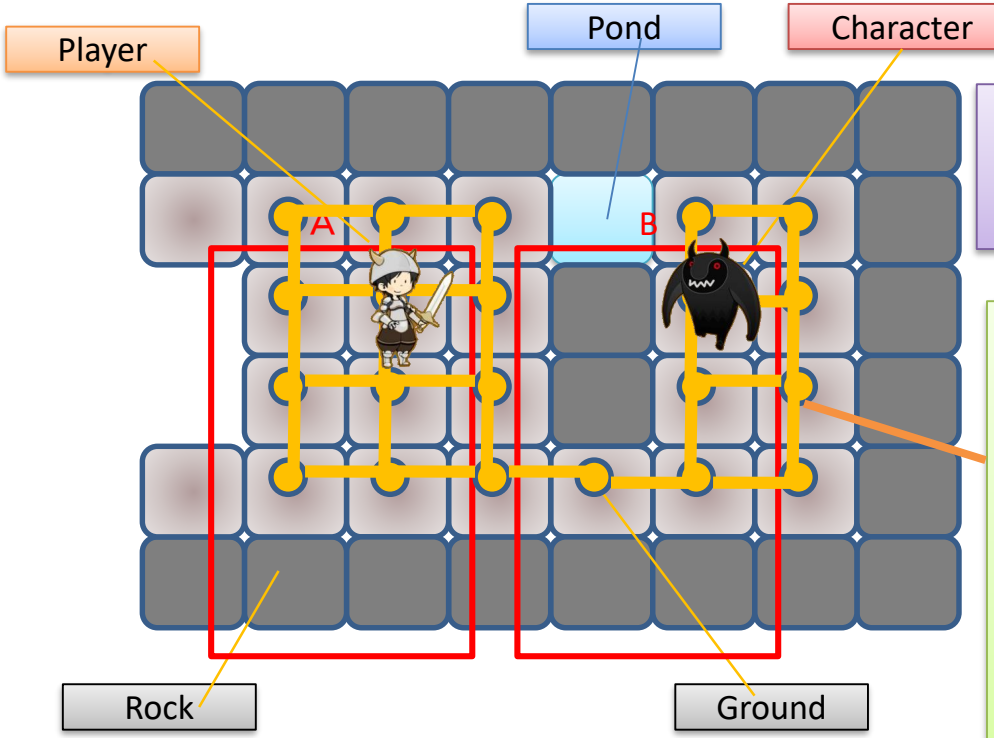


Step 1
Let AI understand terrain＝ Give terrain data to AI

Terrain data
（Way Points）

AI can guess it relative position to a player by using terrain data.

How to design AI ?



Step 2
Let AI know its position by using terrain data.

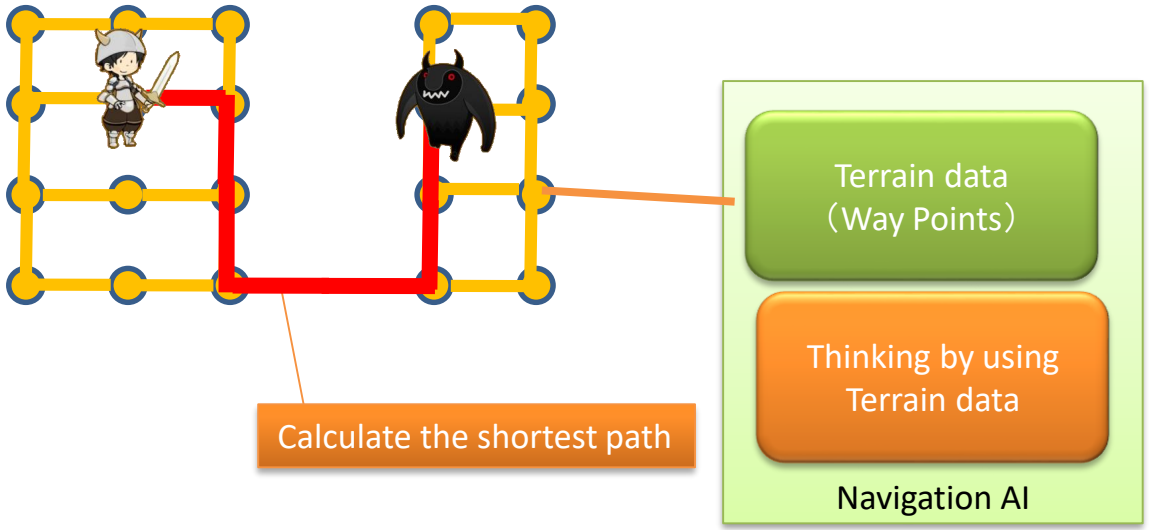
Terrain data
（Way Points）

Thinking about positon by using terrain data

Navigation AI

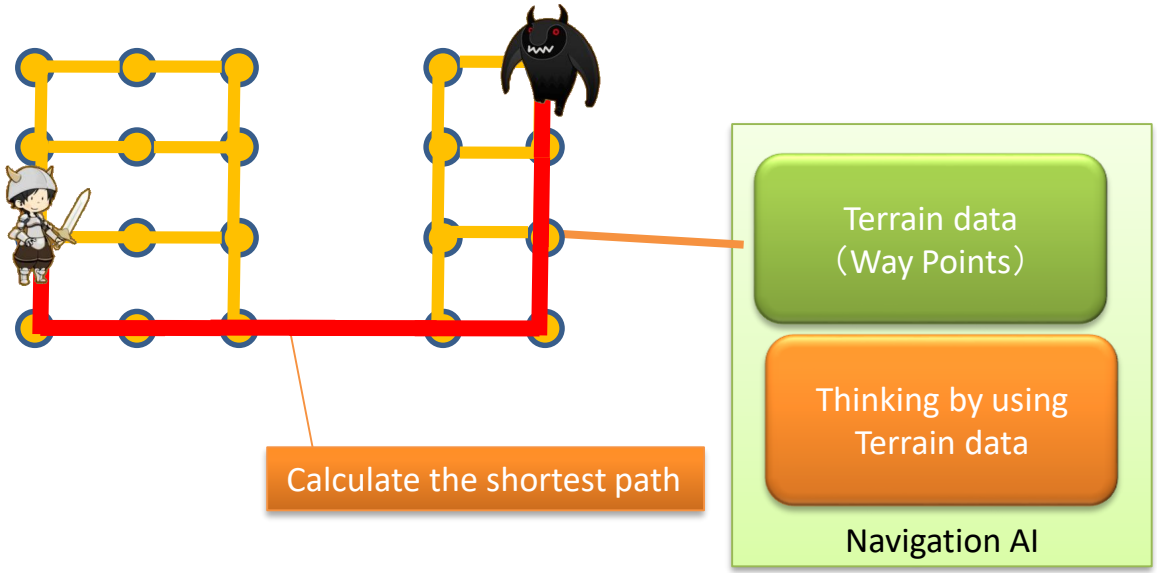
AI can guess its relative position to a player by using terrain data.

How to design AI ?



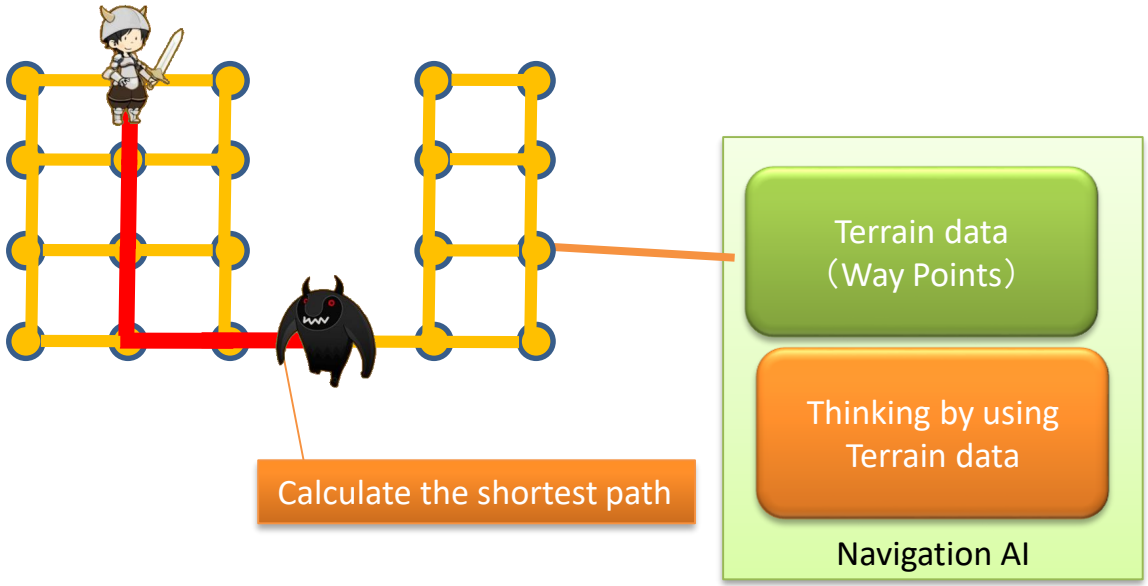
Thinking by using terrain data → Networked graph search

How to design AI ?



Thinking by using terrain data → Networked graph search

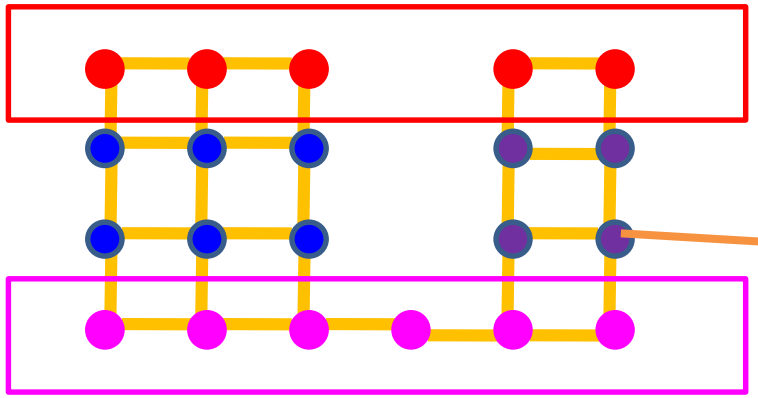
How to design AI ?



Thinking by using terrain data → Networked graph search

How to design AI ?

All points can be seen from any point in a group.



All points can be seen from any point in a group.

Terrain data
（Way Points）

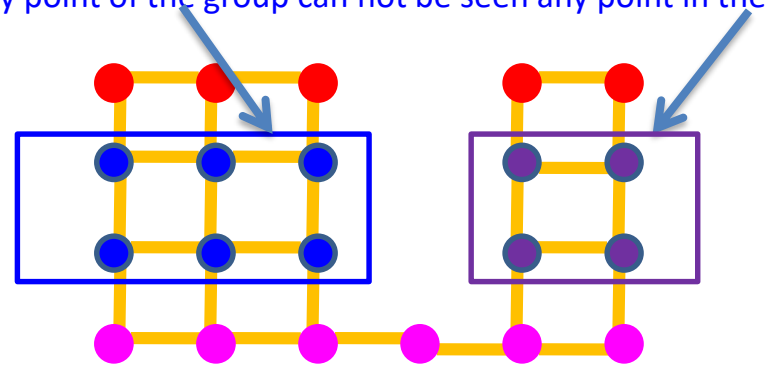
Thinking by using
Terrain data

Navigation AI

Make Networked Graph include LOS (Line of Sight) data.

How to design AI ?

Any point of the group can not be seen any point in the group.



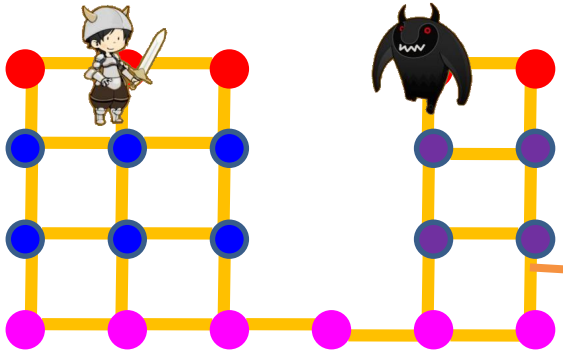
Terrain data
（Way Points）

Thinking by using
Terrain data

Navigation AI

Make Networked Graph include LOS (Line of Sight) data.

How to design AI ?



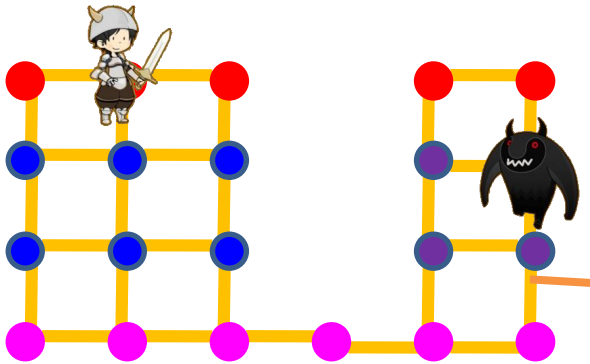
Terrain data
（Way Points）

Thinking by using
Terrain data

Navigation AI

An AI can be seen by the player.

How to design AI ?



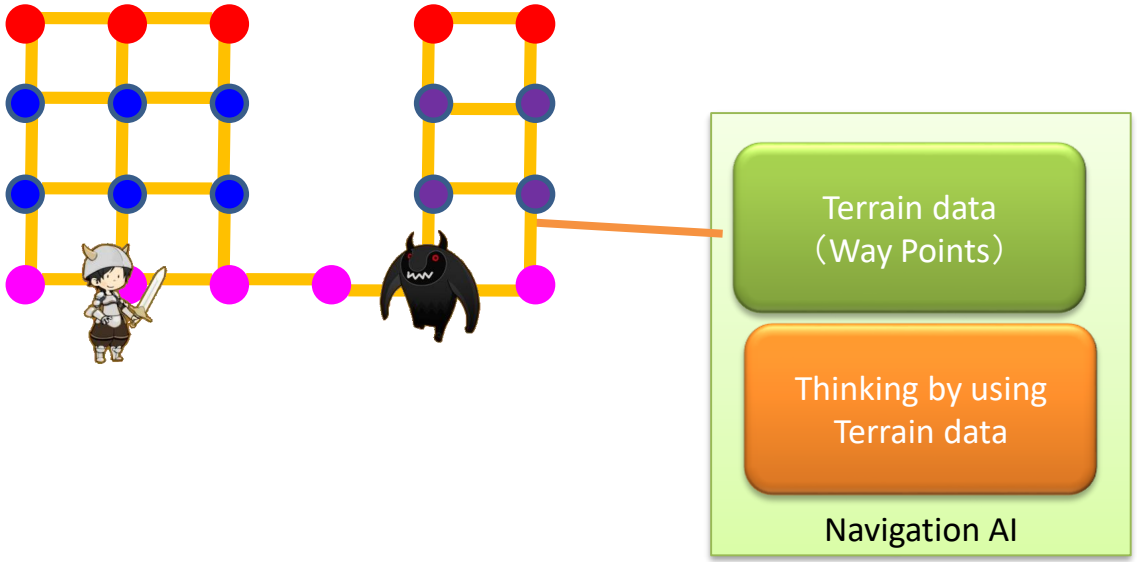
Terrain data
（Way Points）

Thinking by using
Terrain data

Navigation AI

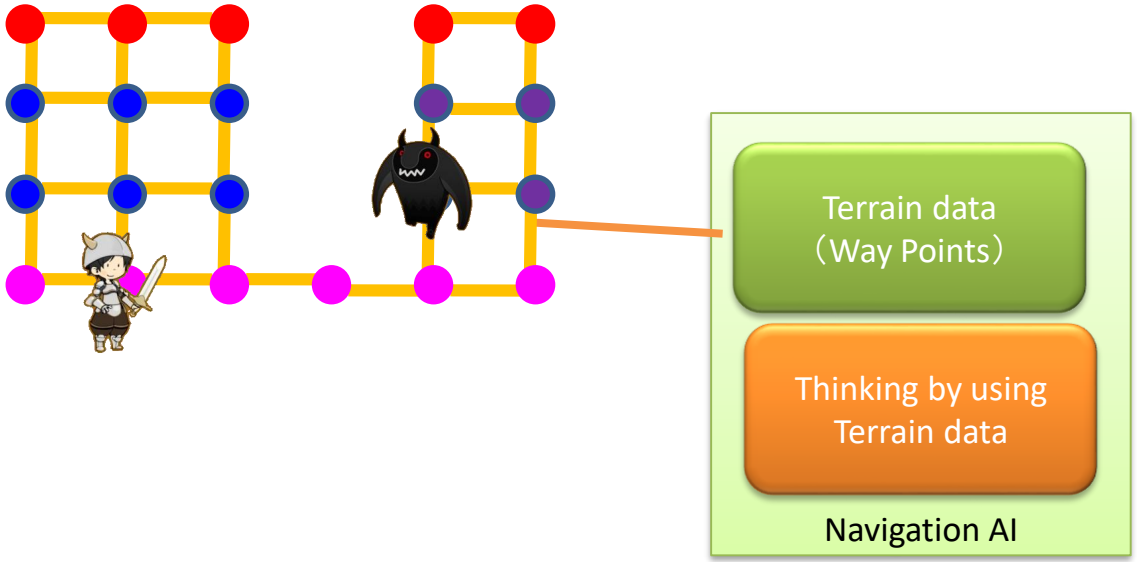
The player can not see the AI.

How to design AI ?



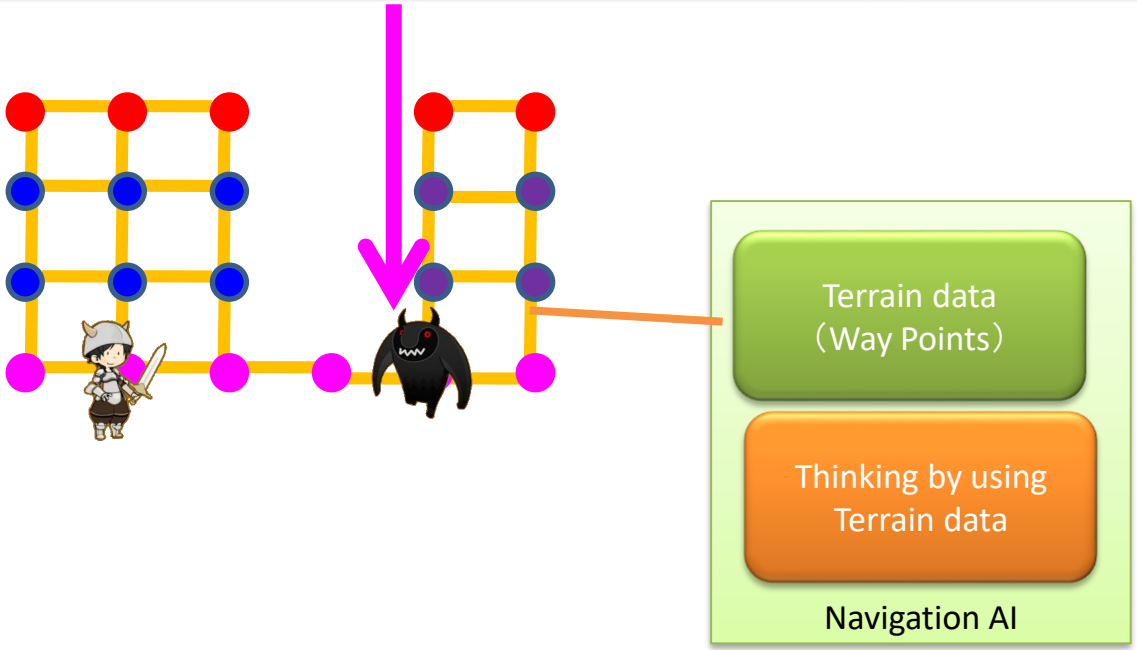
The player can see the AI.

How to design AI ?



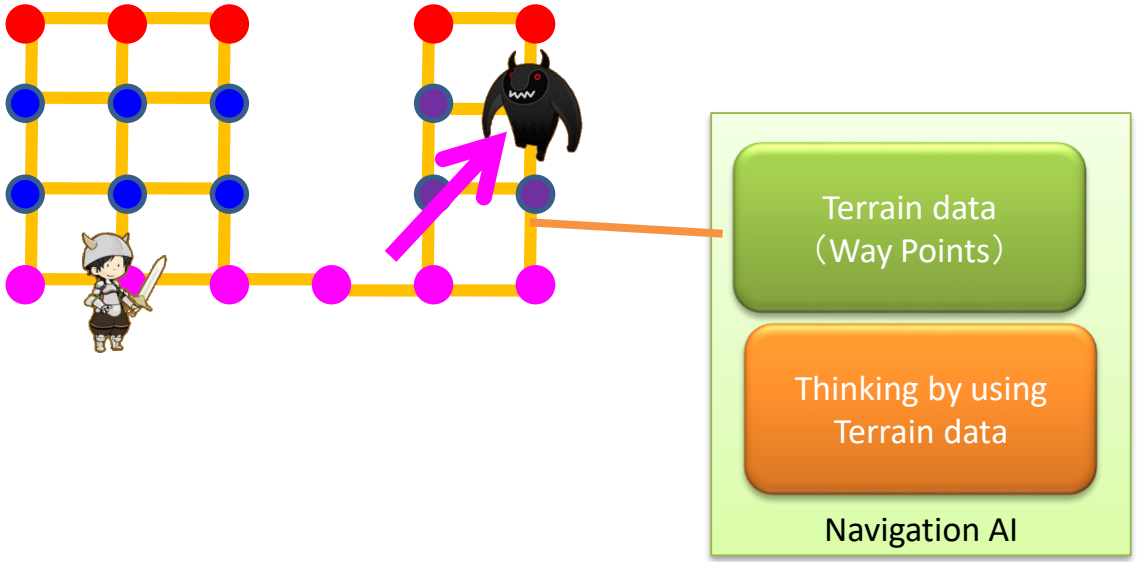
The player can not see the AI.

How to design AI ?



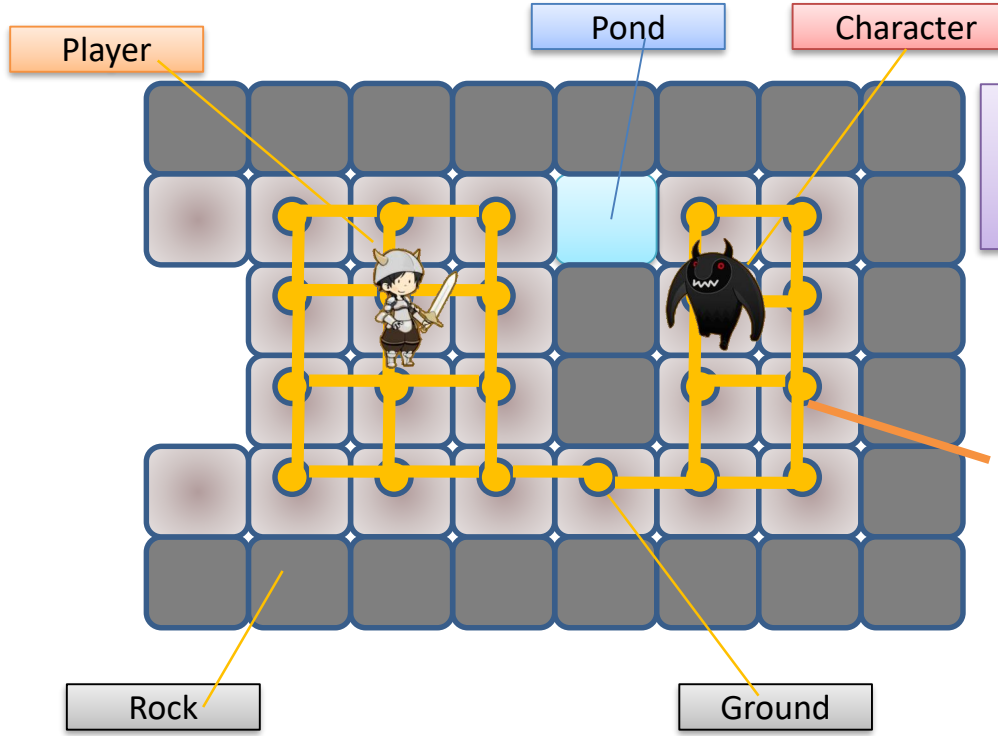
The AI will move so the player can see it.

How to design AI ?



The AI will move so the player can not see it.

How to design AI ?



Step 3
Let AI think about timing when to attack.

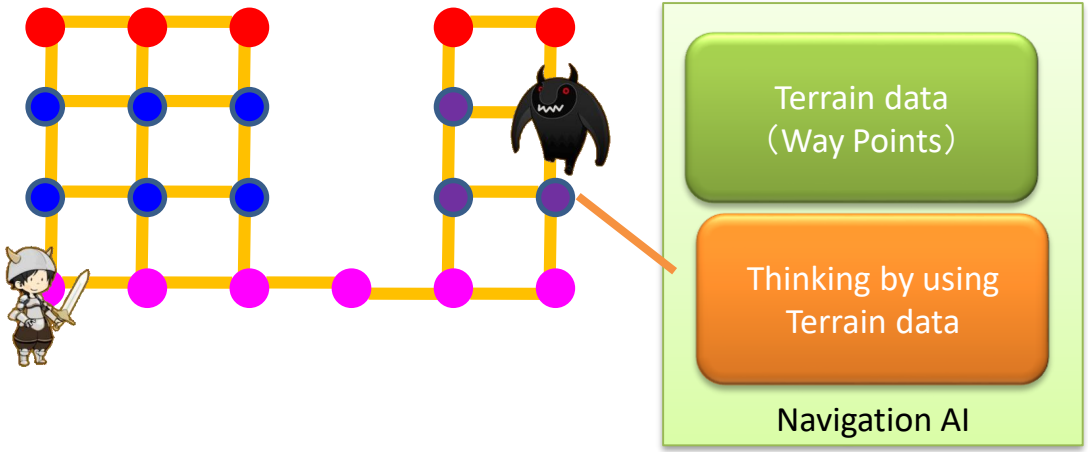
Terrain data
（Way Points）

Thinking its positon by using terrain data

Decision Making

How to design AI ?

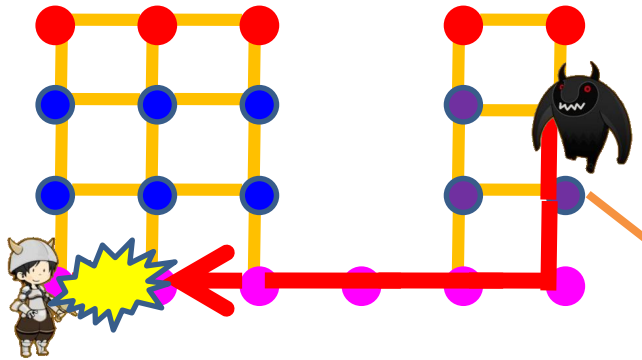
Decision Making



Attack?　Hide?　Threaten?　selection
＝　Decision Making Thinking

How to design AI ?

Decision Making



Terrain data
（Way Points）

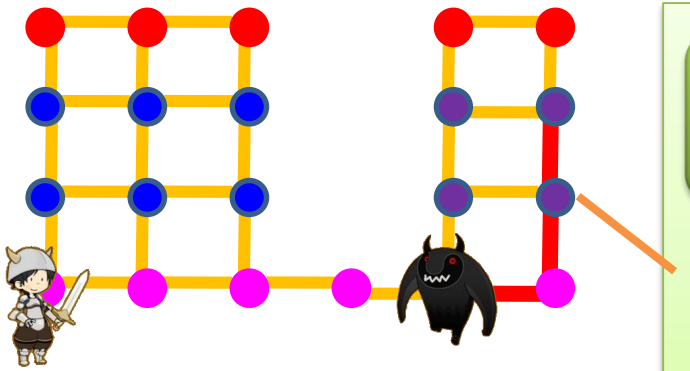
Thinking by using
Terrain data

Navigation AI

Attack

How to design AI ?

Decision Making



Terrain data
（Way Points）

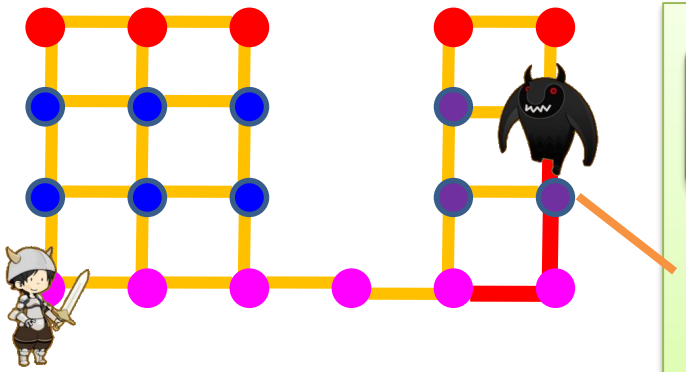
Thinking by using
Terrain data

Navigation AI

Threaten (= Going to the positon where a player can see AI)

How to design AI ?

Decision Making



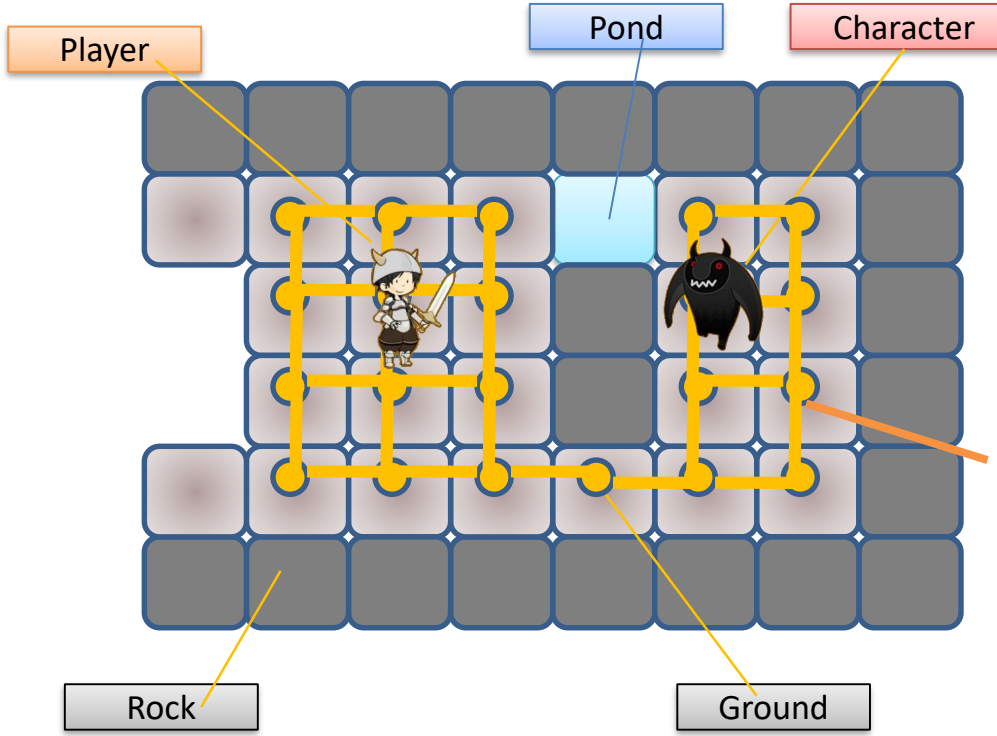
Terrain data
（Way Points）

Thinking by using
Terrain data

Navigation AI

Hide（＝AI goes to the positon where a player can not see AI）

How to design AI ?



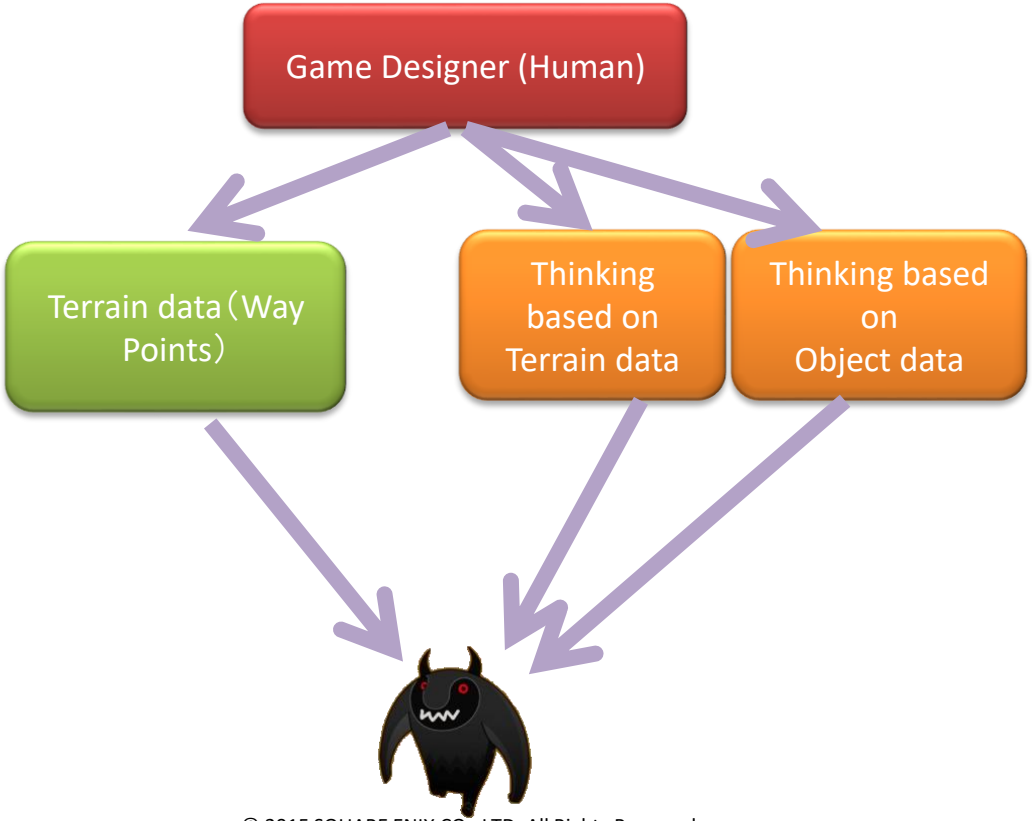
Step 1- 3
Let AI be intelligent.

Terrain data
（Way Points）

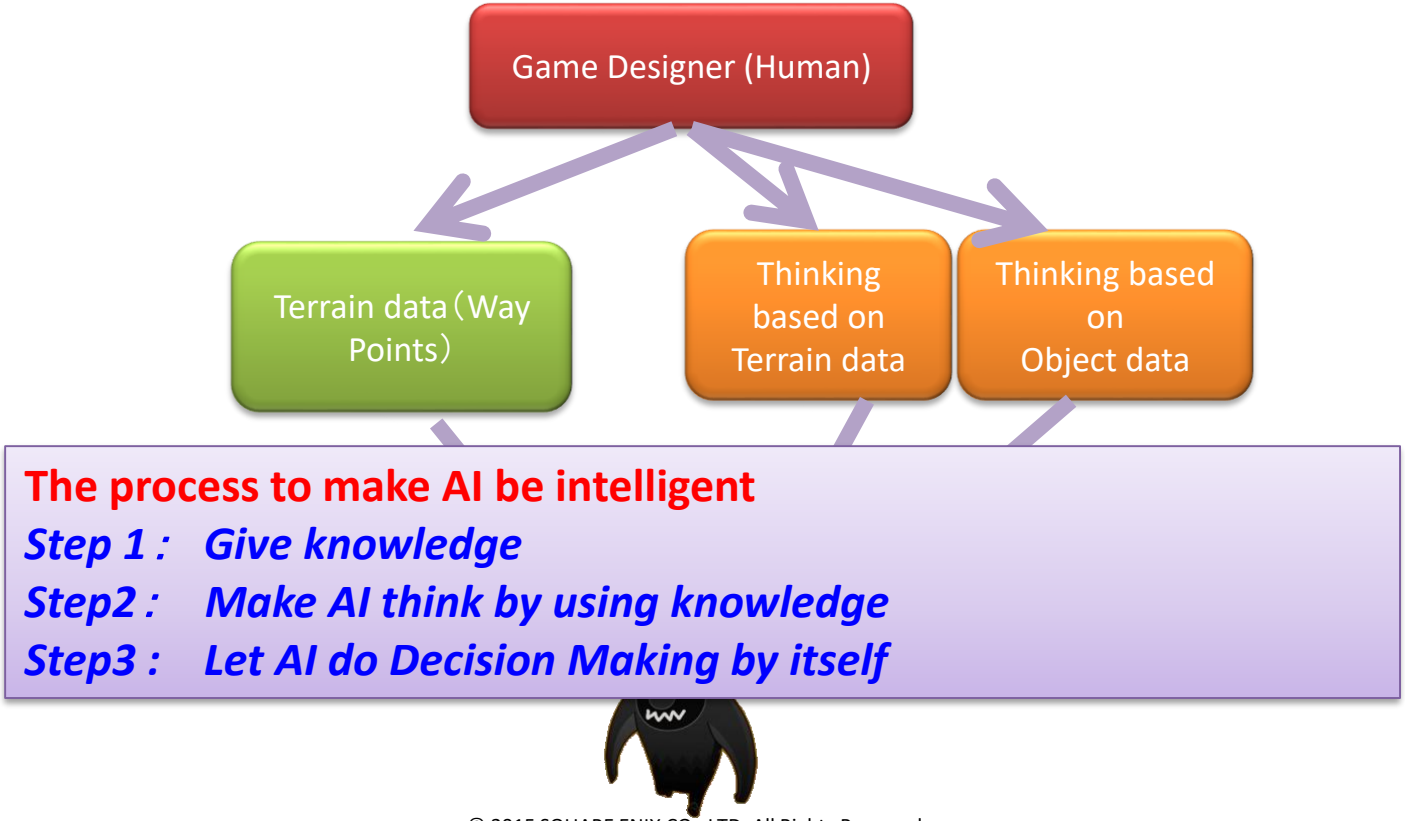
Thinking its positon by using terrain data

Decision Making

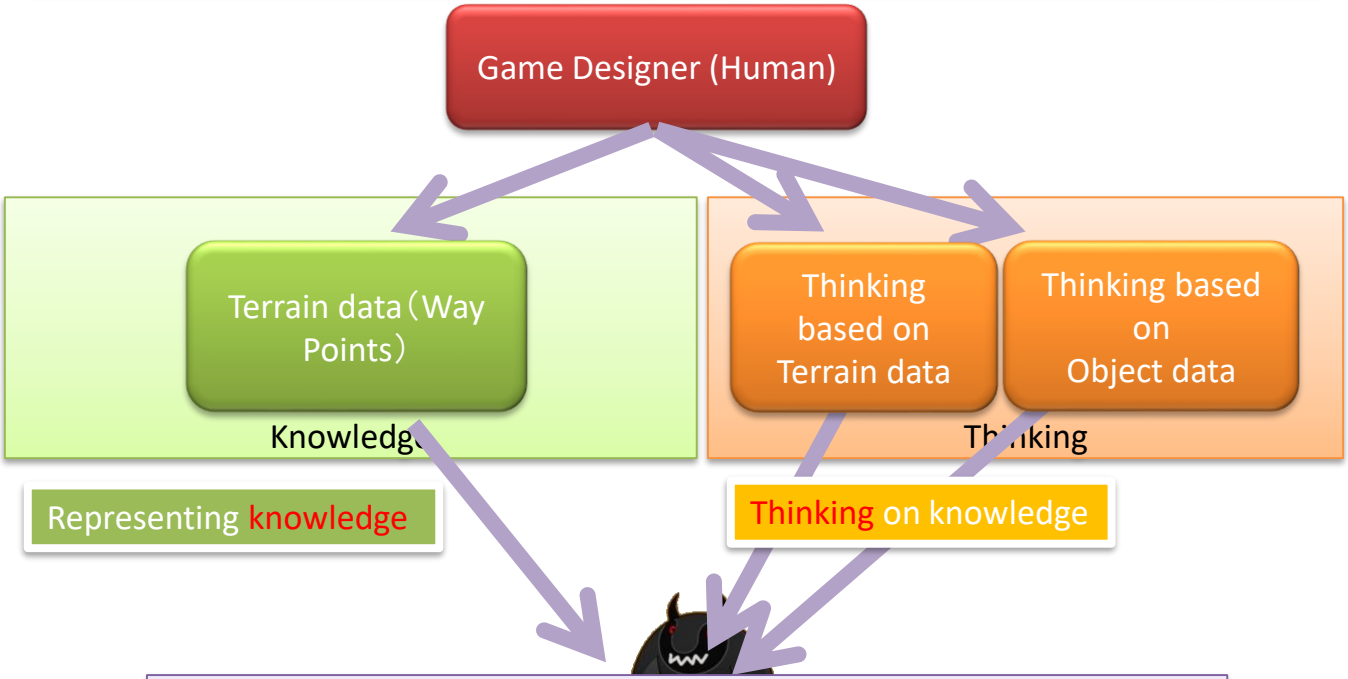
Making Autonomous AI



Making Autonomous AI

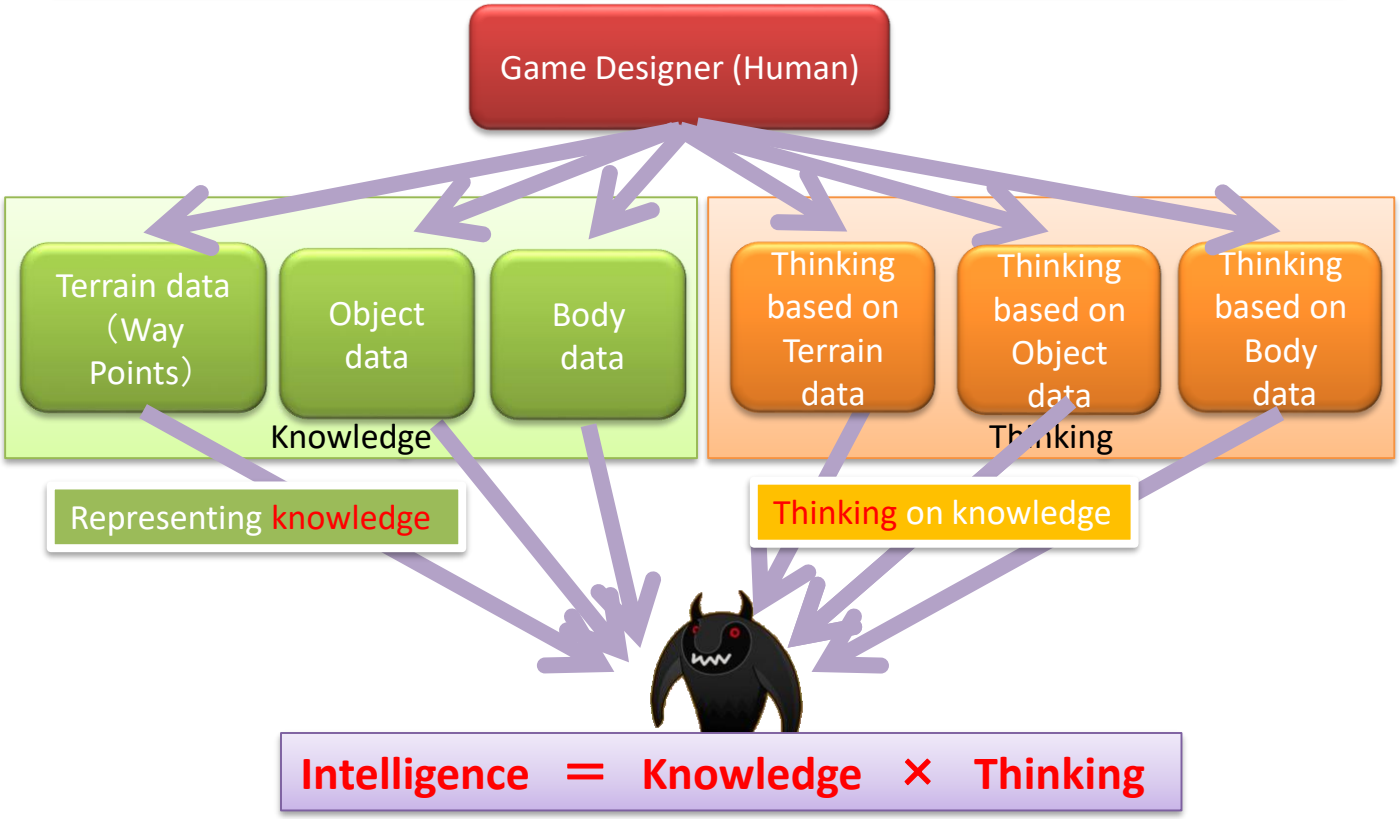


Making Autonomous AI

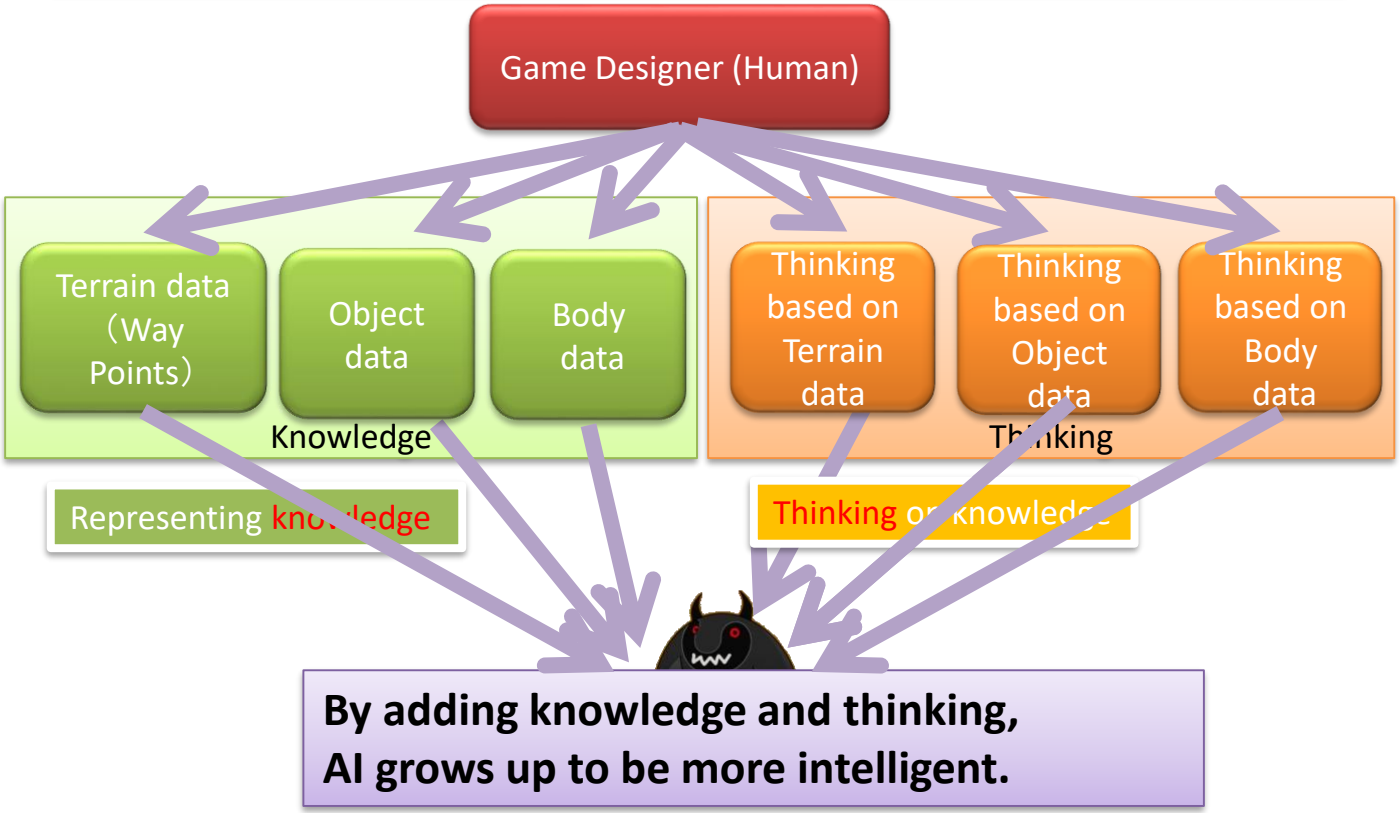


The most fundamental thing to make autonomous AI is to give knowledge and thinking to a character.

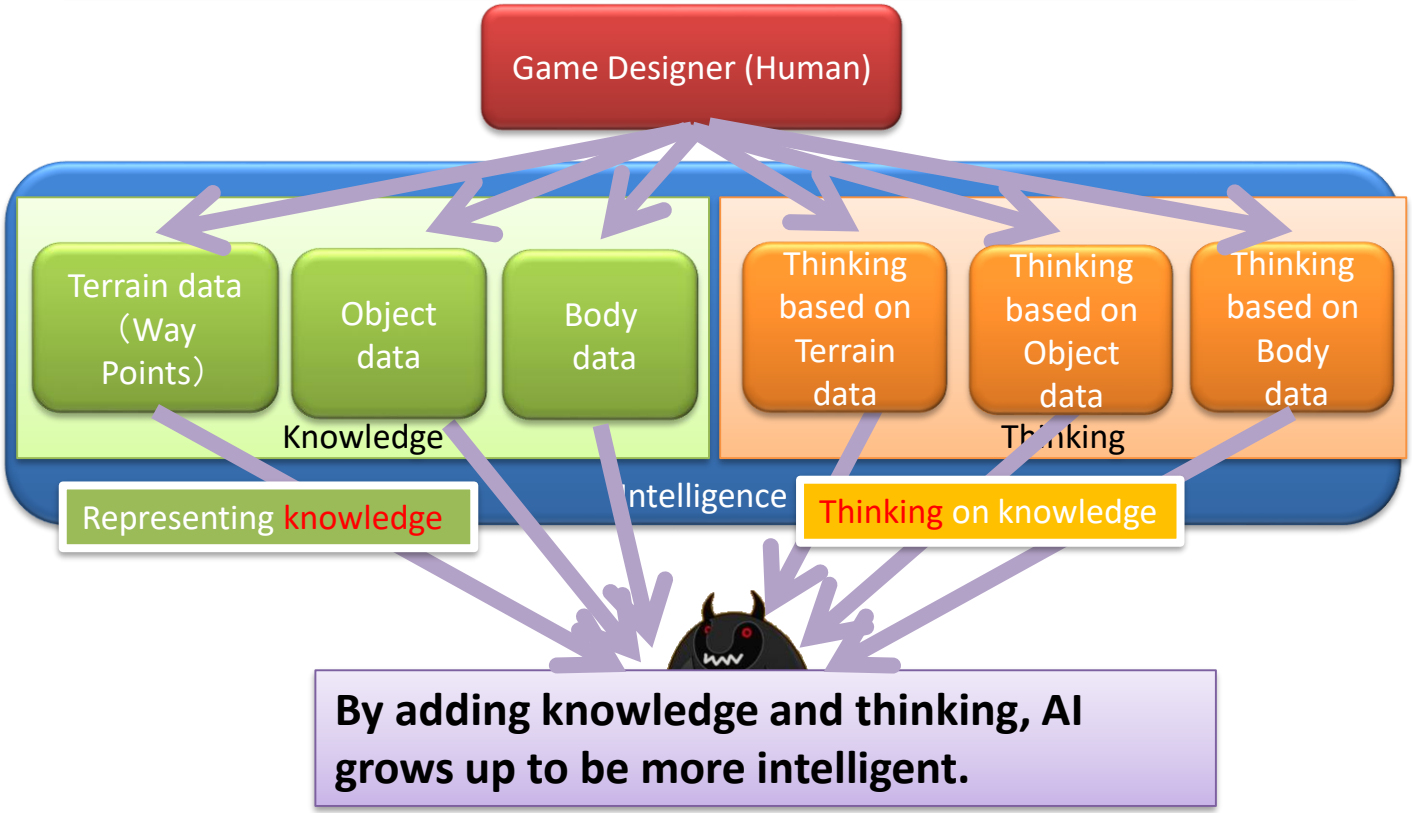
Making Autonomous AI



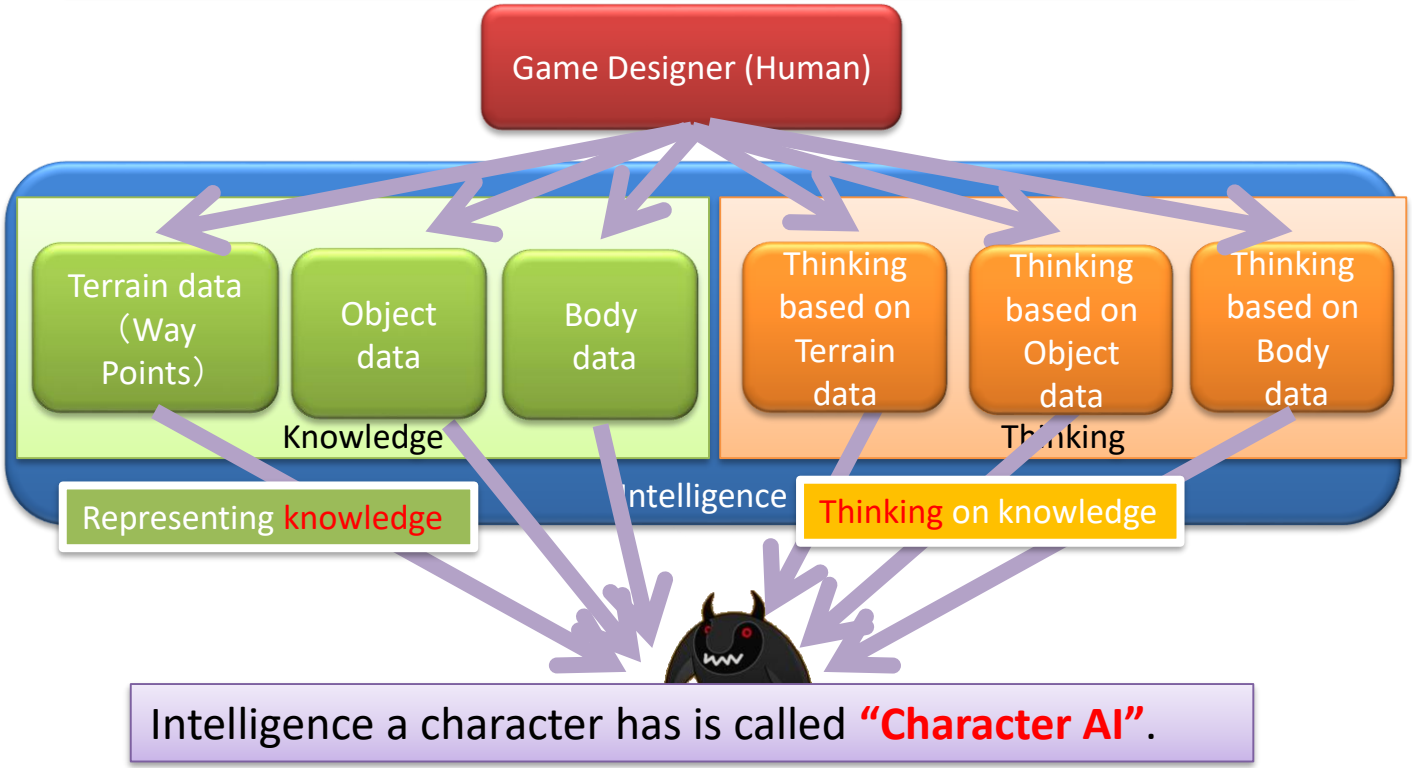
Making Autonomous AI



Making Autonomous AI

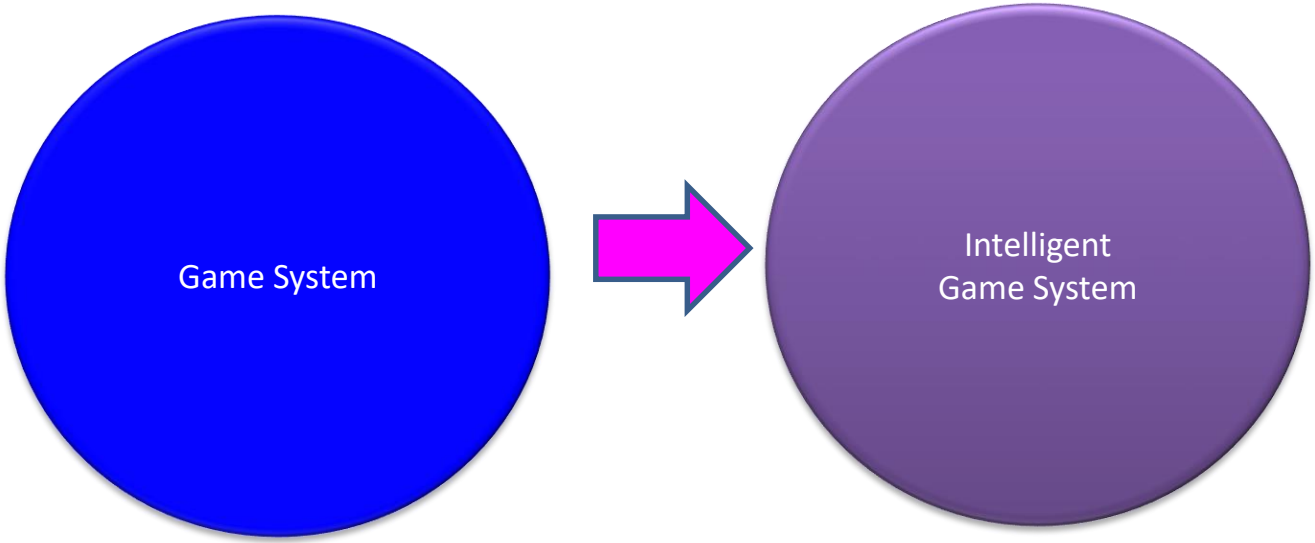


Making Autonomous AI



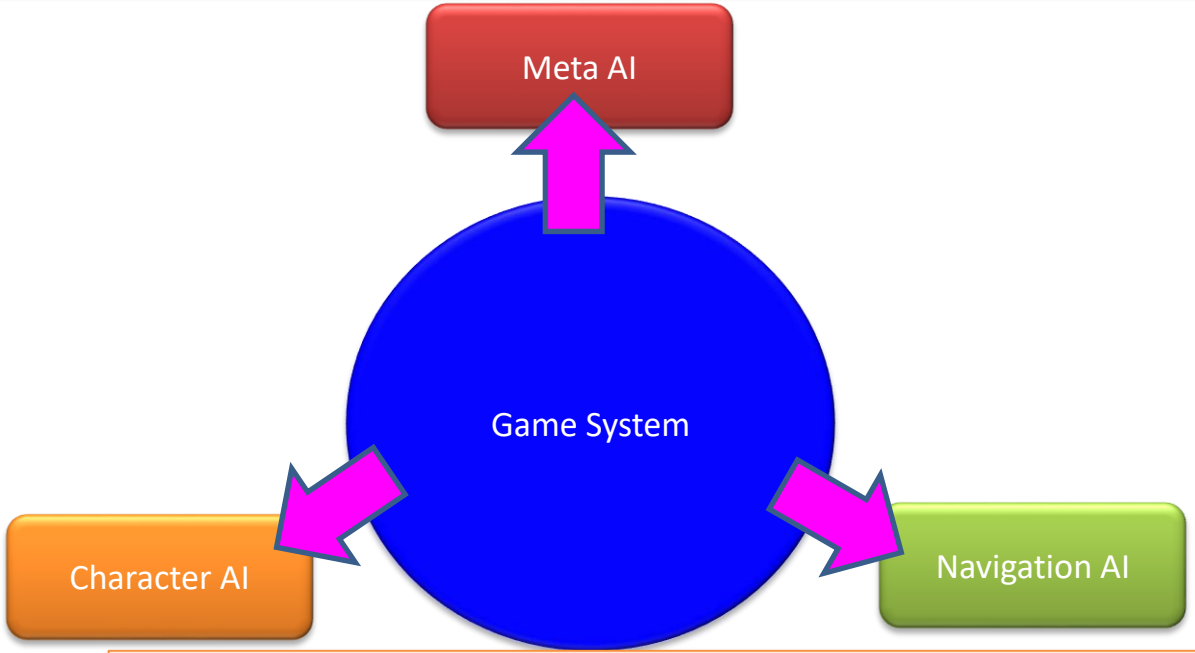
Intelligence a character has is called **“Character AI”**.

Intelligent Game System



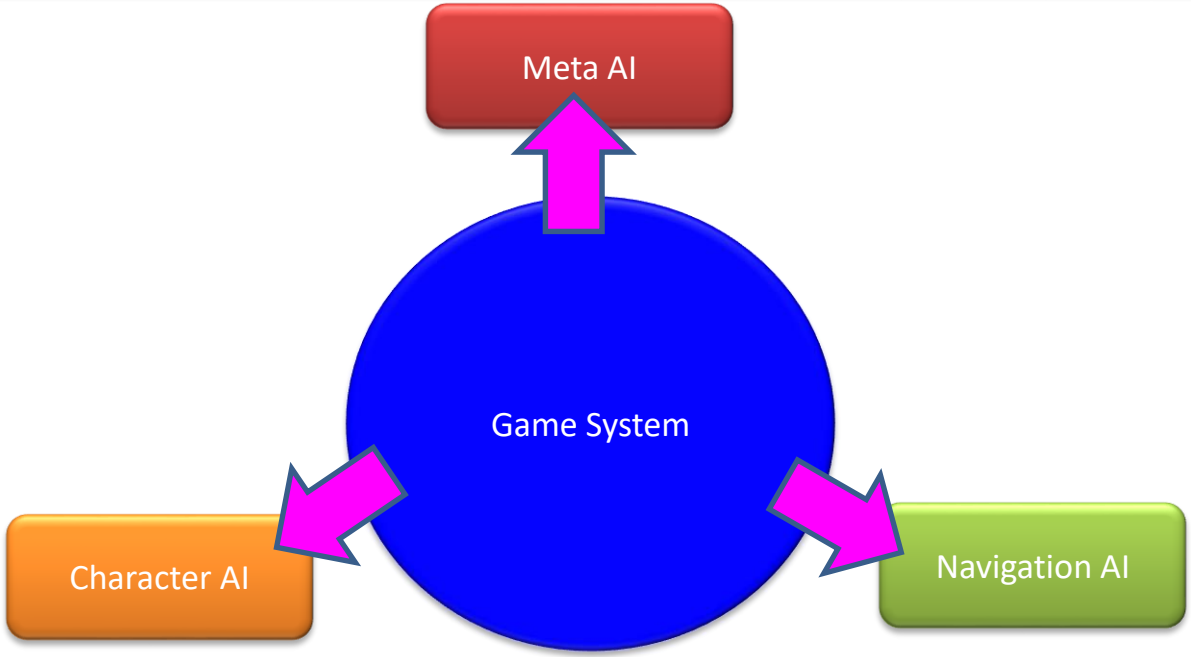
All AI functions are included in the game system.

AI becomes independent

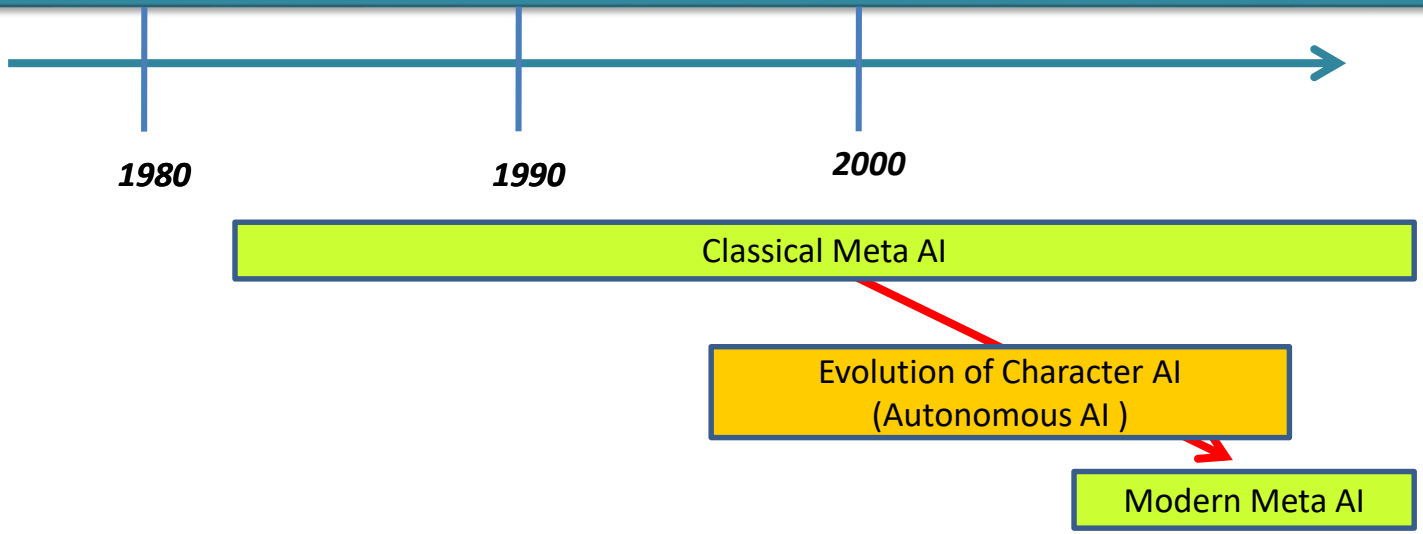


AI in game split into three distributed independent system.
= Distributed Artificial Intelligence

AI becomes independent

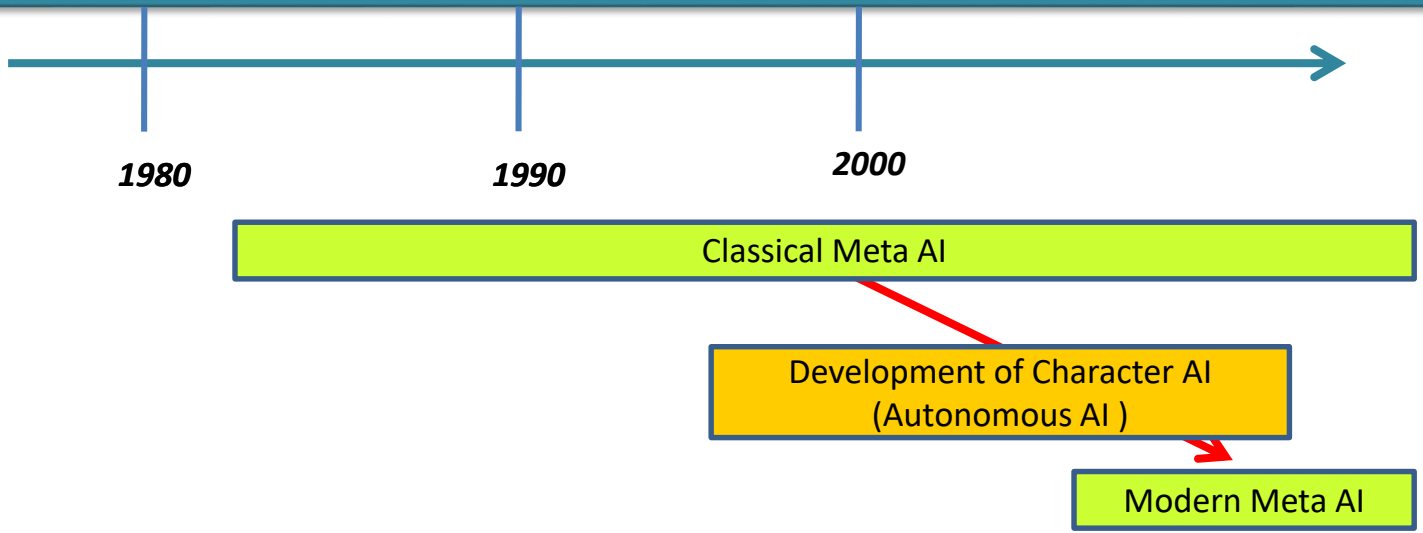


Meta AI History



Meta AI is the AI of game system.

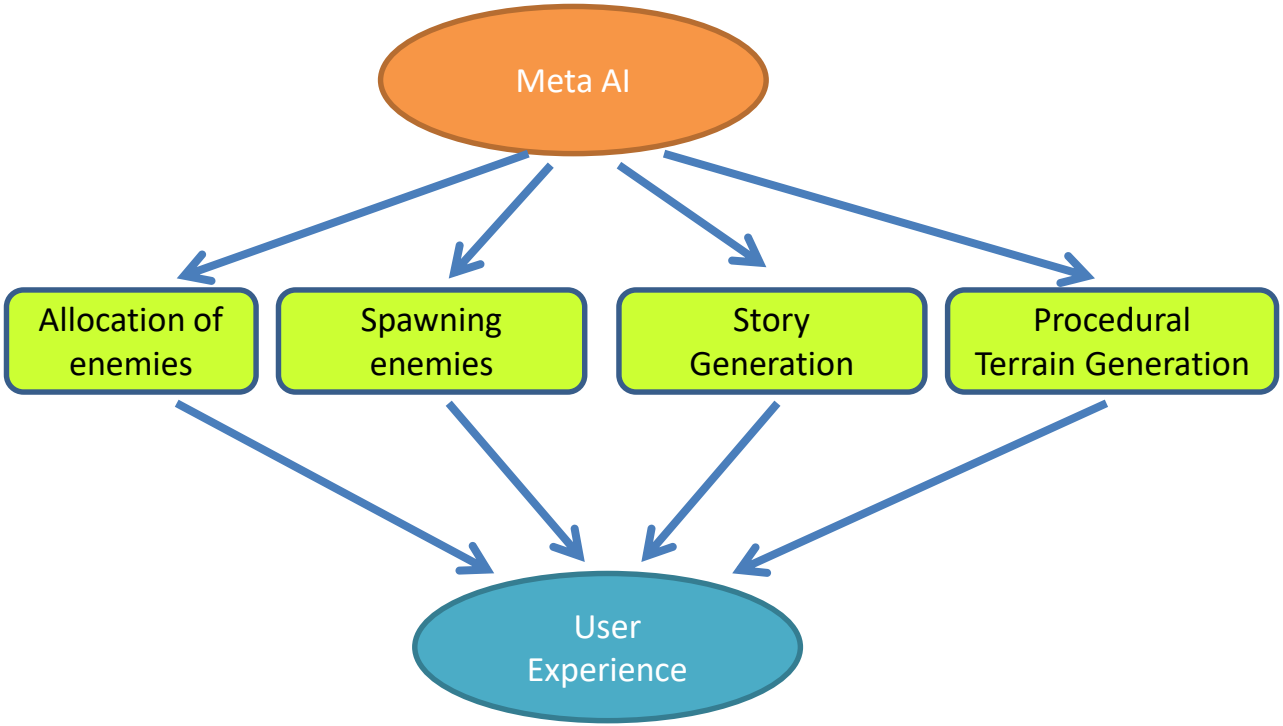
Meta AI History



Classical Meta AI to control difficulty of the game (Weaken enemies).
Modern Meta AI to design game system dynamically.

Modern Meta AI

Meta AI dynamically changes a game



AI Director (Meta AI) = Left 4 Dead

Example : Left 4 Dead

Michael Booth, "**The AI Systems of Left 4 Dead**," Artificial Intelligence and Interactive Digital Entertainment Conference at Stanford.

http://www.valvesoftware.com/publications.html

Adaptive Dramatic Dynamic Pacing

[Basic Idea]

(1) Meta AI populates many enemies, enough to get user's intention up to the value (measured by input).

(2) When user's intention goes over the value, meta AI stops the population.

(3) When user becomes relaxed, go to (1).

Michael Booth, "**The AI Systems of Left 4 Dead**," Artificial Intelligence and Interactive Digital Entertainment Conference at Stanford.
http://www.valvesoftware.com/publications.html

Algorithm of Meta AI

(1) Decide number of enemies to populate by user's escape route length.

(2) Populate enemies along the route in a area around the player.

(3) When a player goes out the area, the population stops, and enemies vanish.

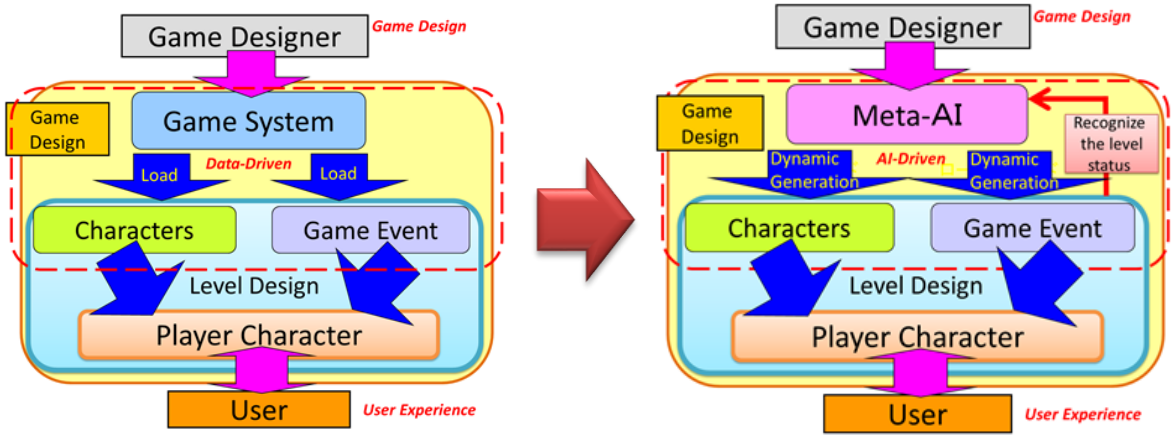
(4) In the state of relax or when the are can be seen from a player, all enemies are eliminated from the map.

Michael Booth, "**The AI Systems of Left 4 Dead**," Artificial Intelligence and Interactive Digital Entertainment Conference at Stanford.
http://www.valvesoftware.com/publications.html

Summary

Classical Game System

Modern Game System

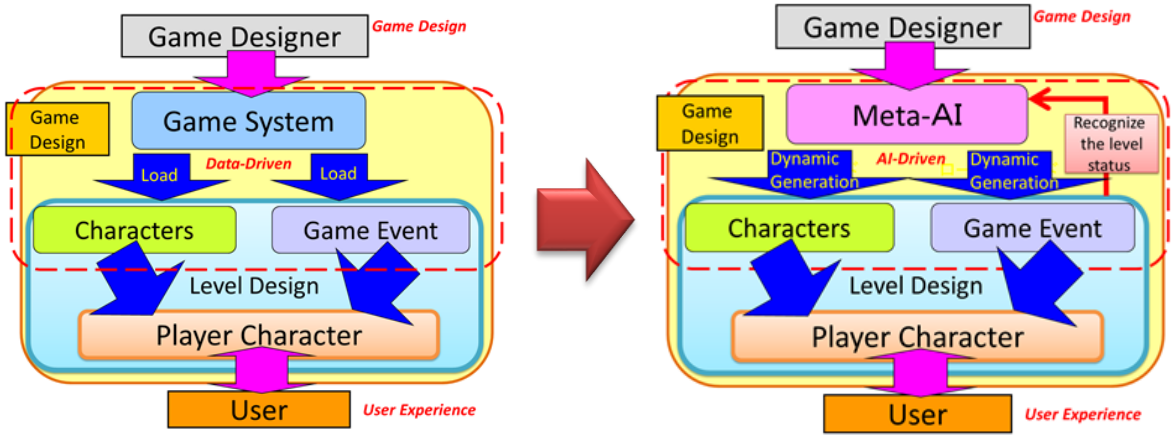


In classical game system, game contents are fixed after the development, but in modern game system, game contents are dynamically created.

Summary

Classical Game System

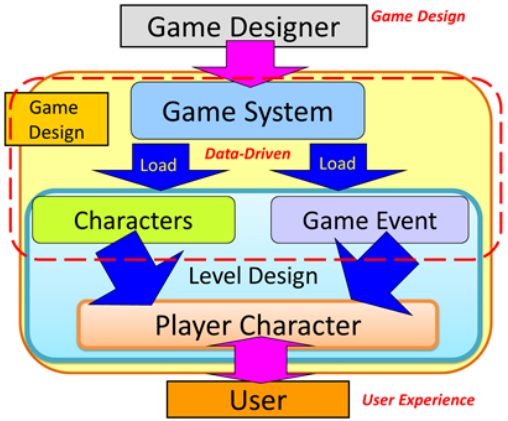
Modern Game System



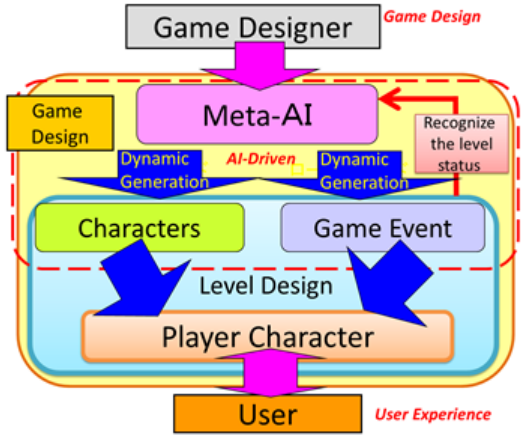
Meta AI dynamically creates a game play flow, and gives an order to character AI and a game event. The reason why meta AI action is simple is that character AI has become autonomous.

Summary

Classical Game System



Modern Game System



By simply replacing Meta AI, game contents can dramatically change.

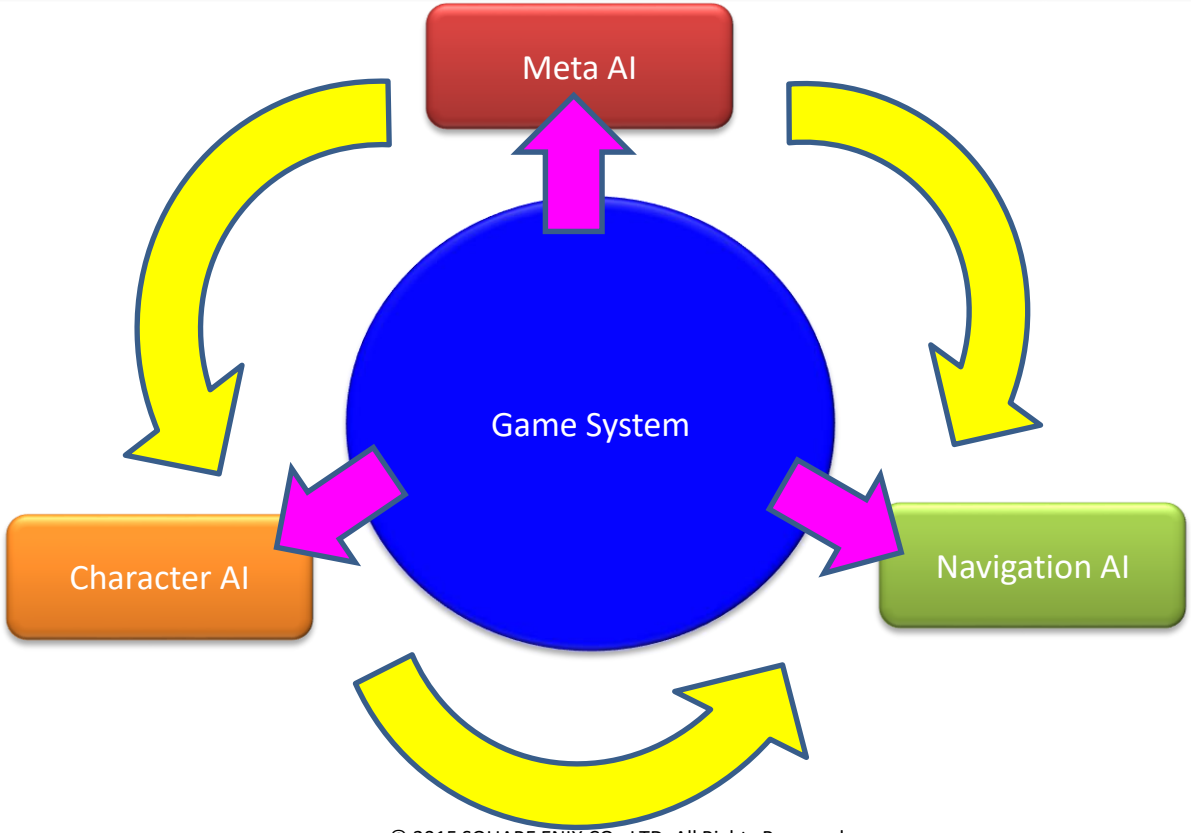
Referenced Papers

(1) Michael Booth, "**Replayable Cooperative Game Design: Left 4 Dead**," Game Developer's Conference, March 2009.

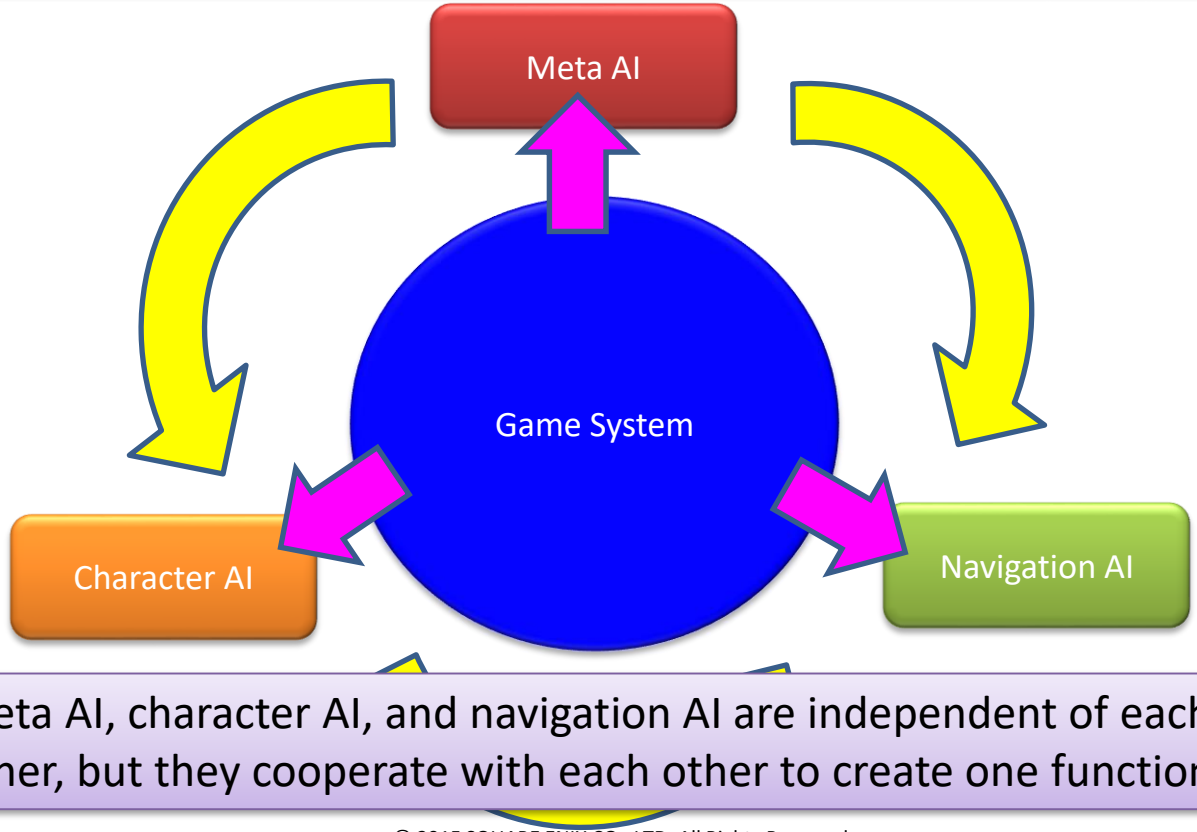
(2) Michael Booth, "**The AI Systems of Left 4 Dead**," Artificial Intelligence and Interactive Digital Entertainment Conference at Stanford.

http://www.valvesoftware.com/publications.html

Distributed AI

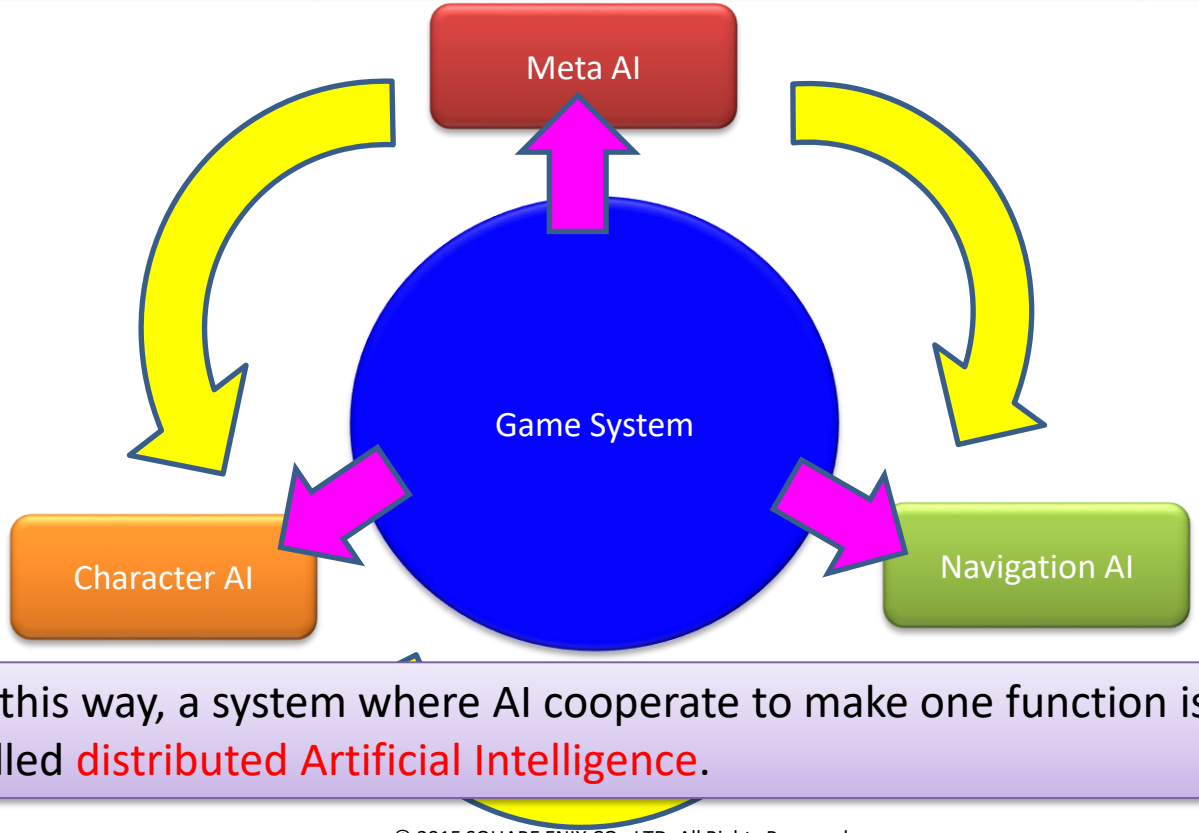


Distributed AI



Meta AI, character AI, and navigation AI are independent of each other, but they cooperate with each other to create one function.

Distributed AI



In this way, a system where AI cooperate to make one function is called distributed Artificial Intelligence.

The first chapter : Summary

- There are three types of game AI: Meta AI, Character AI and Navigation AI.
- Originally there was only one AI, but it has been split into three independent AI.
- Three AI cooperate with each other to make one function.

What is digital game ?

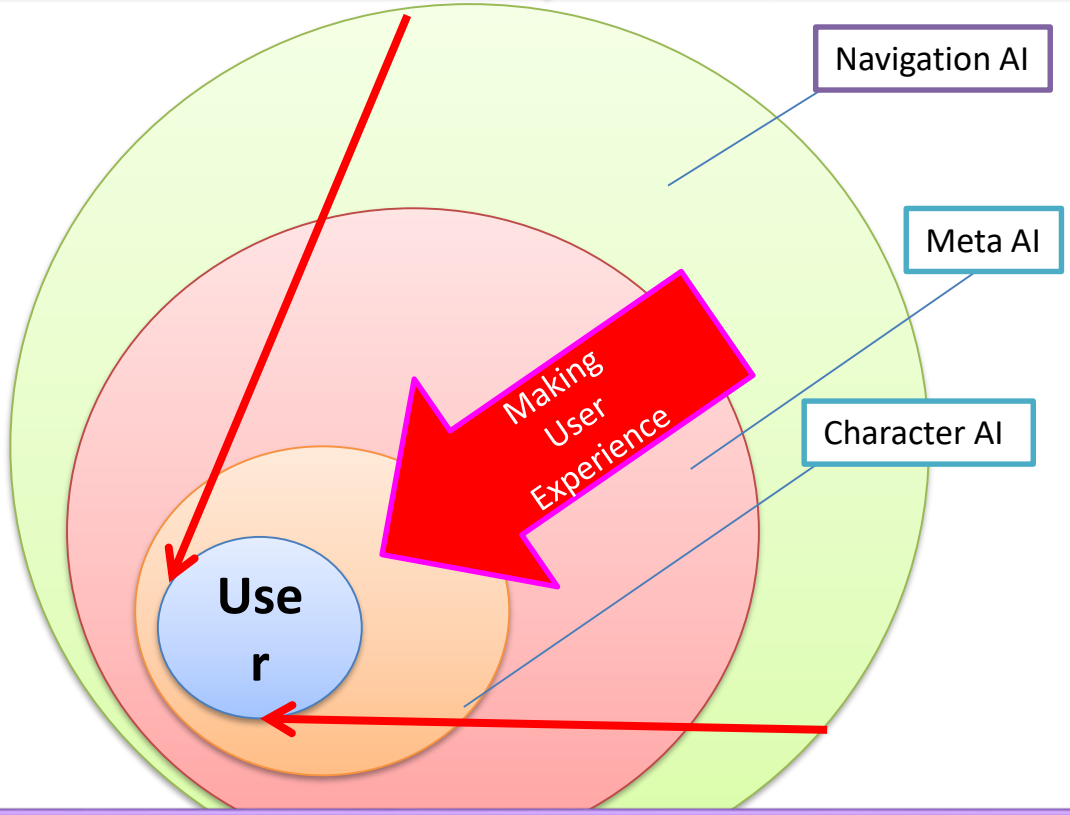
= many variations of user experience.

Game User Experience

- Visual
- Sound
- Controller
- Interaction
- Story
- AI
- ….

AI is not all, but there is the experience only AI produces.

User Experience



The combination of “Navigation AI” ”Meta AI”” Character AI” makes
user experience.

Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button ▶

Chapter 1

WHAT IS FINAL FANTASY XV ?

FINAL FANTASY XV とは

FINAL FANTASY XV とは

- Reality-based Fantasy
- Action RPG
- Car（Travel）、Buddy、Nature

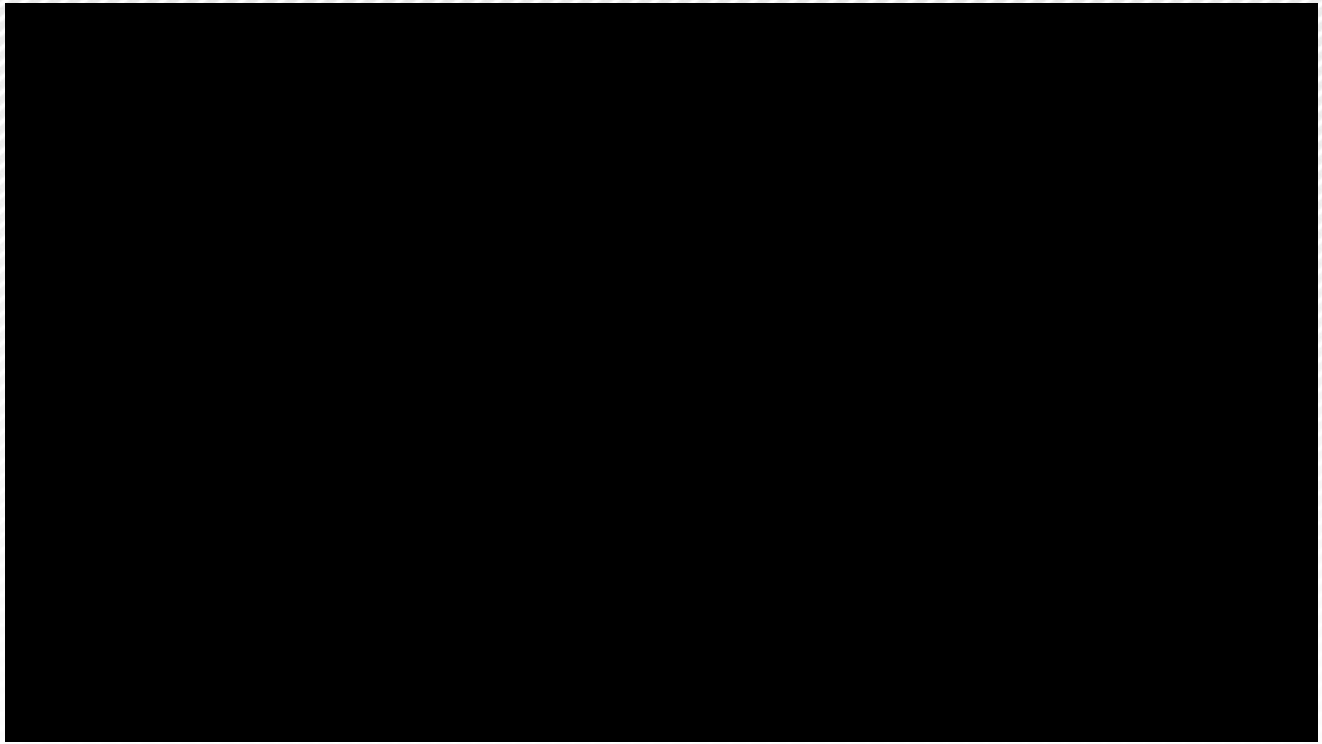
Buddy, Monsters,Nature

Buddy、Nature、Monsters

FINAL FANTASY XV - AI Technical Overview

Making and Characters

FINAL FANTASY XV - AI Technical Overview (movie)



Our Grand 3 Goals

- Making autonomous NPCs in the FFXV world
- Making one united living world of FFXV
- Making a unique User Experience of FFXV

Digital Game AI

Contents

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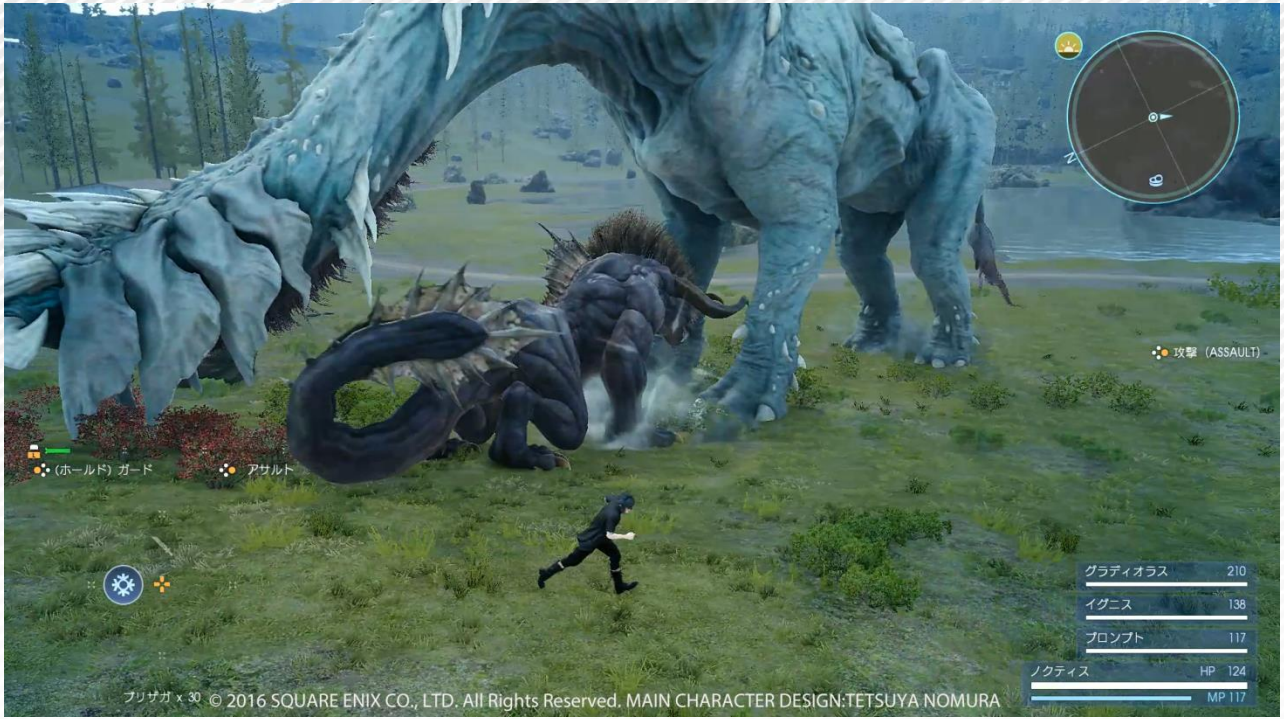
Chapter 4

CHARACTER AI

Intelligence and Body



Intelligence and Body has deep relation

Digital Game AI

Contents

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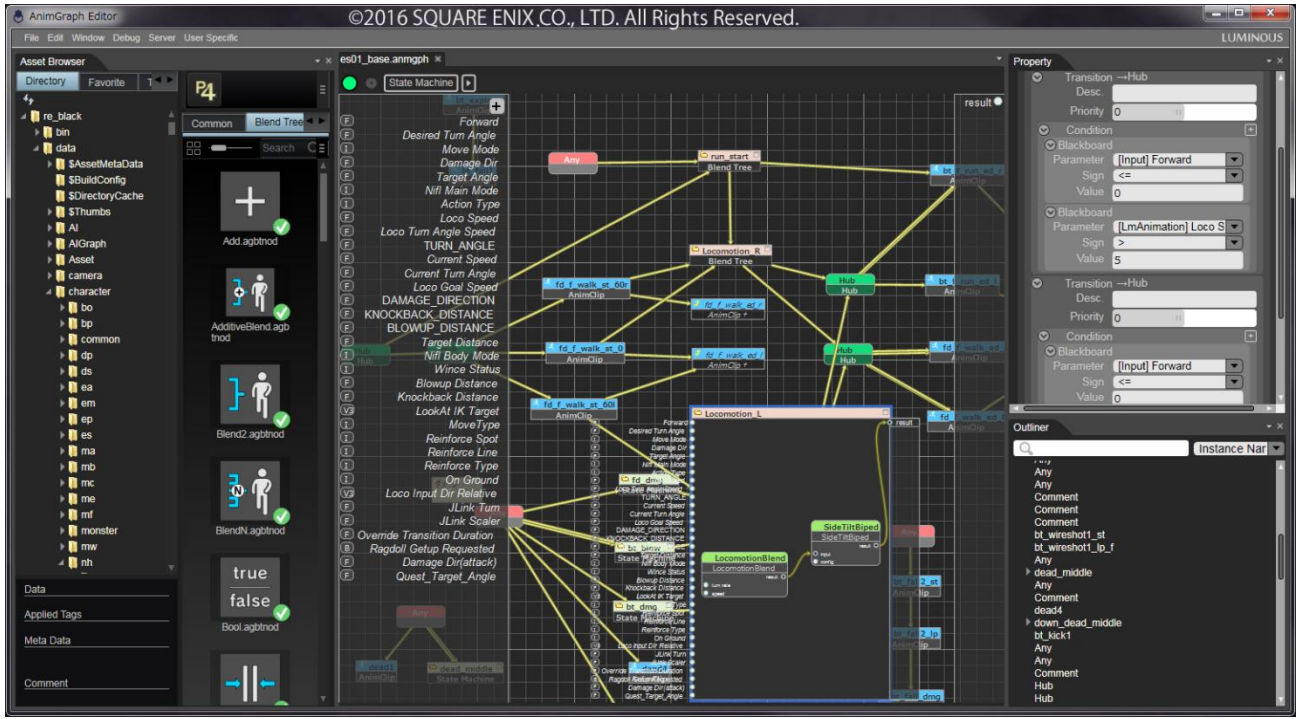
Chapter 4

What is decision making ?

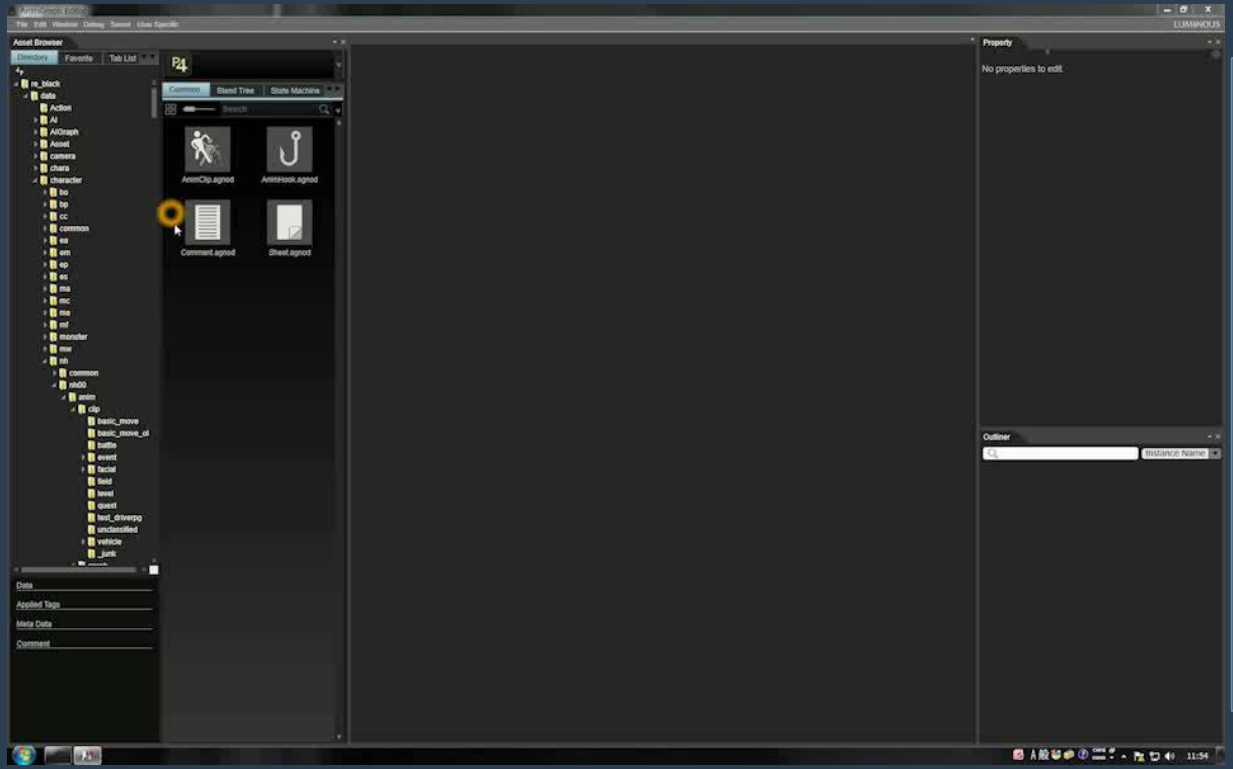
4.1 INTELLIGENCE AND BODY

AnimGraph



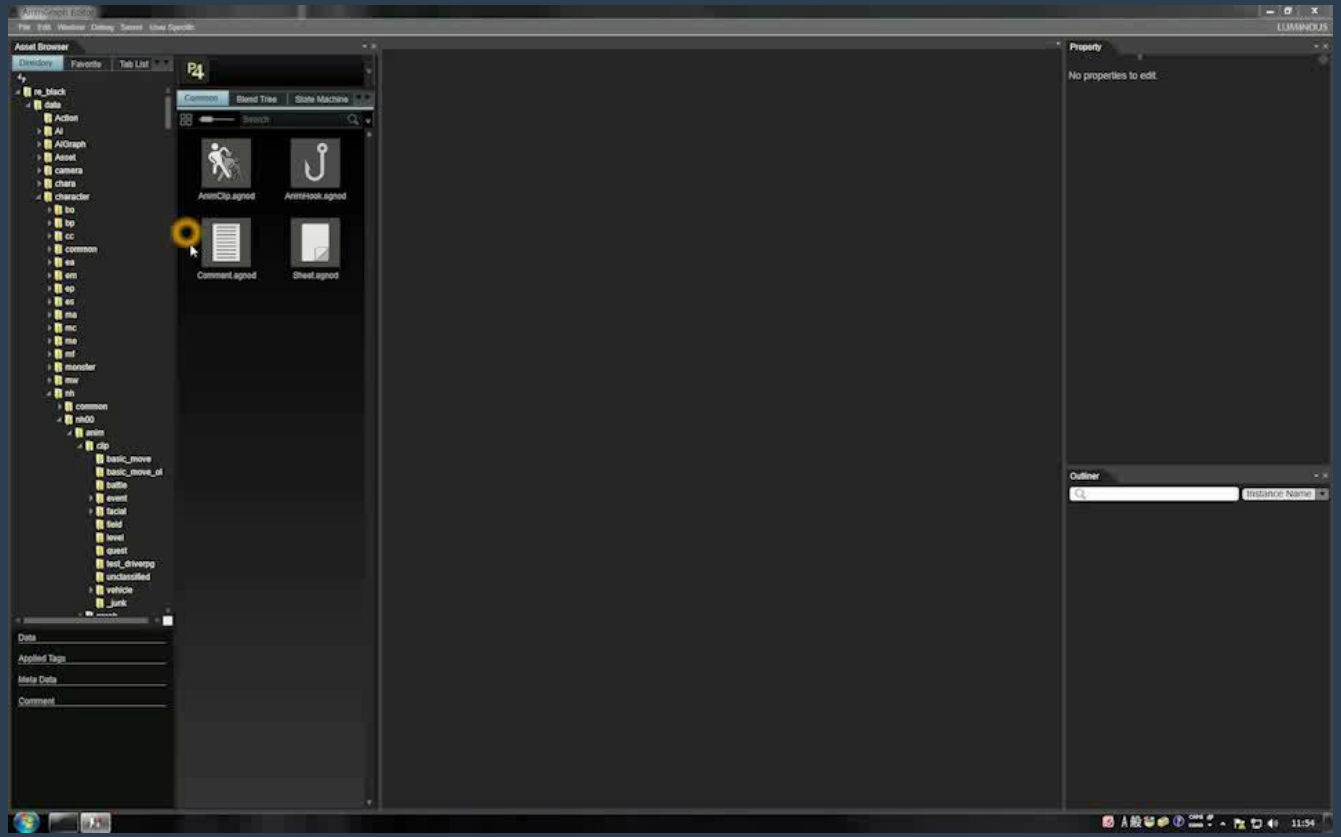
In AnimGraph, Each node is animation-data , and line between nodes is animation-transition.

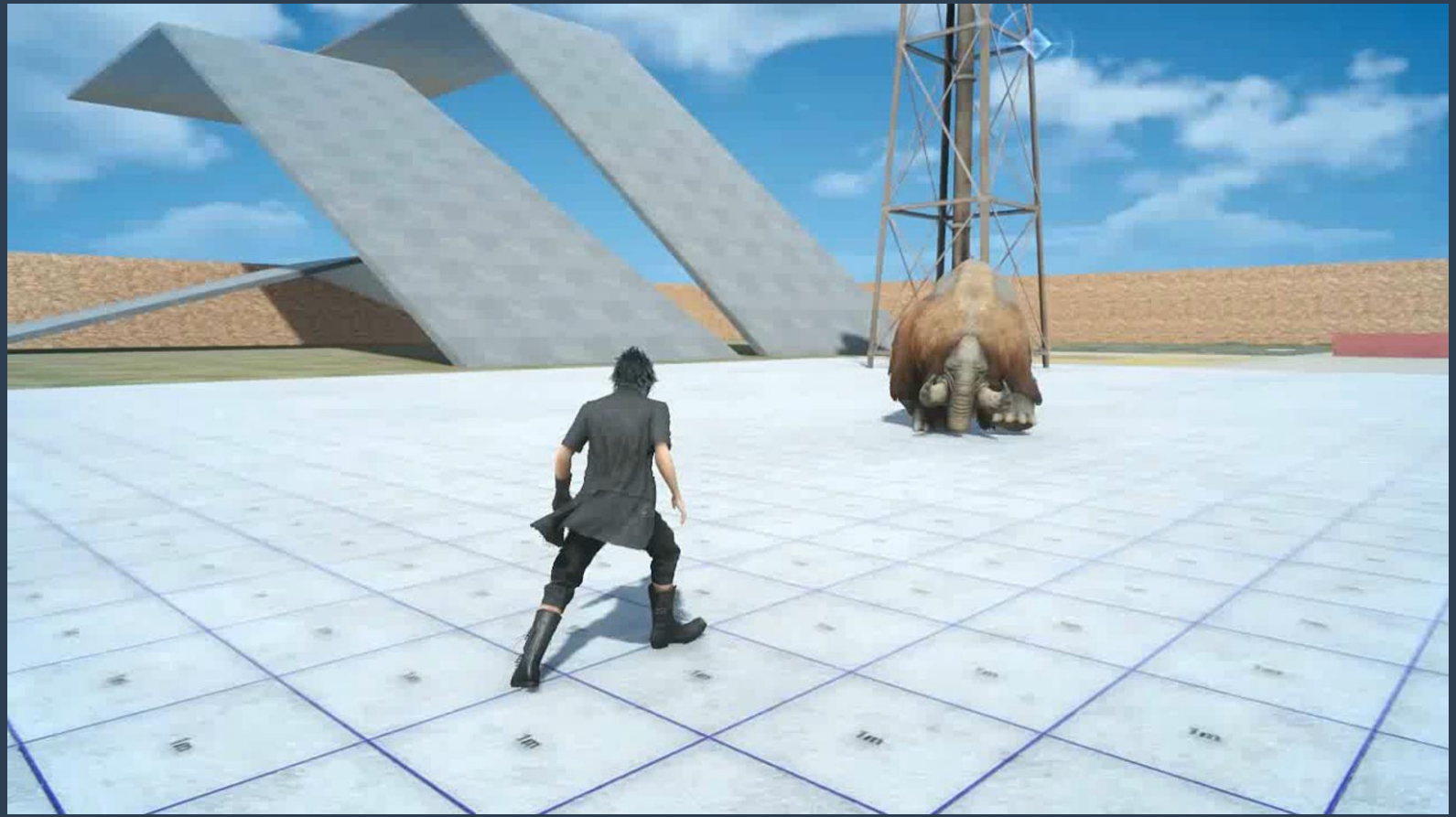
AnimGraph – Data-driven Architecture (Movie)



- Combination of state machines and blend trees
- Concatenate AnimClips exported from DCC tools
  - Blend duration, mirroring, etc.
- The usability is tuned for animators

AnimGraph – Data-driven Architecture (Movie)





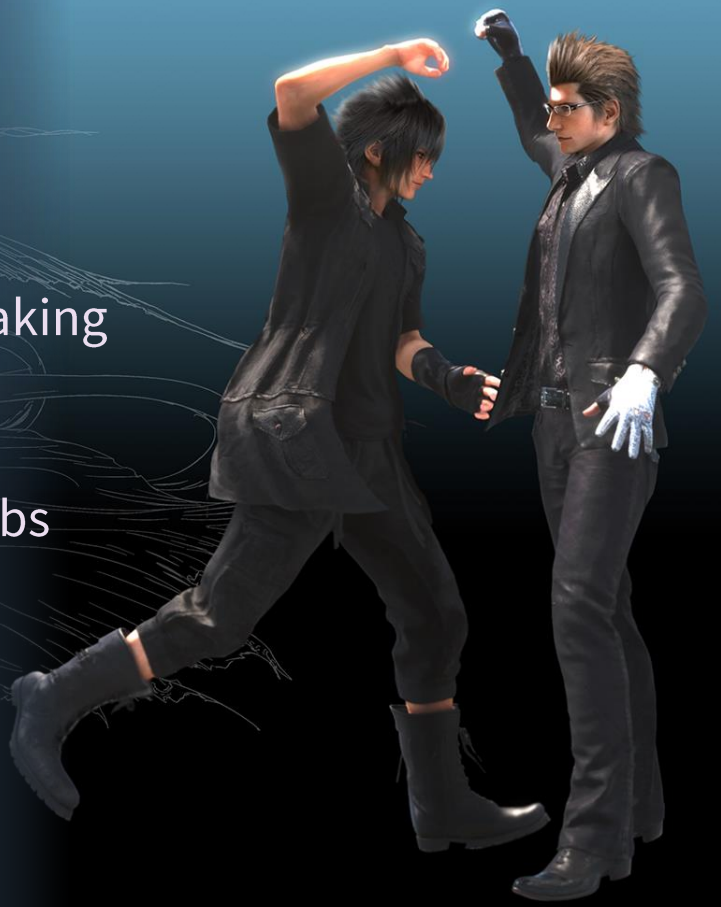
Challenge

Intelligence

- Abstract decision making

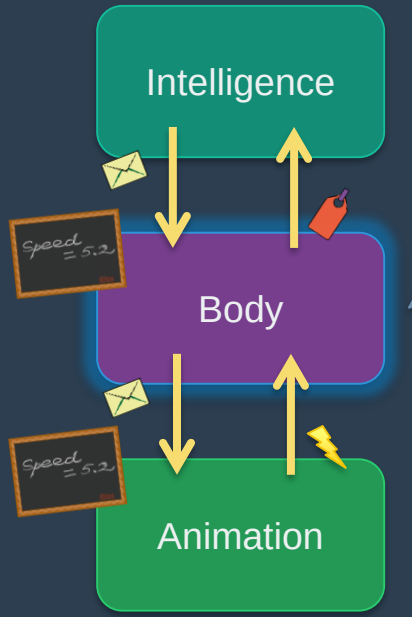
Animation

- Drives kinematic limbs



How to unite AI and Animation?

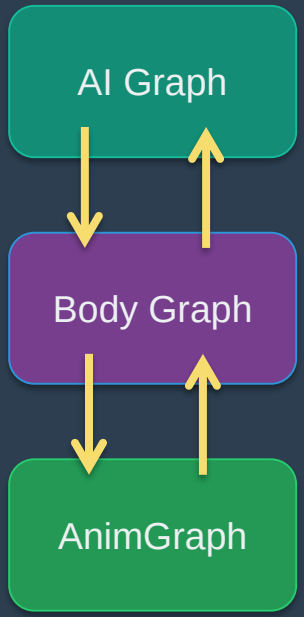
Body Layer



- Intermediate layer between AI and Animation
  - Communicate with messages and blackboard variables
- Manages various physical states
  - Running / Swimming / In a battle, etc.

BodyGraph

Data-driven Architecture



game designer

too strong? aggressively surprise! gently navigate encourage

programmer

organized reusability avoid conflict priority

animator

beautifully quick response naturally smoothness snappy

Intelligence
（AI Graph）

Finite State Machines
Behavior Trees

Messages
Blackboard Variables

Message Handled
State Tagging

Body
(Body Layer)

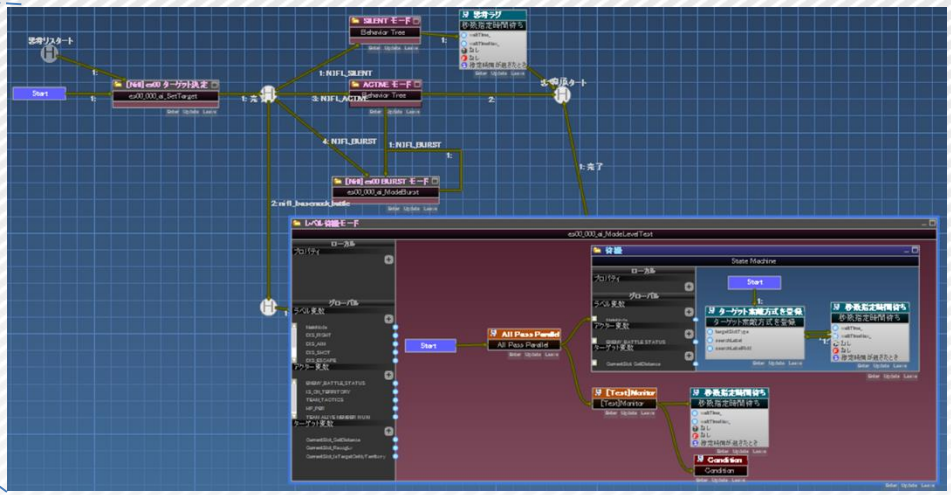
Finite State Machines

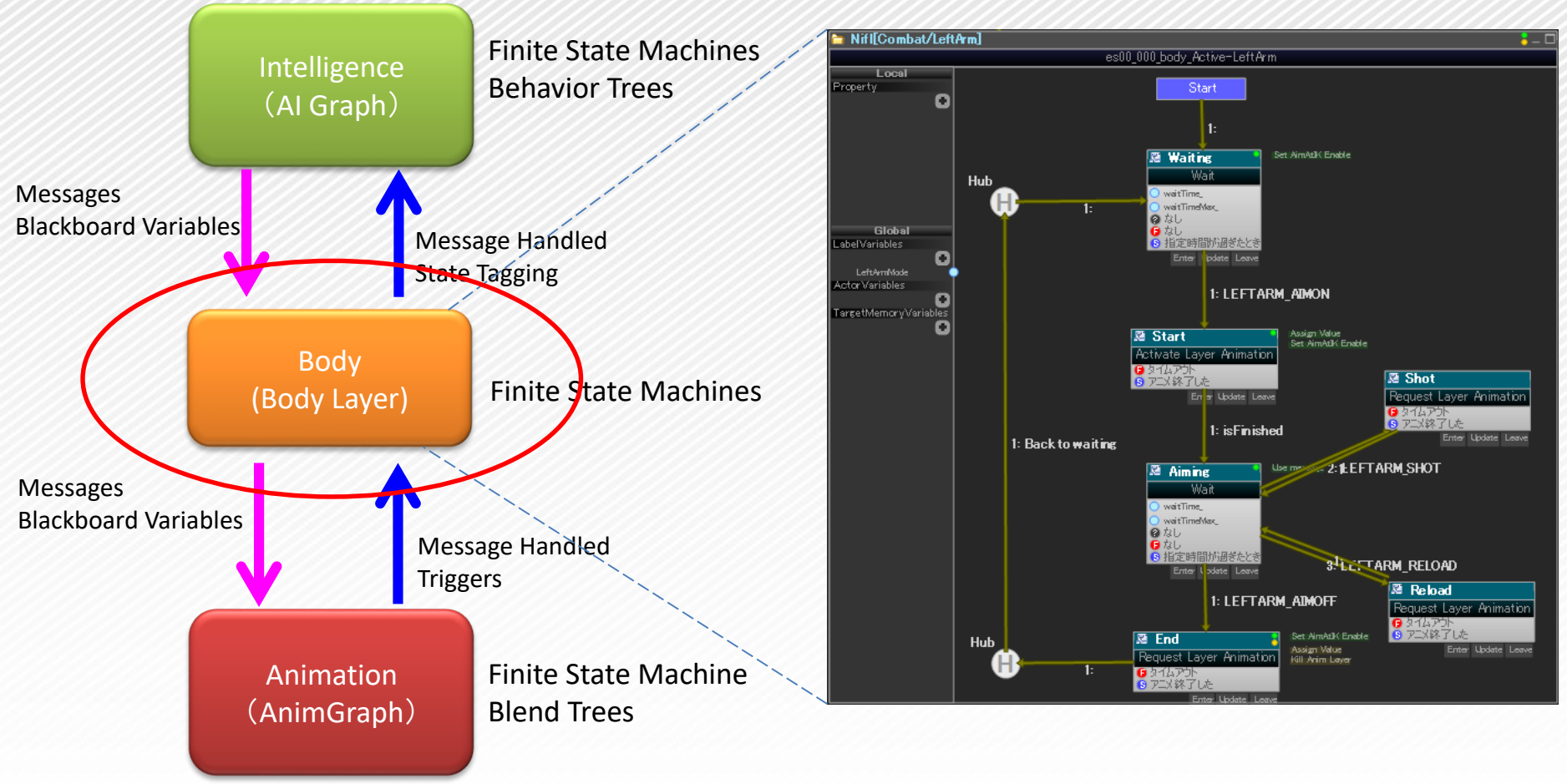
Messages
Blackboard Variables

Message Handled
Triggers

Animation
（AnimGraph）

Finite State Machine
Blend Trees





Intelligence
（AI Graph）

Finite State Machines
Behavior Trees

Messages
Blackboard Variables

Message Handled
State Tagging

Body
(Body Layer)

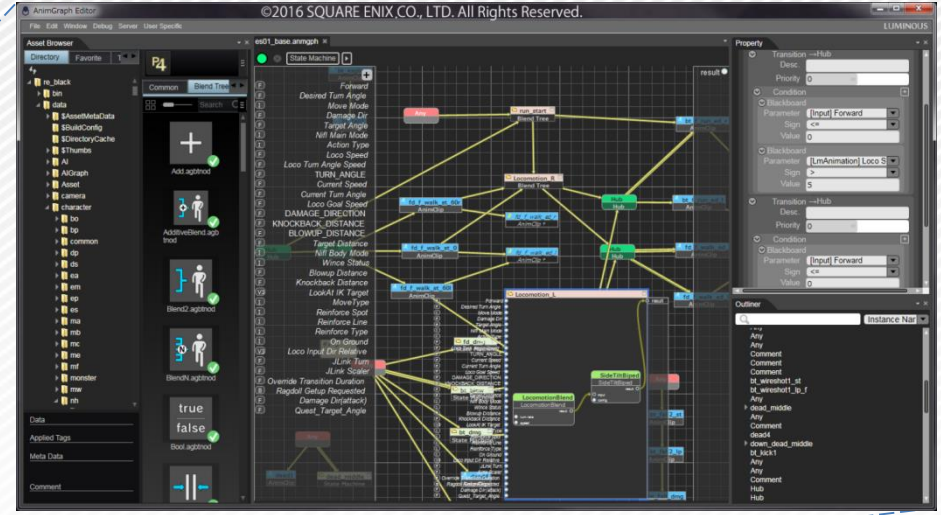
Finite State Machines

Messages
Blackboard Variables

Message Handled
Triggers

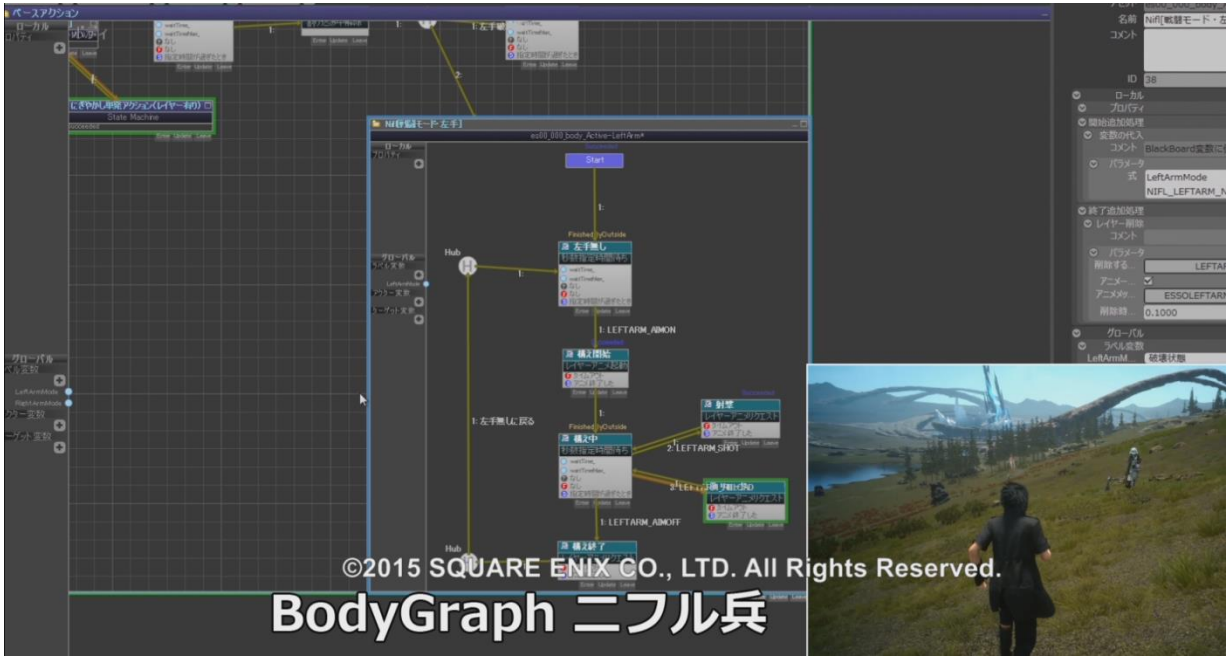
Animation
（AnimGraph）

Finite State Machine
Blend Trees



Linkage of AI and body control

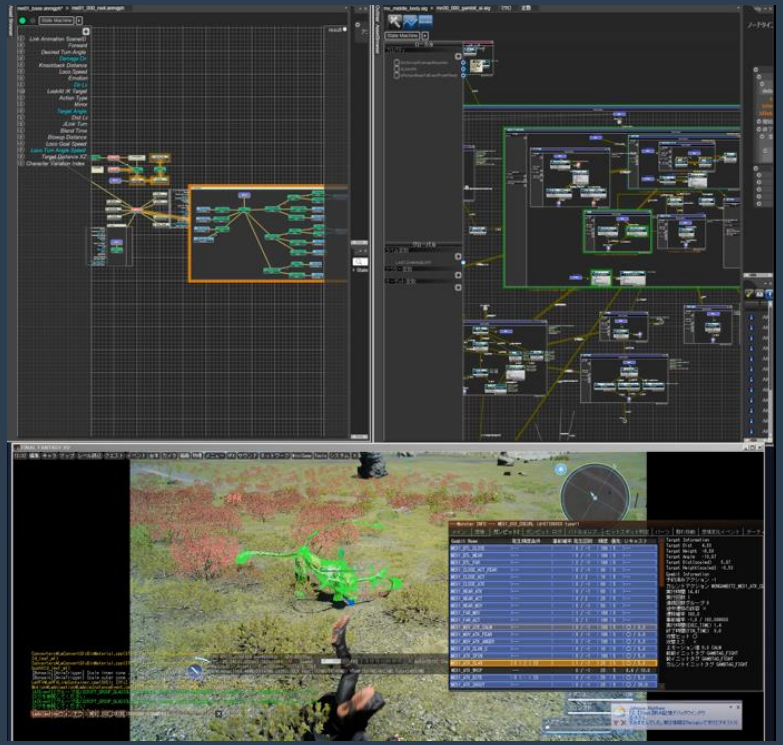
- Link of Body State machine and AI Graph



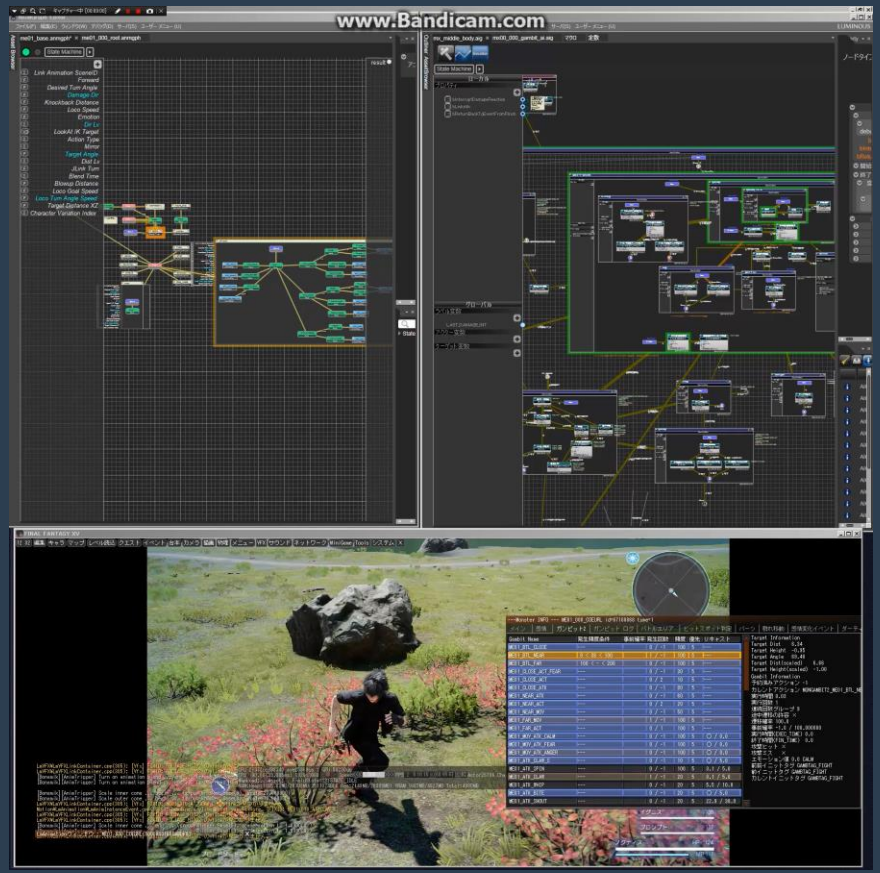
Linkage of AI and body control

- Link of Body State machine and AI Graph

AI Graph & BodyGraph of Monster (movie)



AI Graph & BodyGraph of Monster (movie)

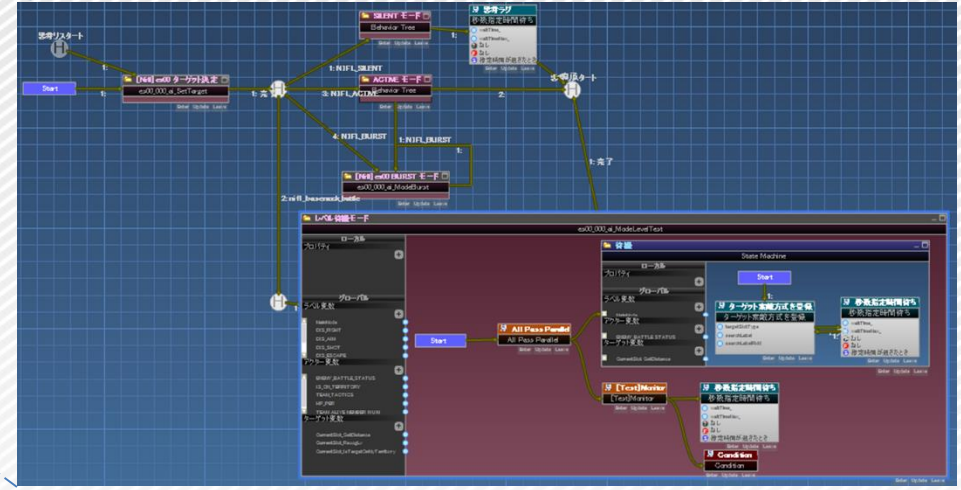


Intelligence
（AI Graph）

Finite State Machines
Behavior Trees

Messages
Blackboard Variables

Message Handled
State Tagging



Body
(Body Layer)

Finite State Machines

Messages
Blackboard Variables

Message Handled
Triggers

Animation
（AnimGraph）

Finite State Machine
Blend Trees

Digital Game AI

Contents

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Chapter 4

What is decision making ?

4.2 INTRODUCTION TO DECISION MAKING

2.1 Character’s thinking

WHAT IS DECISION MAKING?

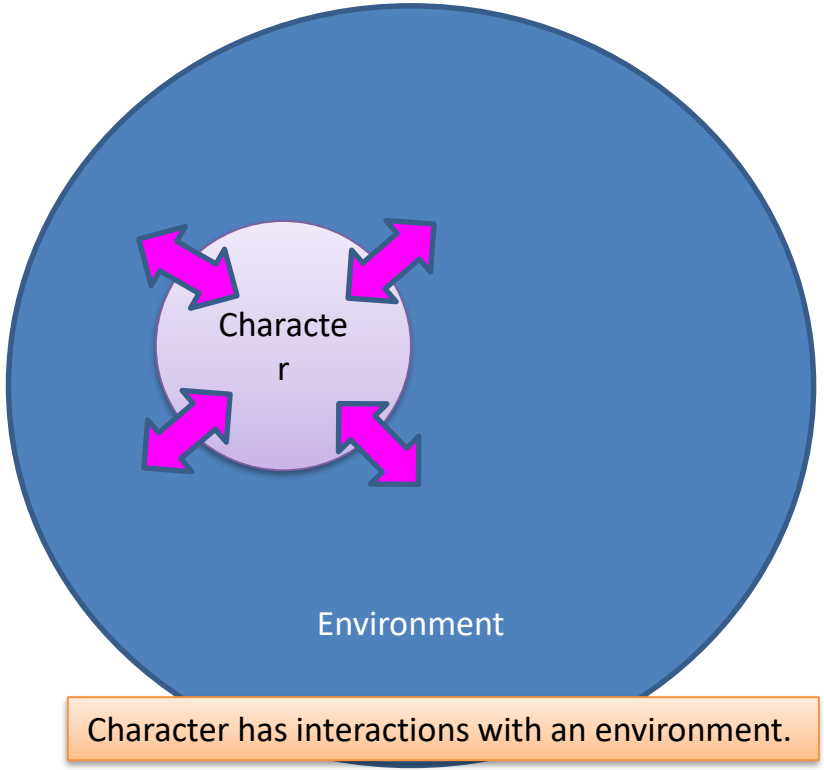
Character thinks because...

- To live in the environment, a living thing must make its own action.
- Making its own future.
- Making their society.

Environment and Intelligence

- A living thing lives in harmony with an environment, or fights with it. The relation between living things and the environment is based on their interaction.
- Interaction is an action on the environment.
- A high intelligence has abstract goals and policies, which give their actions unique features.

Environment and Character



Character has interactions with an environment.

Interaction Level
（Category）

Abstract Level

Information level

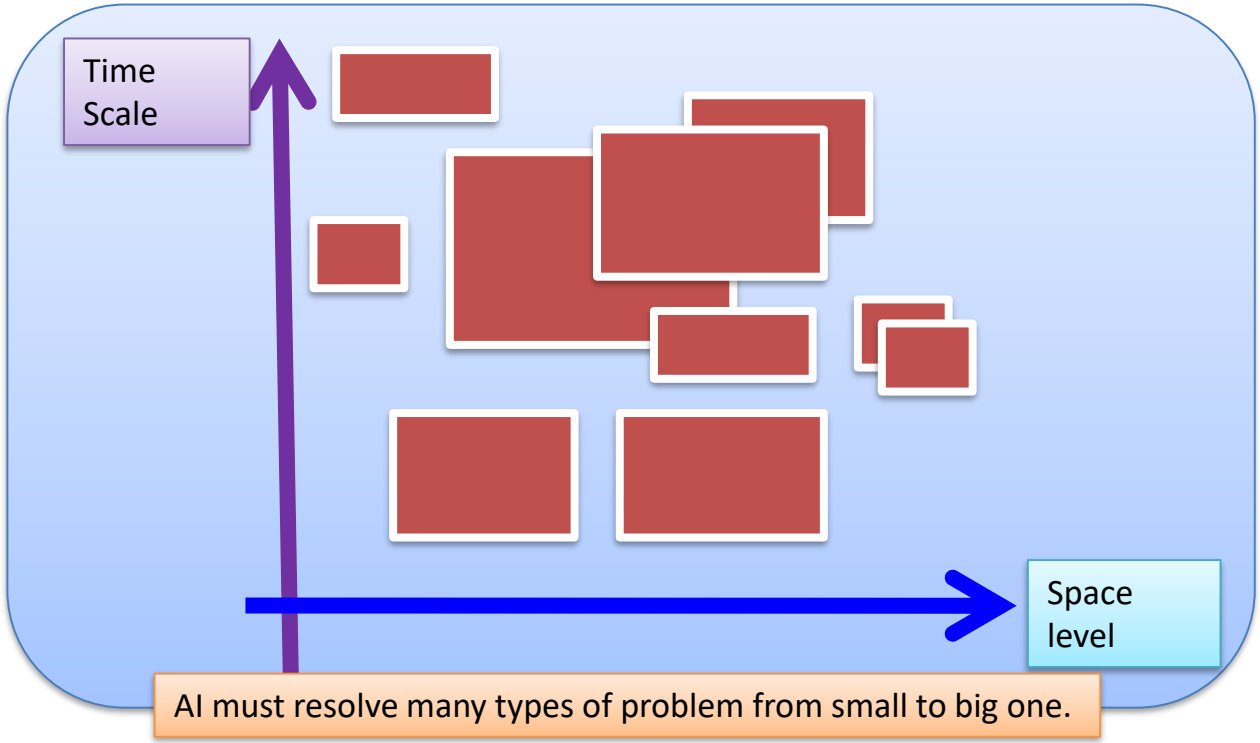
Situation level

Reactive level

Body level

Physical level

Interaction Level
（Category）



AI must resolve many types of problem from small to big one.

Decision Making

General Artificial Intelligence ＝ **Solving a problem**
Character Artificial Intelligence ＝ **Not necessary solving a problem**

Finally, within a limited time, decide a mental and physical action.

Decision Making Function

(1) Decide a body motion, and mental action.
(2) Update a body state.
(3) Update a mind state.
(4) Updating recognition and knowledge.
（Weapon selection or targeting）
(5) Selecting an object AI should pay attention to.

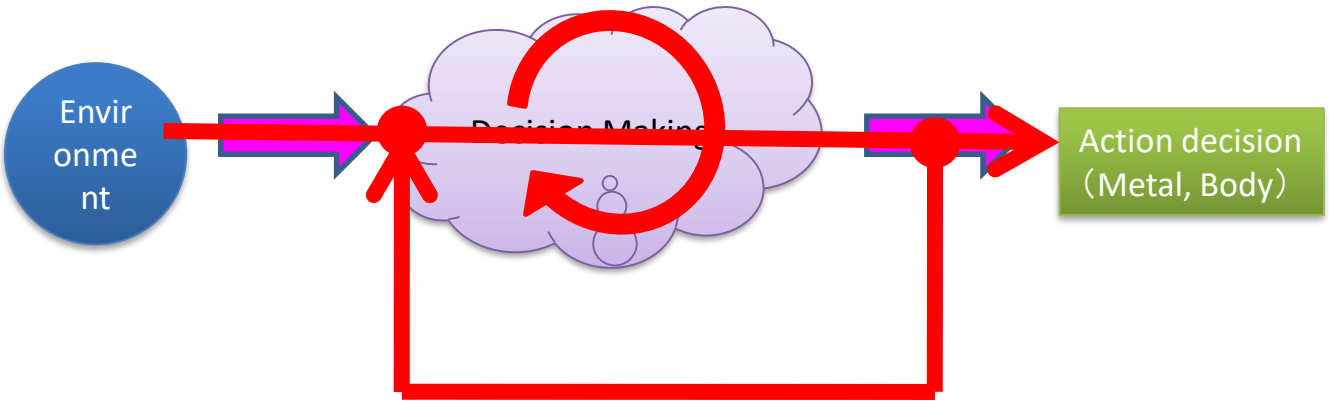
Decision Making

Two big roles of decision making
- Decide mental and body state reaction to the stimulus from the environment.
- Updating recognition and knowledge.

Decision Making Function

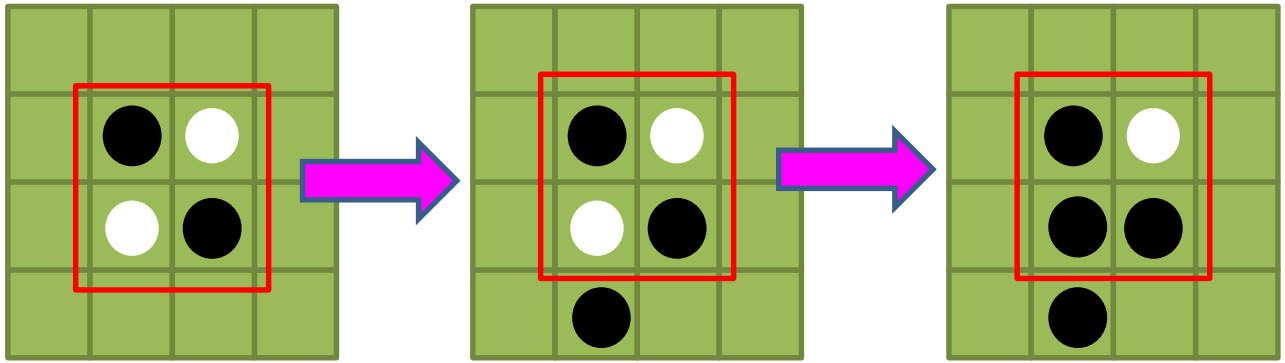
- Making a decision.
- Recognizing an environment.
- Keeping feedback to decision making process .

Decision Making



Feedback system for decision making like an electric circuit.

Decision Making example
(Turn based game)



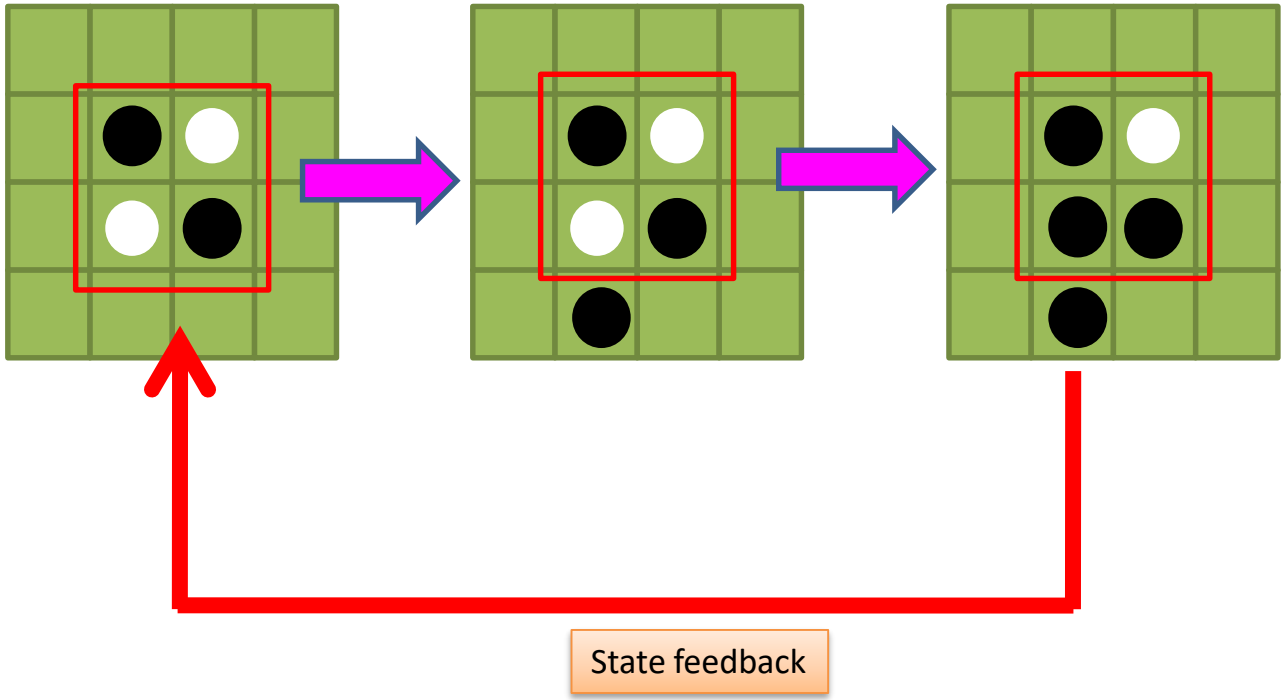
Game state does not Change until a player action.

AI must think a next move by guessing a player's next action.

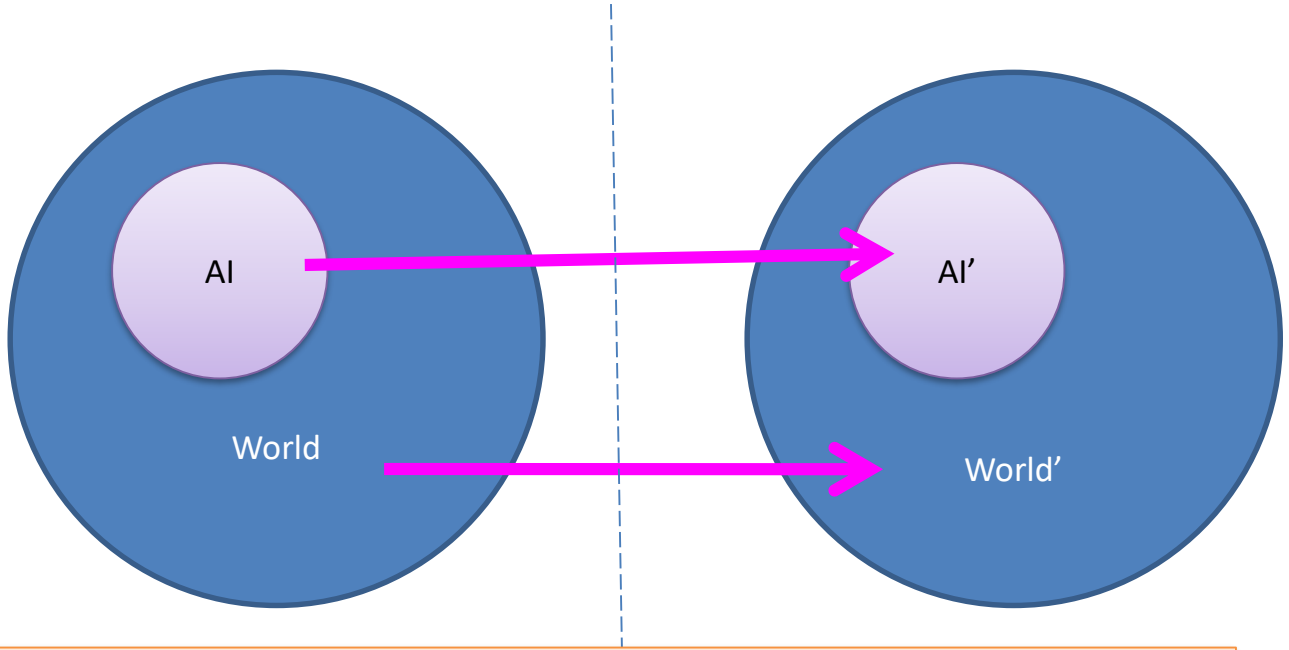
Game State changes by following game rule.

AI must give a feedback by thinking whether a move can get a good result it wished for.

Decision Making Essential

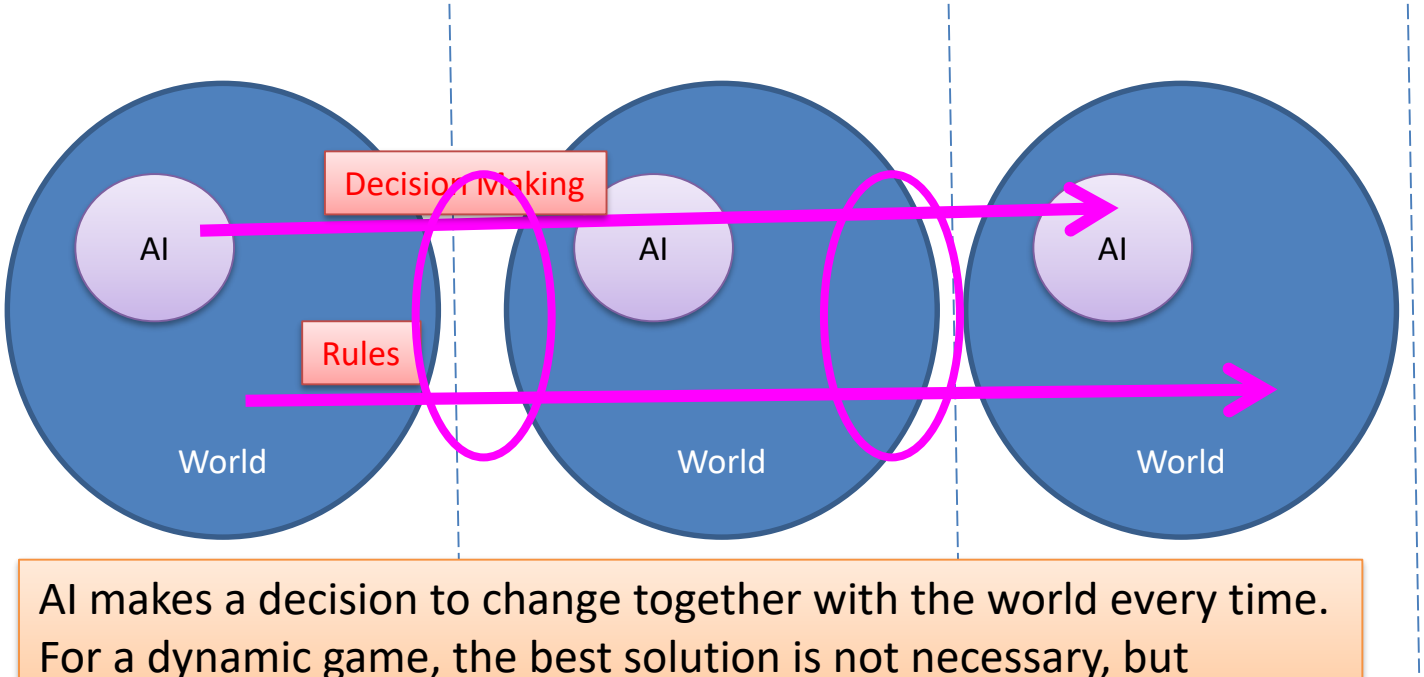


Decision Making example
（Digital Action game）



AI and the world change coincidently.
AI changes by its decision making, and the world changes by game rules and dynamics.

Decision Making example
（Digital Action game）

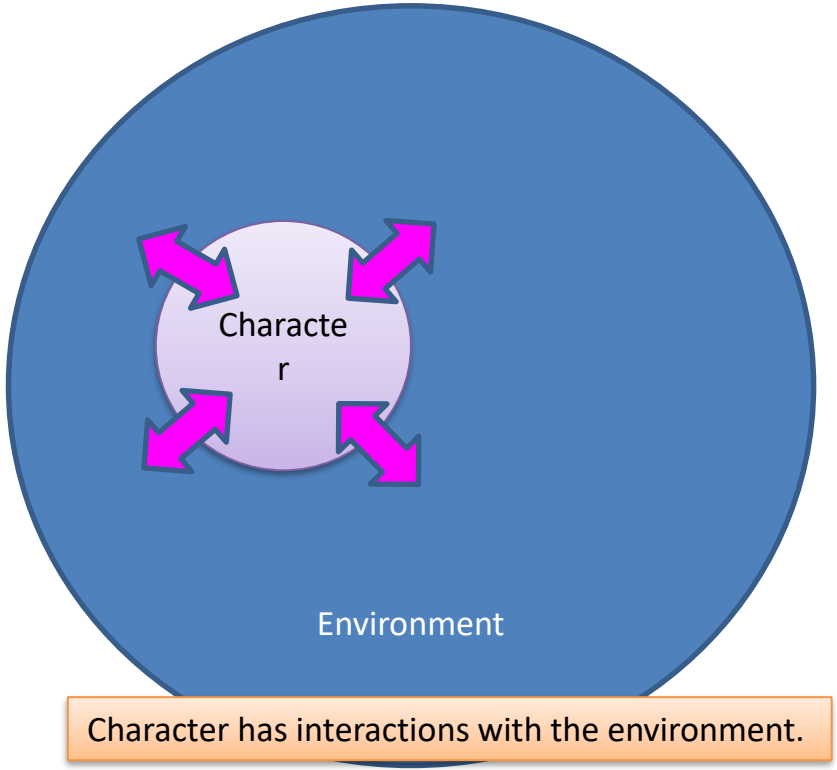


AI makes a decision to change together with the world every time.
For a dynamic game, the best solution is not necessary, but
an ability to create a temporary solution is necessary.

2.2

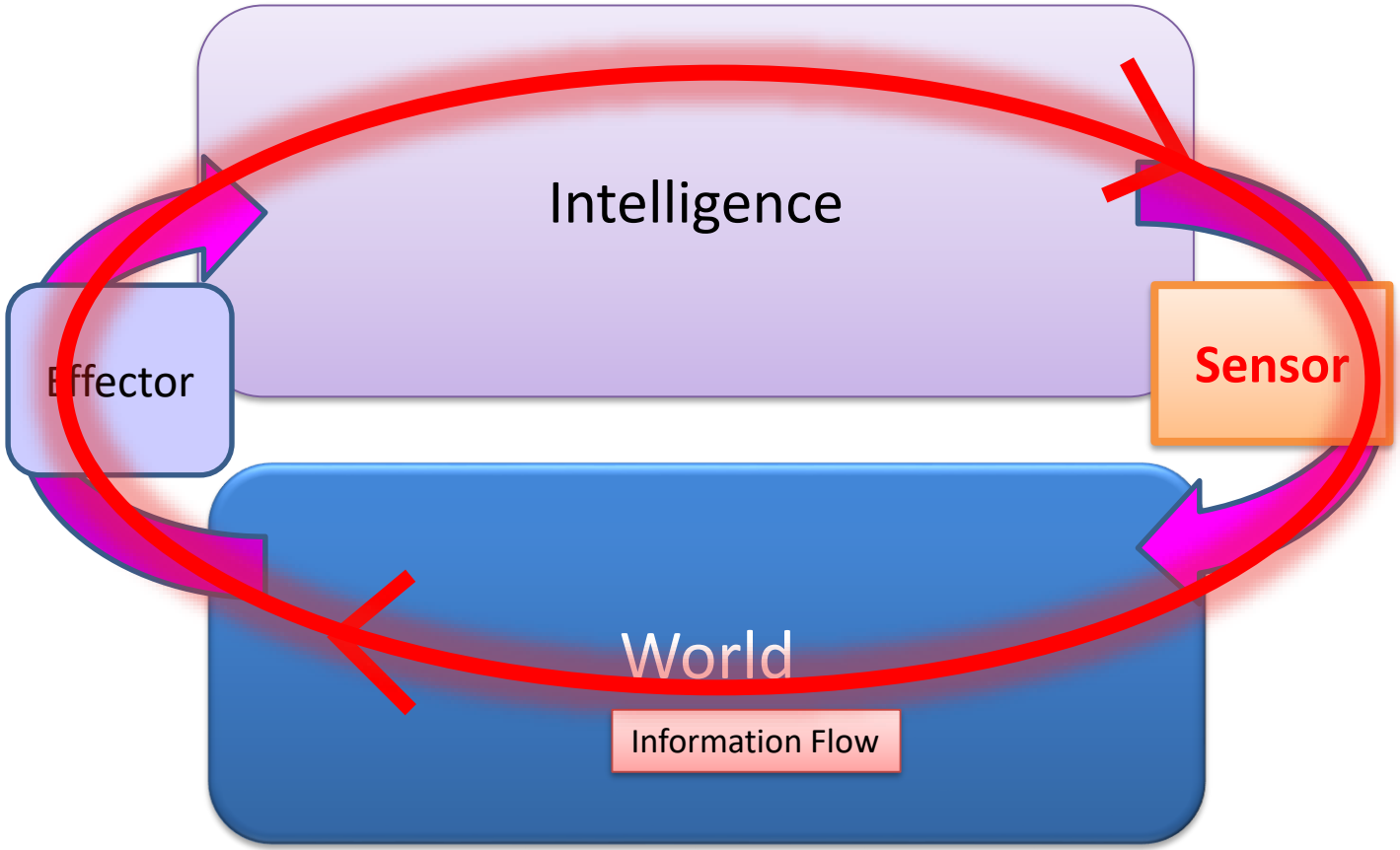
AGENT ARCHITECTURE

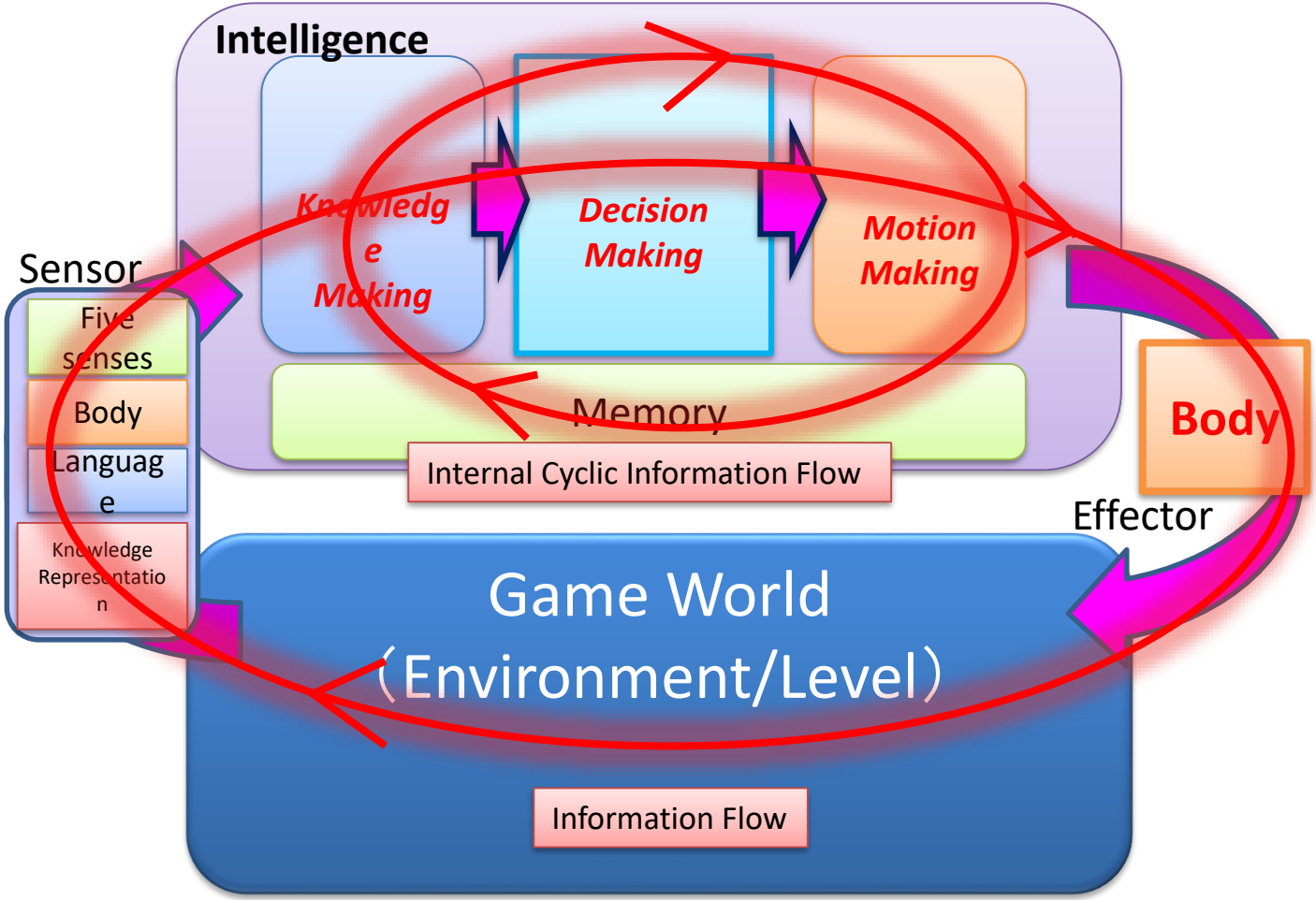
Environment and Character



Character has interactions with the environment.

Agent Architecture





Information Flow

Information Flow

- Information flow connects the outer (environment) and the inner (intelligence).

Internal Cyclic Information Flow

- It is caused by mental activity to organize an inner mind state.

Making AI is achieved by designing Information flow.

Information Flow

Information Flow

- Information flow connects the outer (environment) and the inner (intelligence).

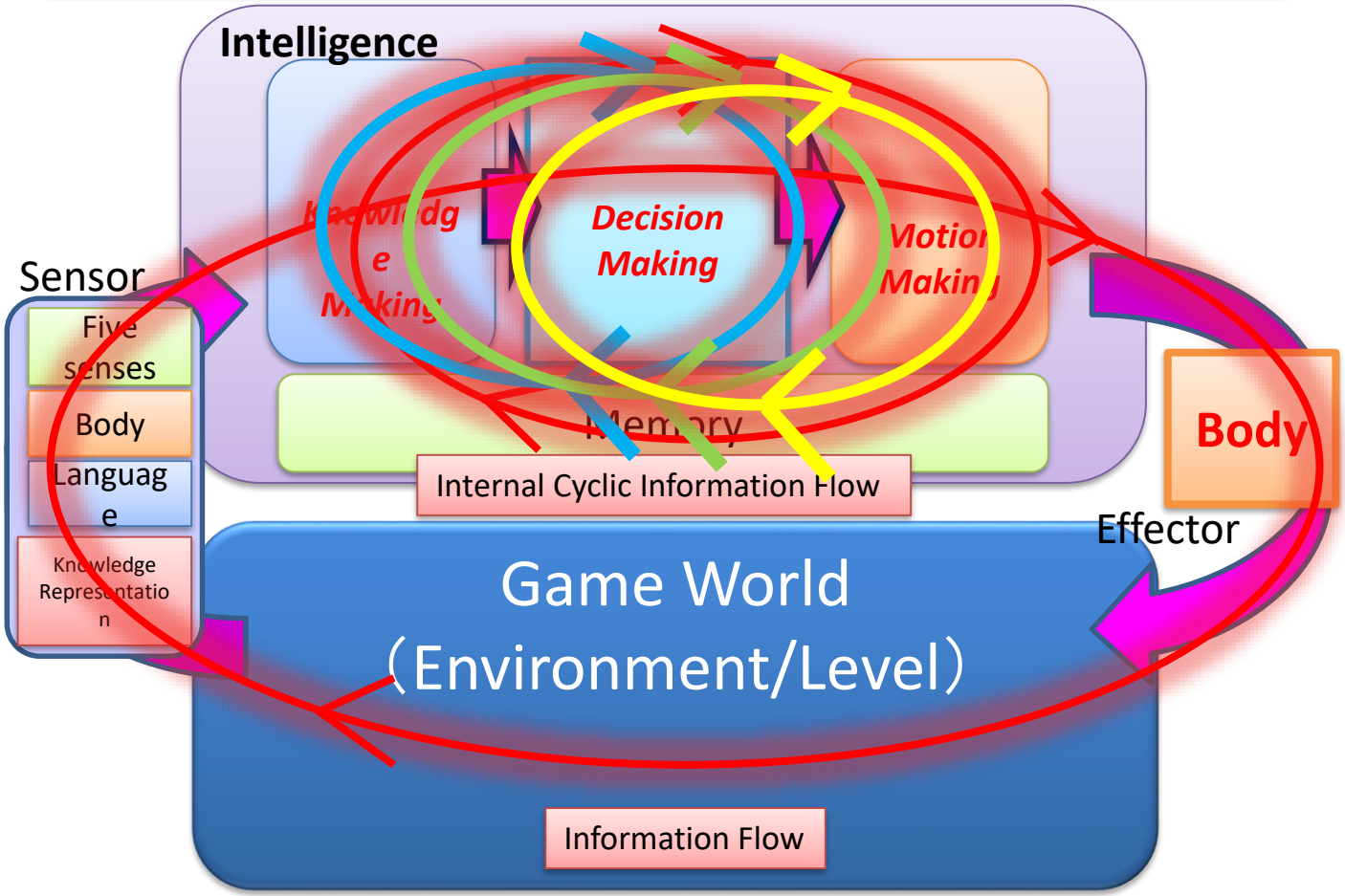
Internal Cyclic Information Flow

- It is caused by mental activity to organize an inner mind state

Making AI is achieved by designing Information flow.

There is much information flowing inside a mind.

Agent Architecture



2.3

DECISION MAKING ALGORITHM

Decision making for static/dynamic game

	Static game（Board game, turn-based game）	Dynamic game（Action game）
Decision Making	Selecting a move	Making a motion
World	It does not change until a new move.	It keeps changing.
Thinking	Selecting the best move by analyzing game state.	Thinking about a relation with the world and itself.

Decision making for dynamic games should keep watching the changes of the game, and also keep its will consistent. It is like “Riding on a horse”.

Decision Making・World・Policy

For dynamic games

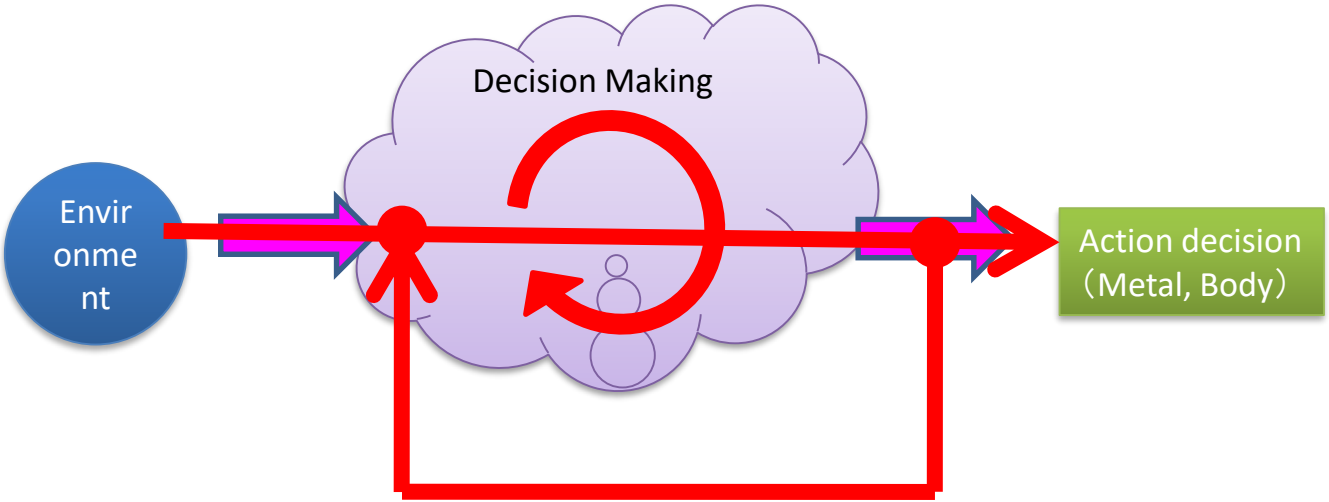
＝ A decision-making should think a world state change.

＝ **There is a policy for each decision making style.**

Reactive・Non-reactive

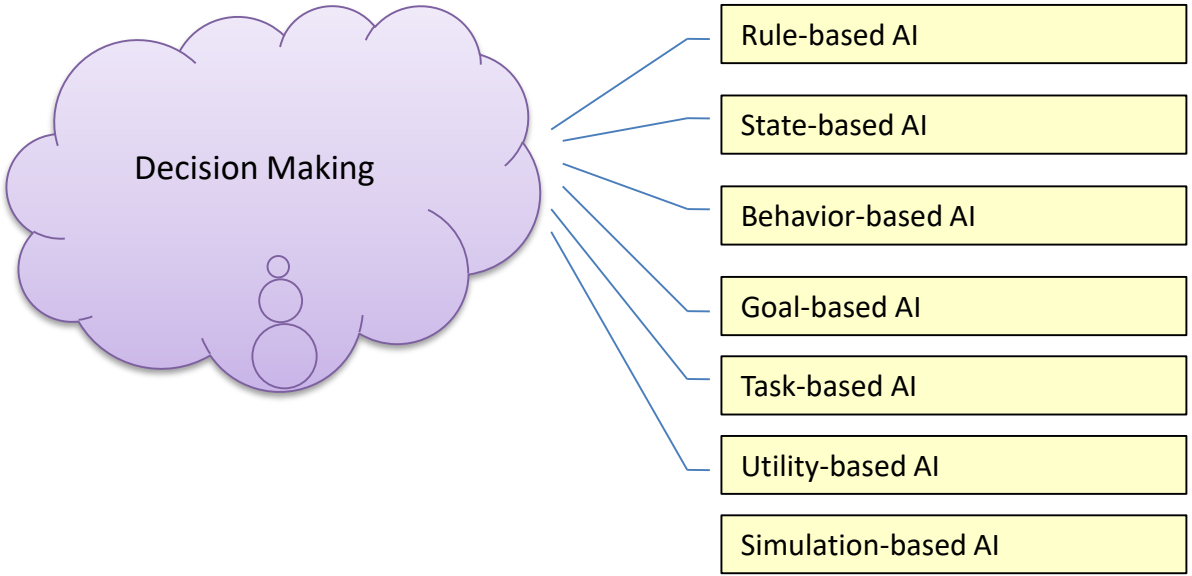
- Reactive ＝ Reaction to the change of environment.
- Non-reactive ＝ Making an abstract action by following a goal and plan.

Decision Making



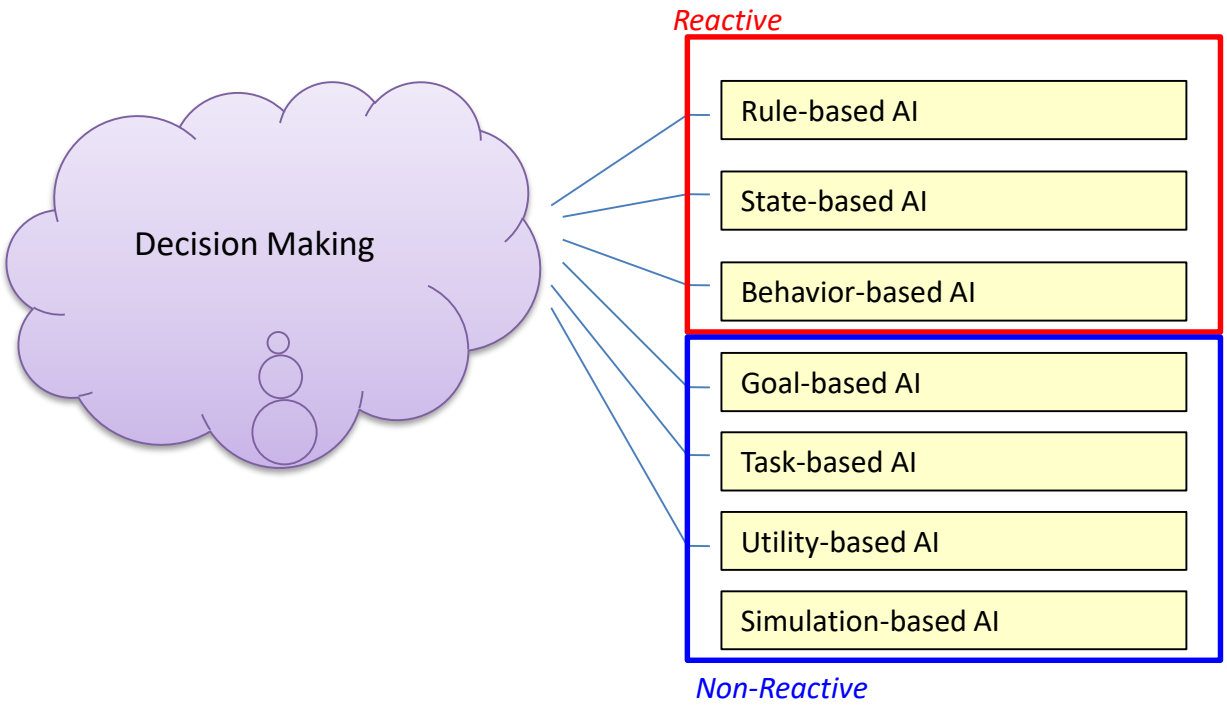
Decision Making Model

Usually decision-Making is a very complex process.
But in artificial intelligence, there are some simple basic styles.



Decision Making Model

Usually decision-Making is a very complex process.
But in artificial intelligence, there are some simple basic styles.



Rule-based Decision Making

Rule

IF（ Condition Statement ） then （Result Statement）

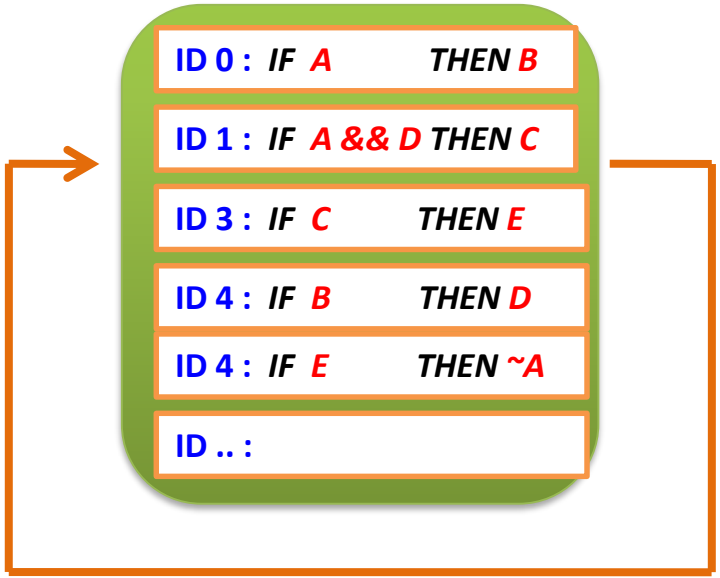
The form is called “Rule”.

Of course, a structure like IF (… IF (…. IF…))) can be called rule-based, but,

Rule-based algorithm means
a rule is used for decision-making as a fundamental element.

Inference Engine

There are many rules. If a condition statement in a rule is true, the rule is “fired”. A result statement in a fired rule becomes true, and it fires another rule.

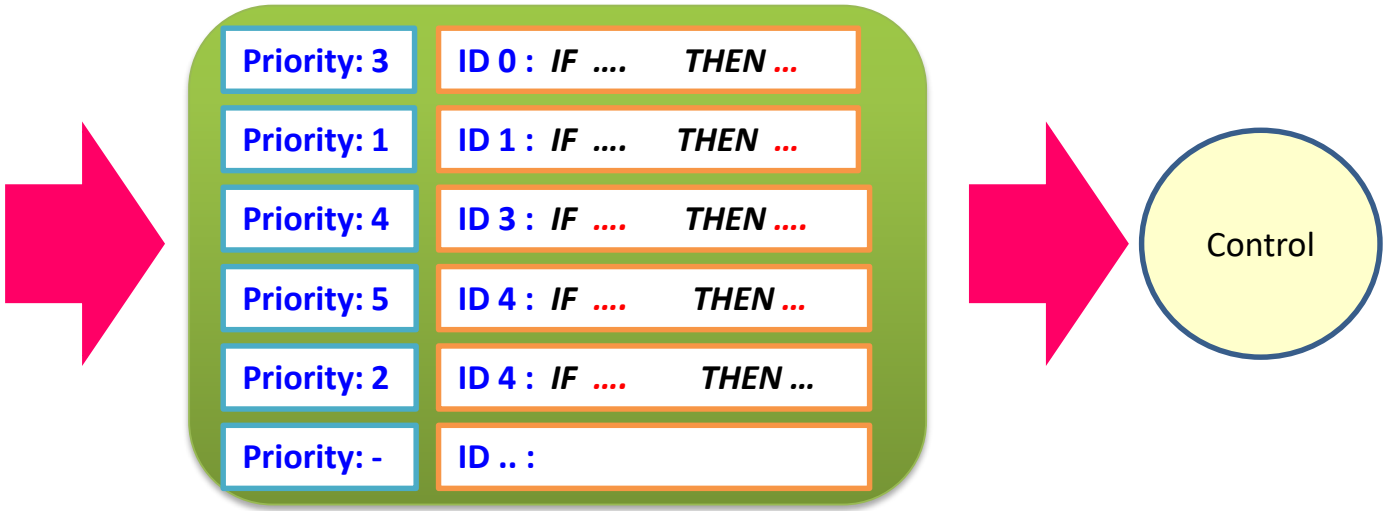


A	B	C	D	E
T	F	F	F	F
T	T	F	F	F
T	T	F	T	F
T	T	T	T	F
T	T	T	T	T
F	T	T	T	T
F	F	F	T	T
……				
……				
……				

A change of true/False

Rule Control

Rule ＝ IF（Action Condition） then （Action Command）

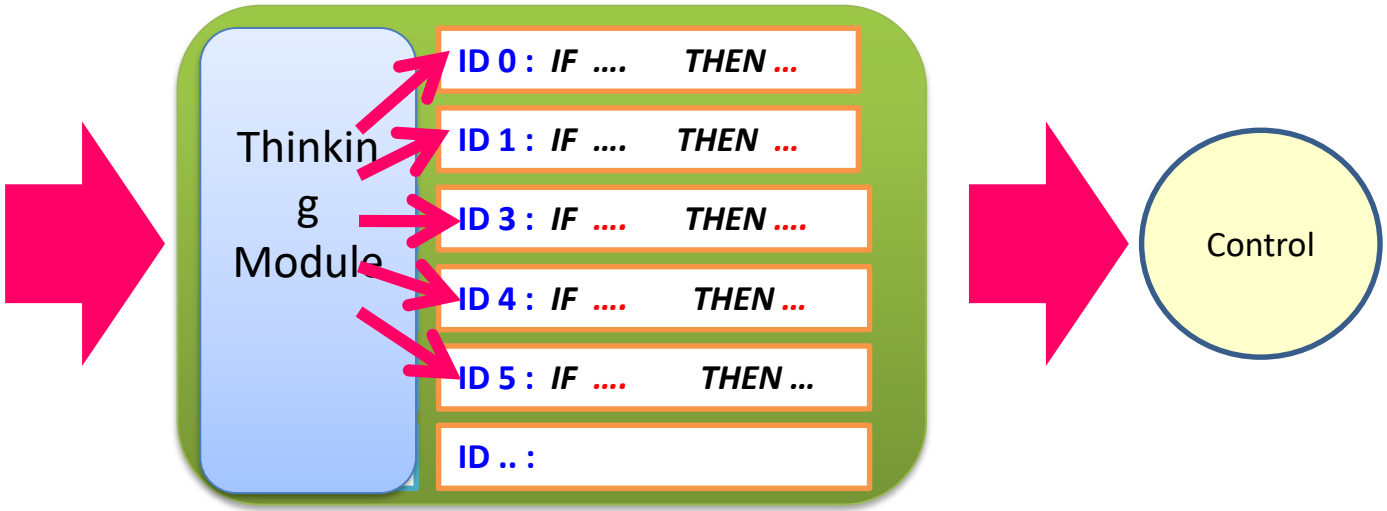


A constant priority value or dynamic priority is attached to each rule.
The rule with highest priority is fired in all fired rules.

The system is used by tactical thinking and character behavior.

Rule Control

Rule ＝ IF（Action Condition） then （Action Command）



Thinking module picked up one rule from the game situation.

Example

Action game

ID 0 : *IF （an enemy found） THEN （escape）*

ID 1 : *IF （cannot find any）THEN （random walk）*

ID 2 : *IF （found item）THEN （get the item）*

ID 3 : *IF （found door） THEN （go through it）*

RPG

ID 0 : *IF （enemy is strong） THEN （Magic）*

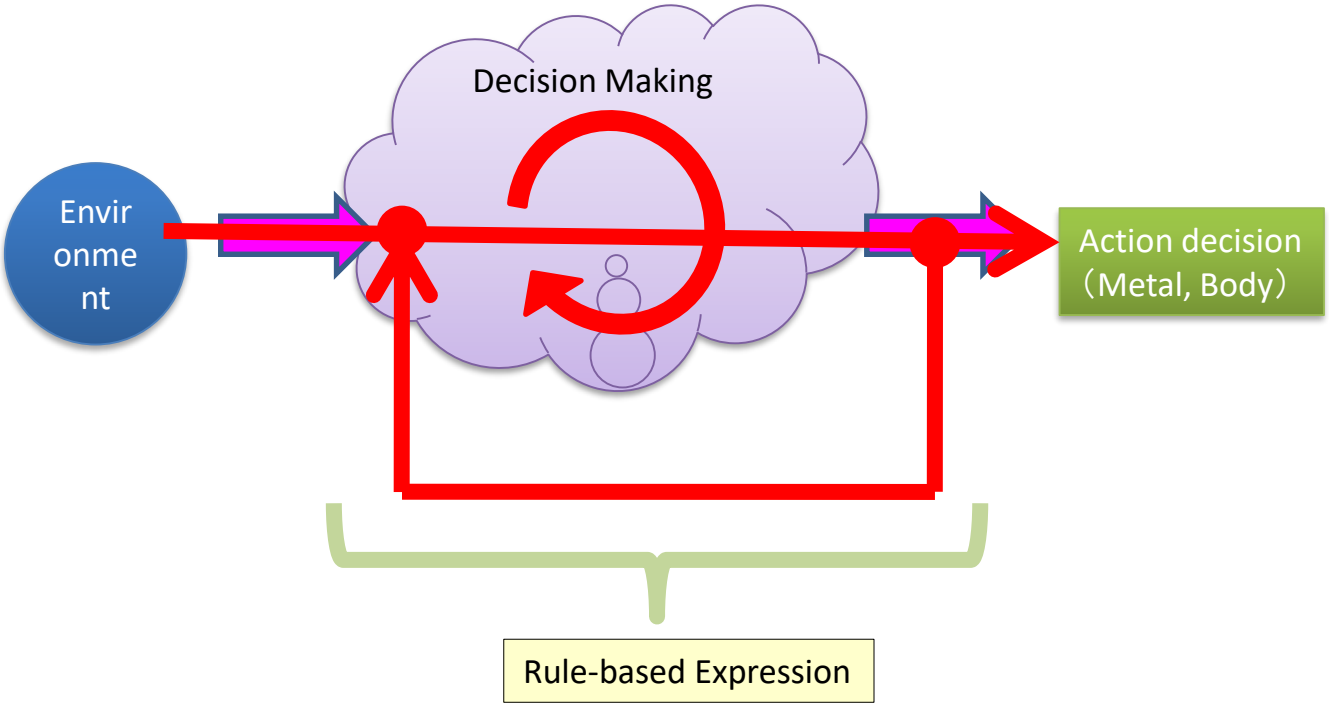
ID 1 : *IF （found many enemies）THEN （attack the weakest）*

ID 2 : *IF （HP<20） THEN （spell refresh magic ）*

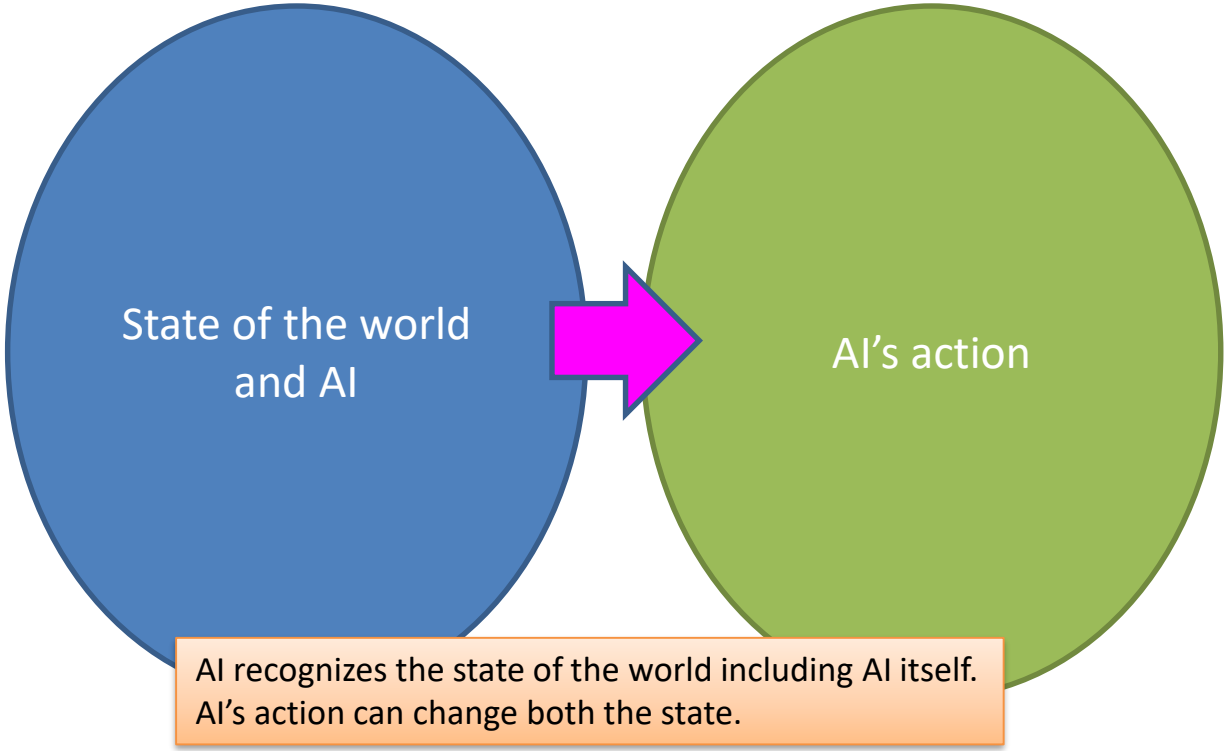
ID 3 : *IF （found a hole） THEN （avoid it）*

http://gomibako.symphonic-net.com/vote.cgi?genre=act_b&rating=9

Decision Making

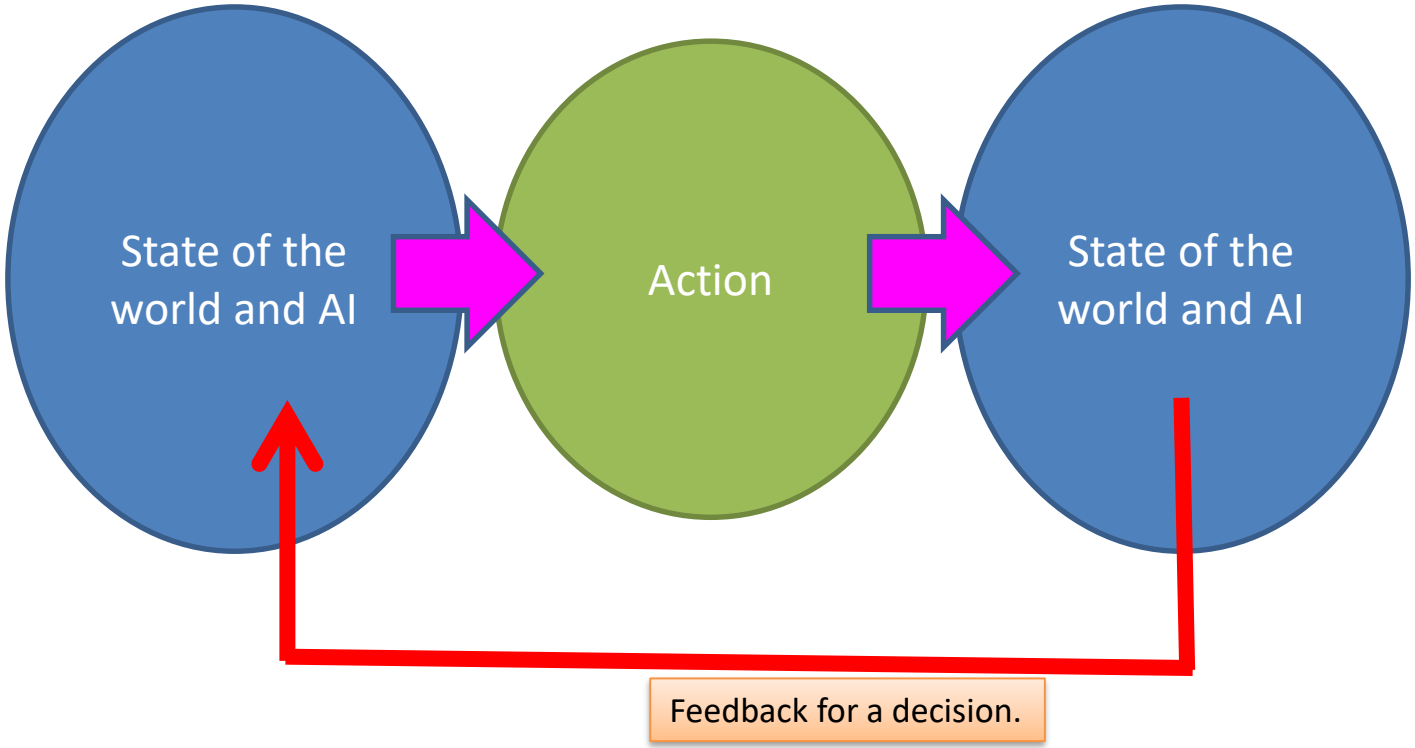


Decision Making

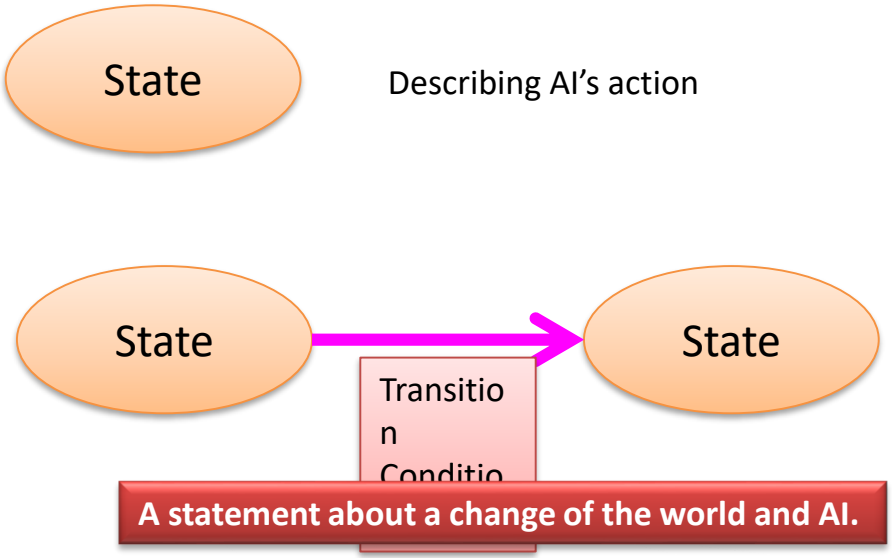


AI recognizes the state of the world including AI itself.
AI's action can change both the state.

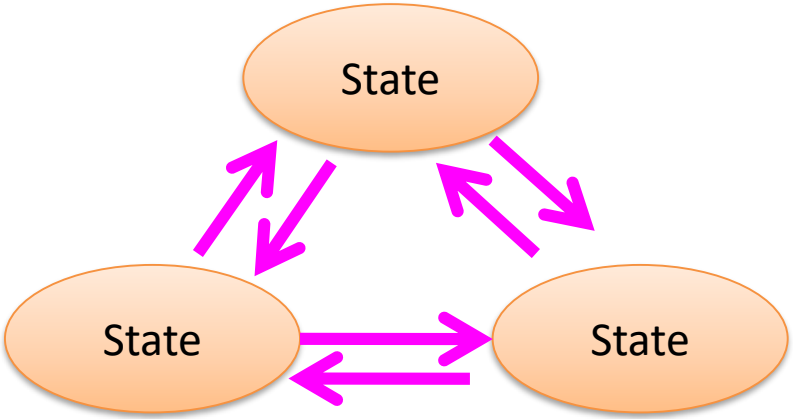
Rule



State Based AI



State Machine

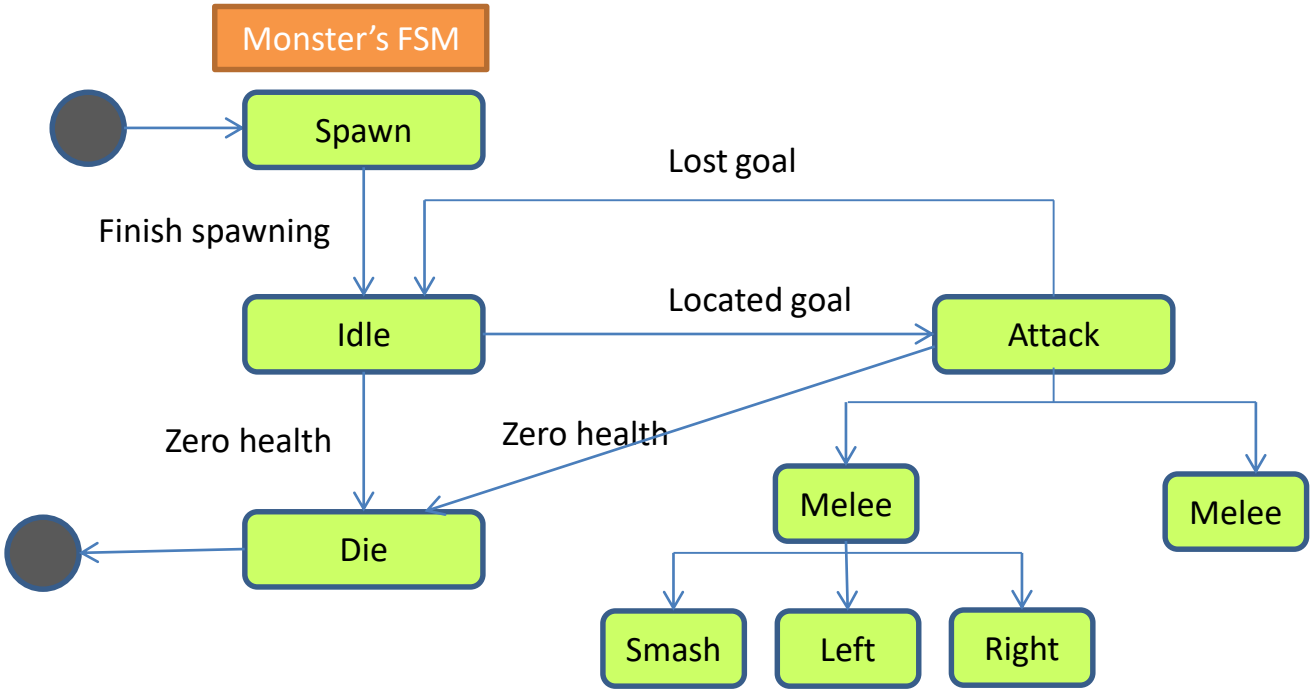


State Machine（Finite State Machine）

AI's action is described in a state, and
a change of the world and AI is described in a transition condition.

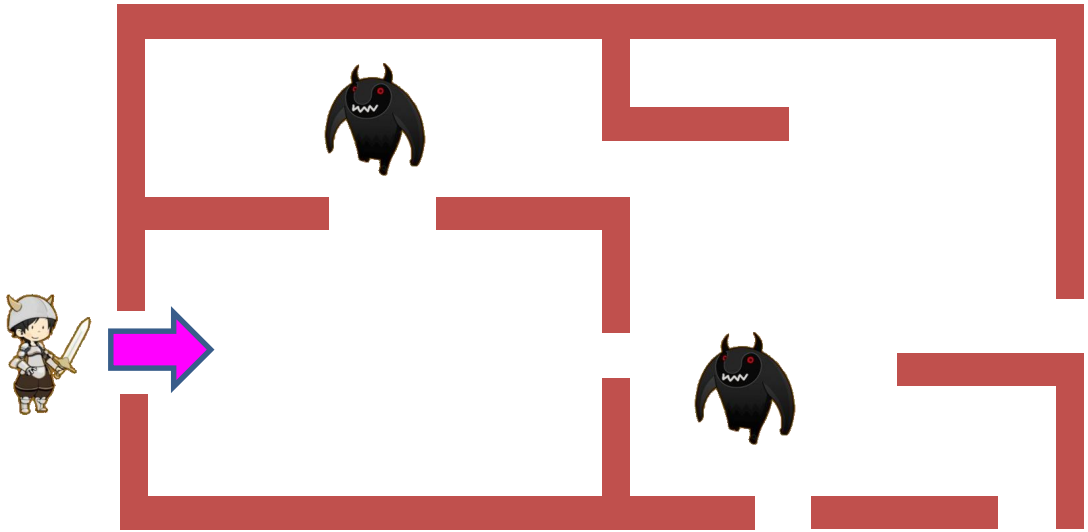
A state machine has a loop structure but does not have feedback dynamics.

(Example) Quake HFSM



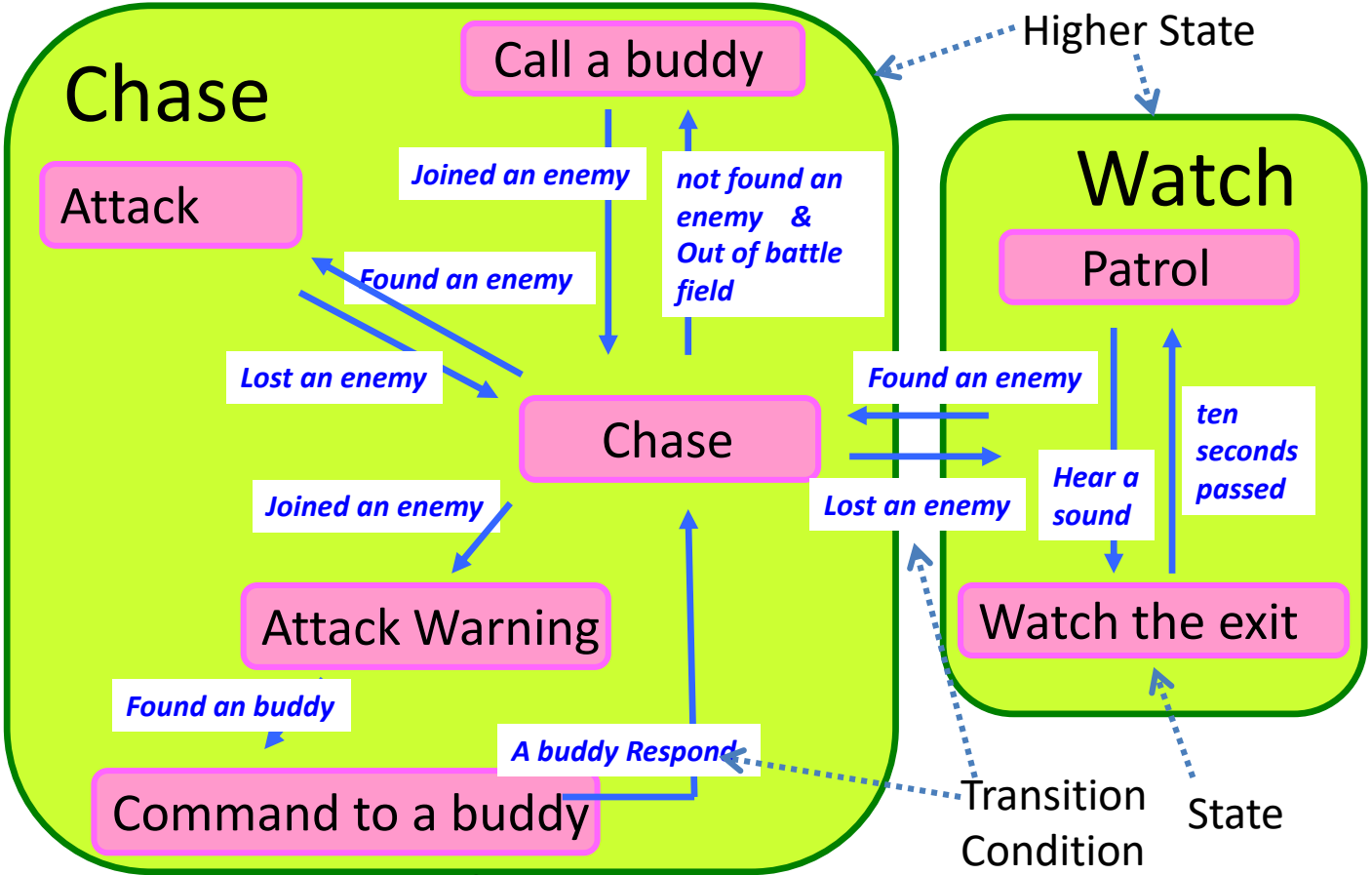
http://ai-depot.com/FiniteStateMachines/FSM-Practical.html

Hierarchical State Machine



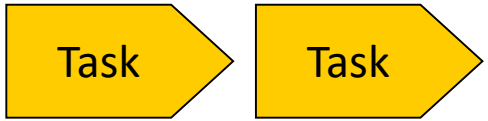
Two enemy characters are patrolling. One player comes to the room.
AI character is described as Hierarchical Finite State Machine (HFSM).

Hierarchical State Machine



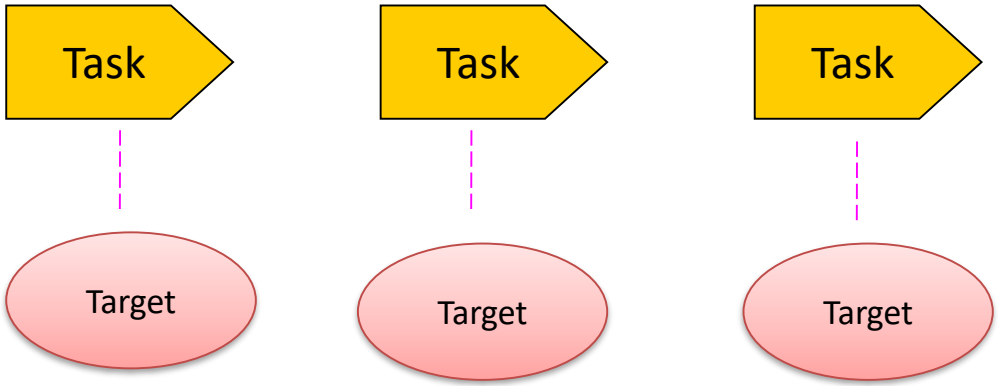
Task based AI

Task describes AI action



Tasks have relation with each other.
For example, task order, task hierarchy , task…

Task based AI



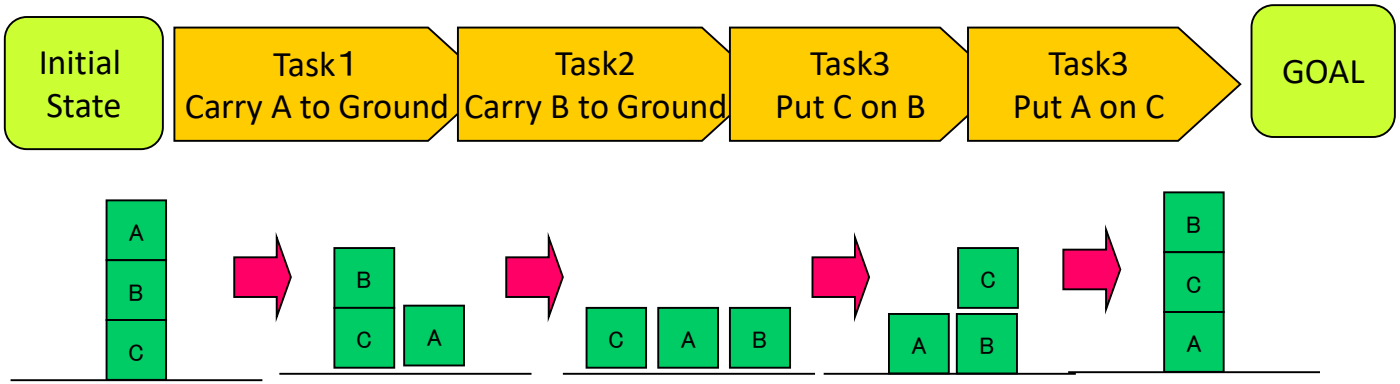
Tasks are defined as actions to the same target, and they can cooperate with each other.

Task based AI

A big task is formed by combining some small tasks.

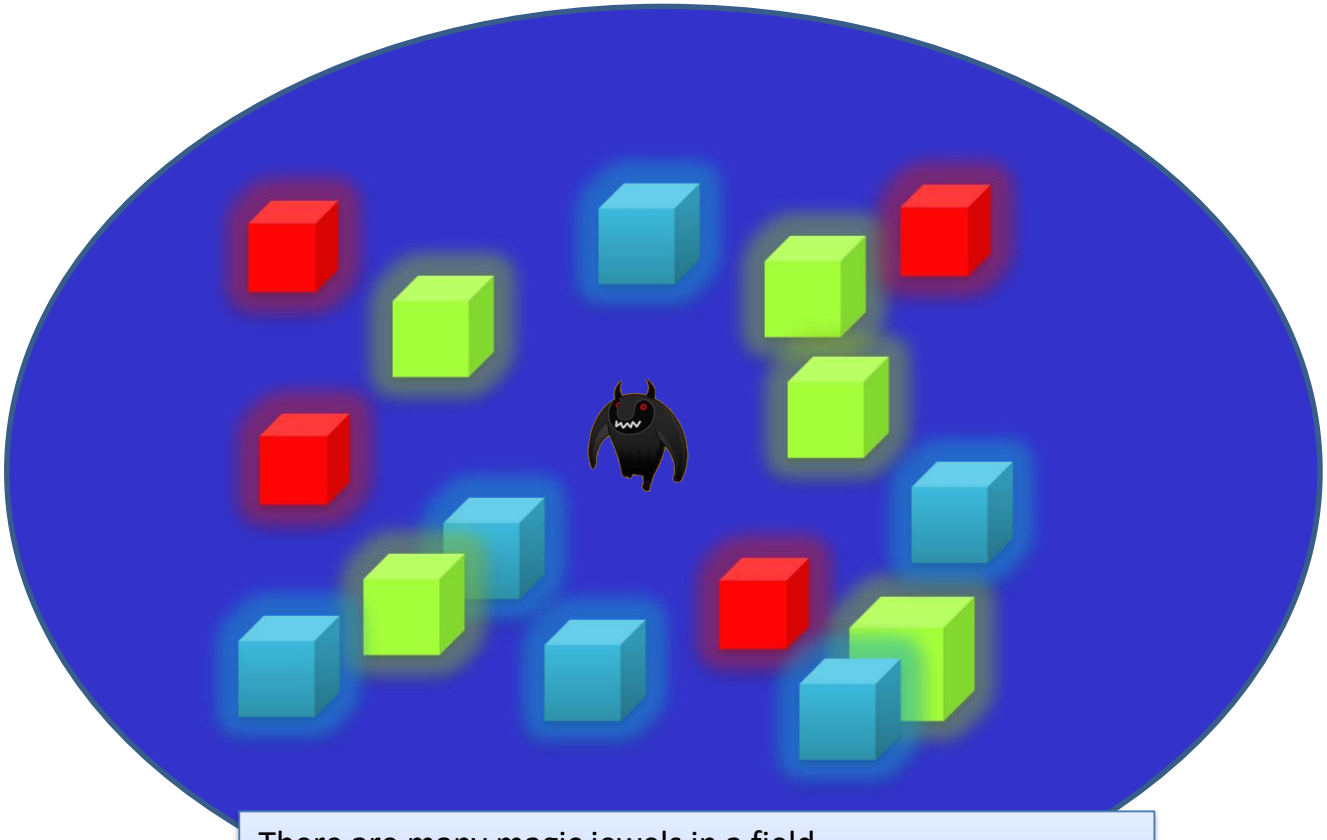
A task must represent a simple practical action.

(Simple case)



Hierarchical Task Network

- Task-based AI is a simple but strong method.
- But for modern complex and big games, it should be adapted to multi-scale time and space.
- Hierarchical Task Network System (HTN) is often used for a character AI.



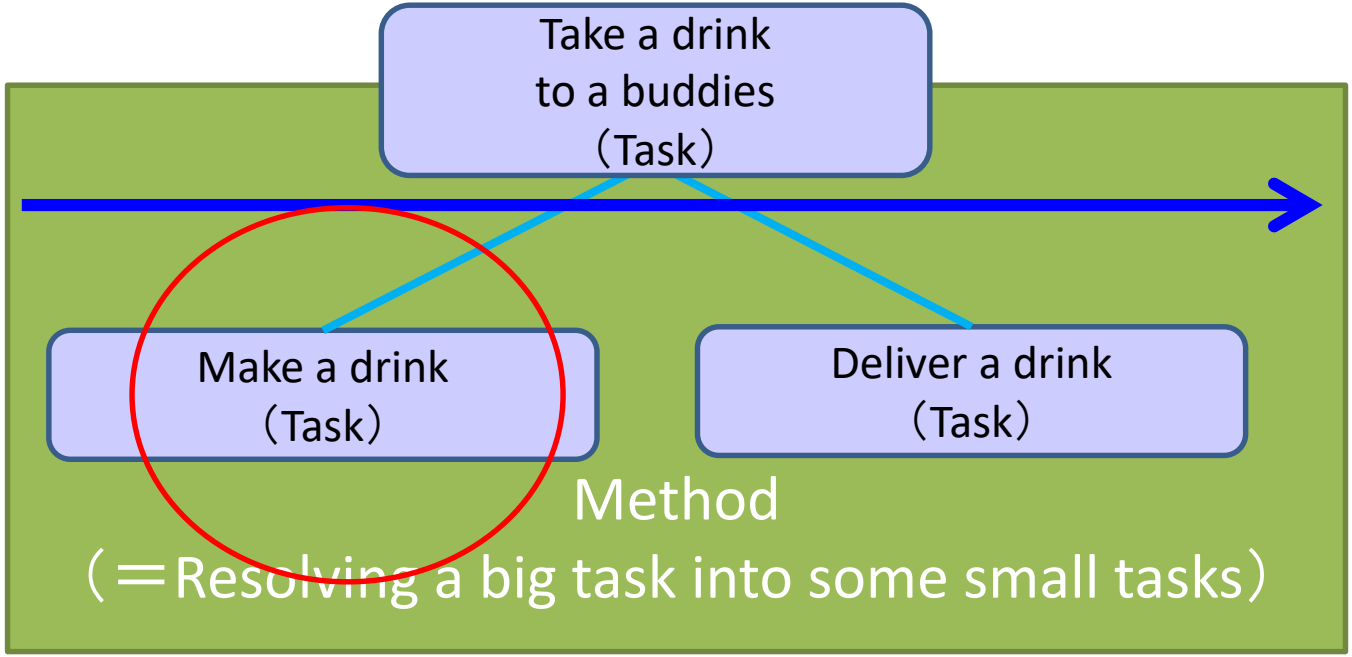
There are many magic jewels in a field.
NPC can make a recovery drink by combining magic jewels.

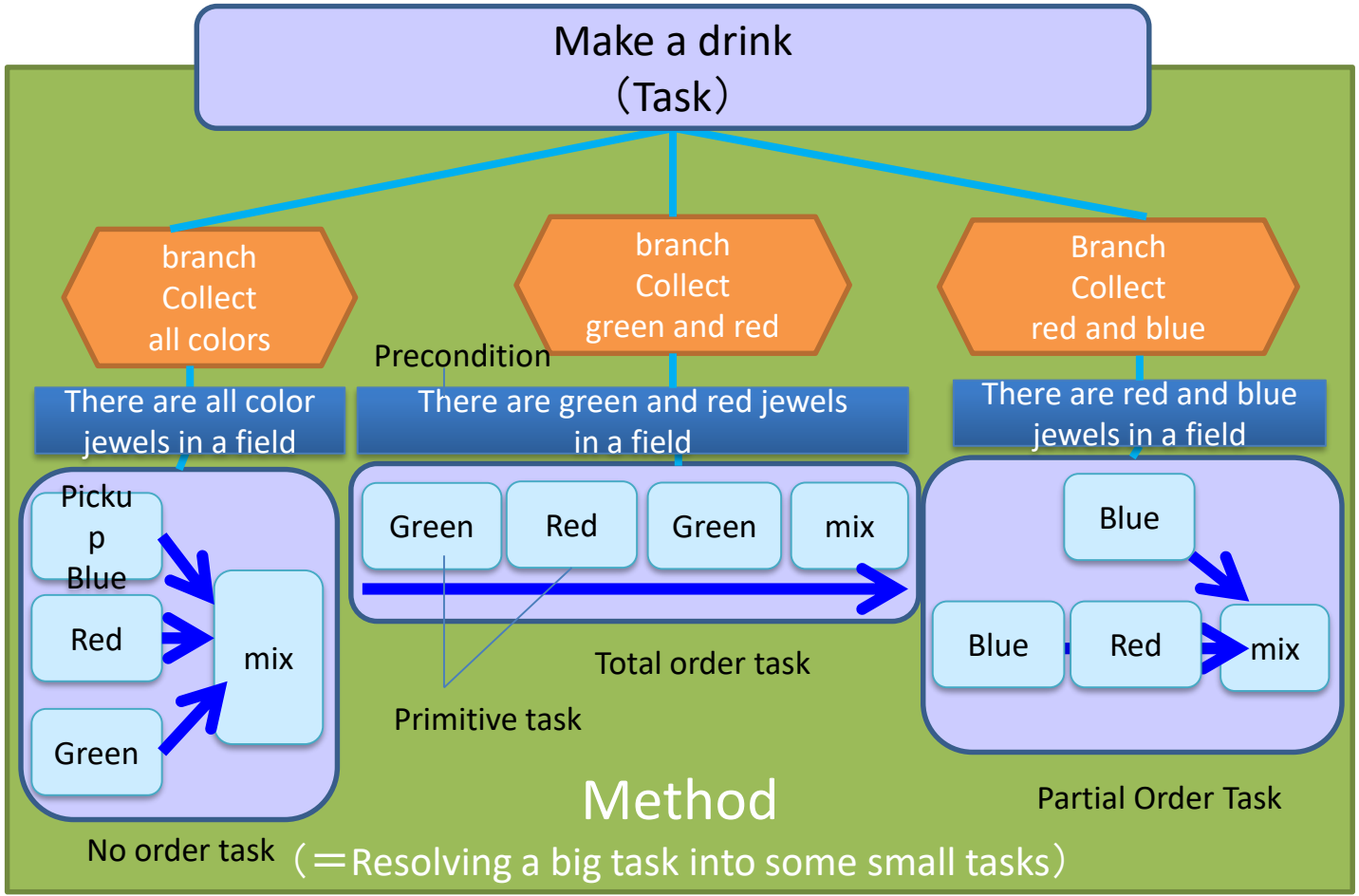
Final goal is to take recovery drink to the buddy monster.

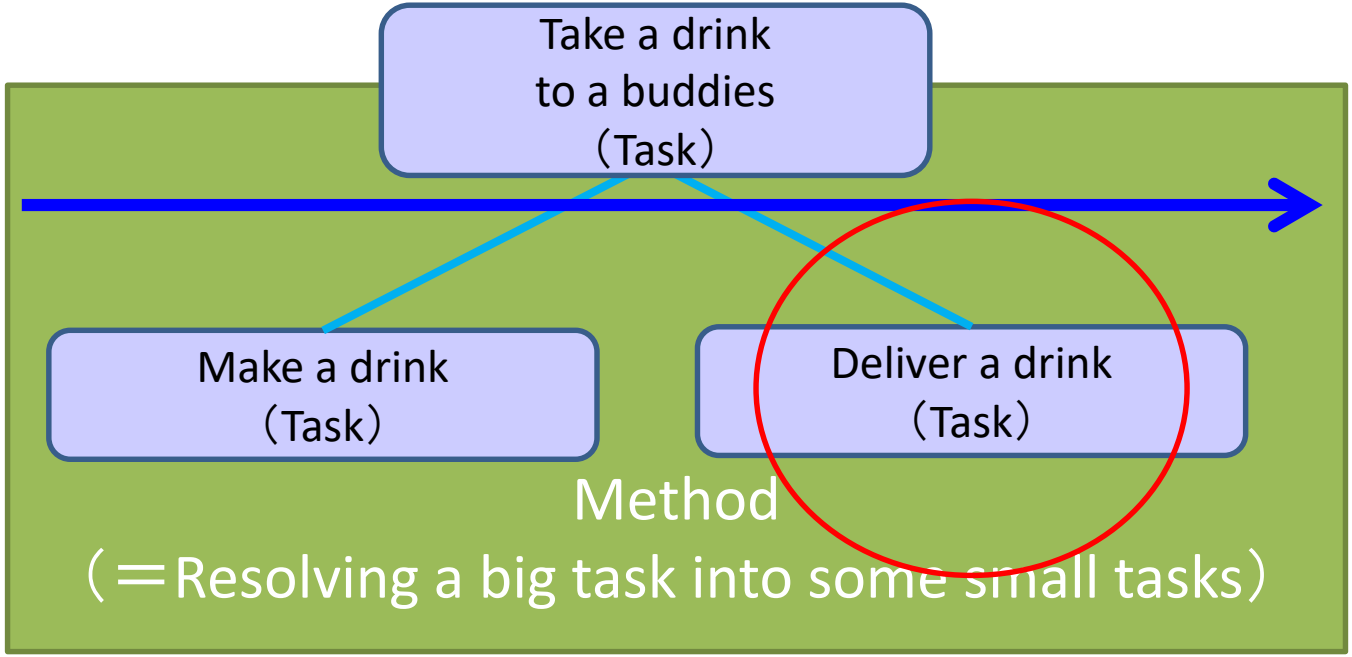
Making Recovery Drink from Magic Jewels (Game Setting)

The way to make it is three:

- Picking up a red, blue, green Jewel in any order
- Picking up green, red, green in this order.
- Picking up two blue jewels and red one. But it is required to pick up blue one before red one.

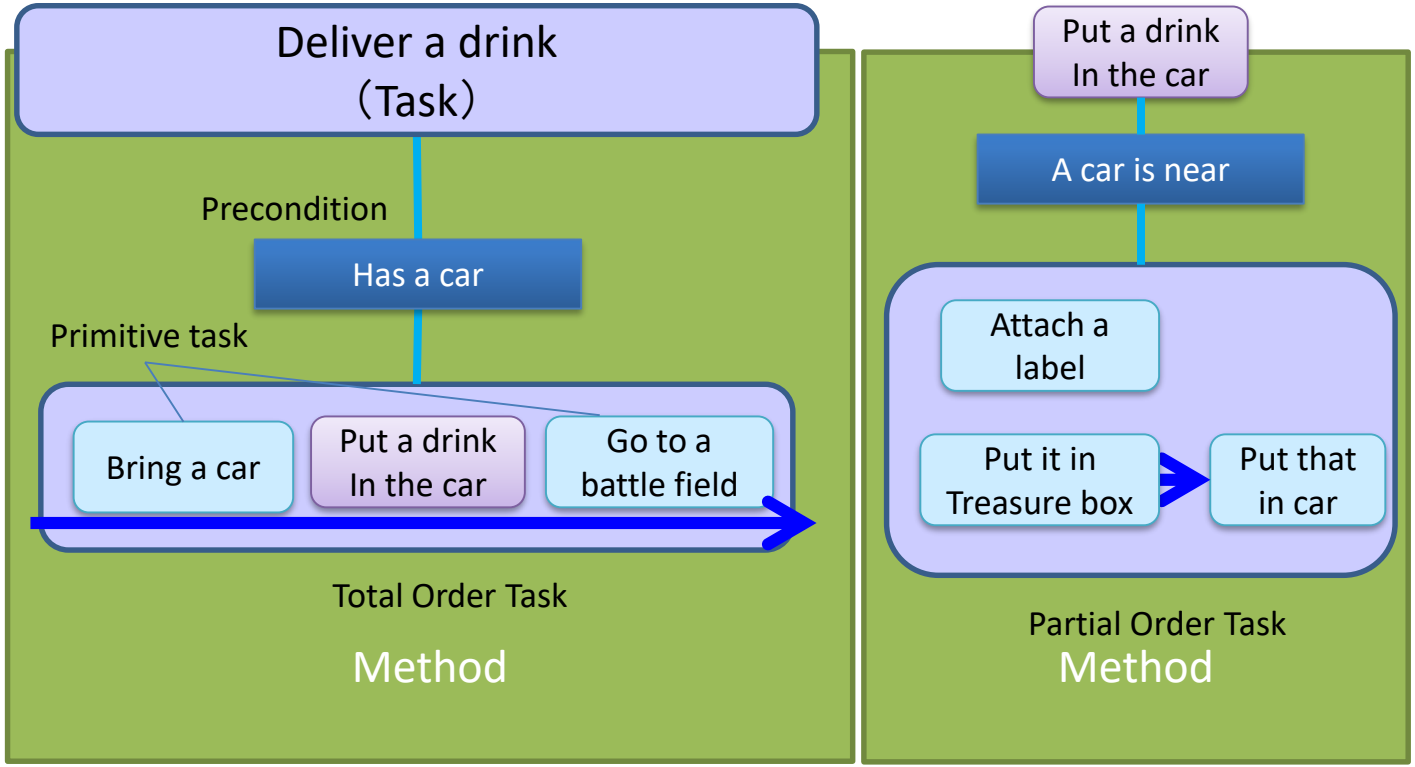




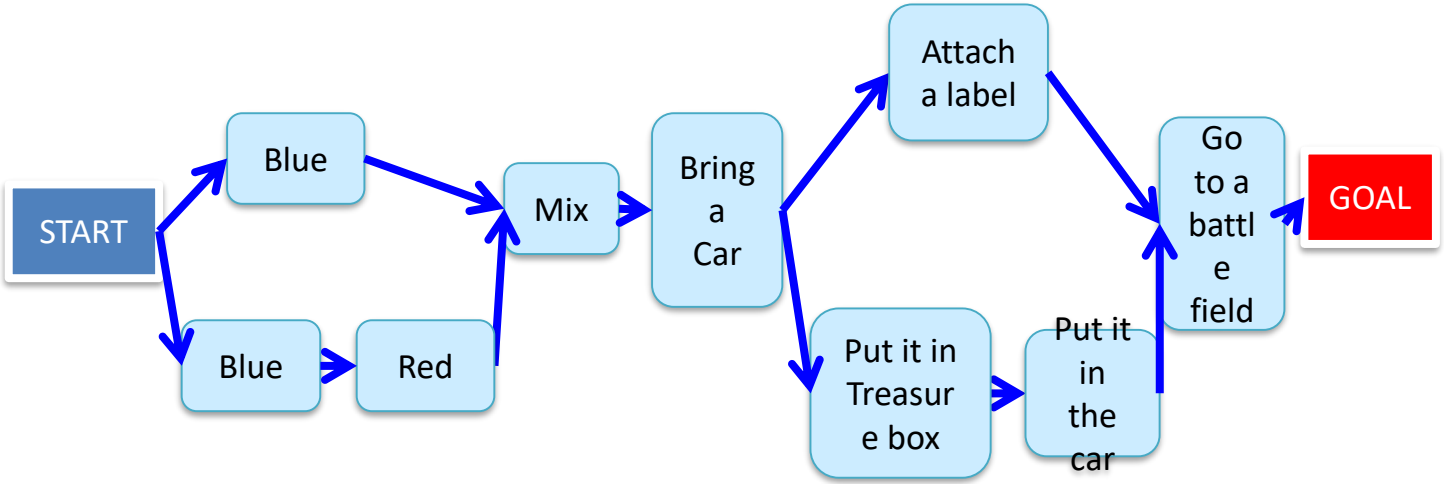


Deliver a drink

- Bring a car , Put drinks in the car, Go to the battle field.
- Drinks should be packaged in a treasure box.
- A Label should be attached to a treasure box.



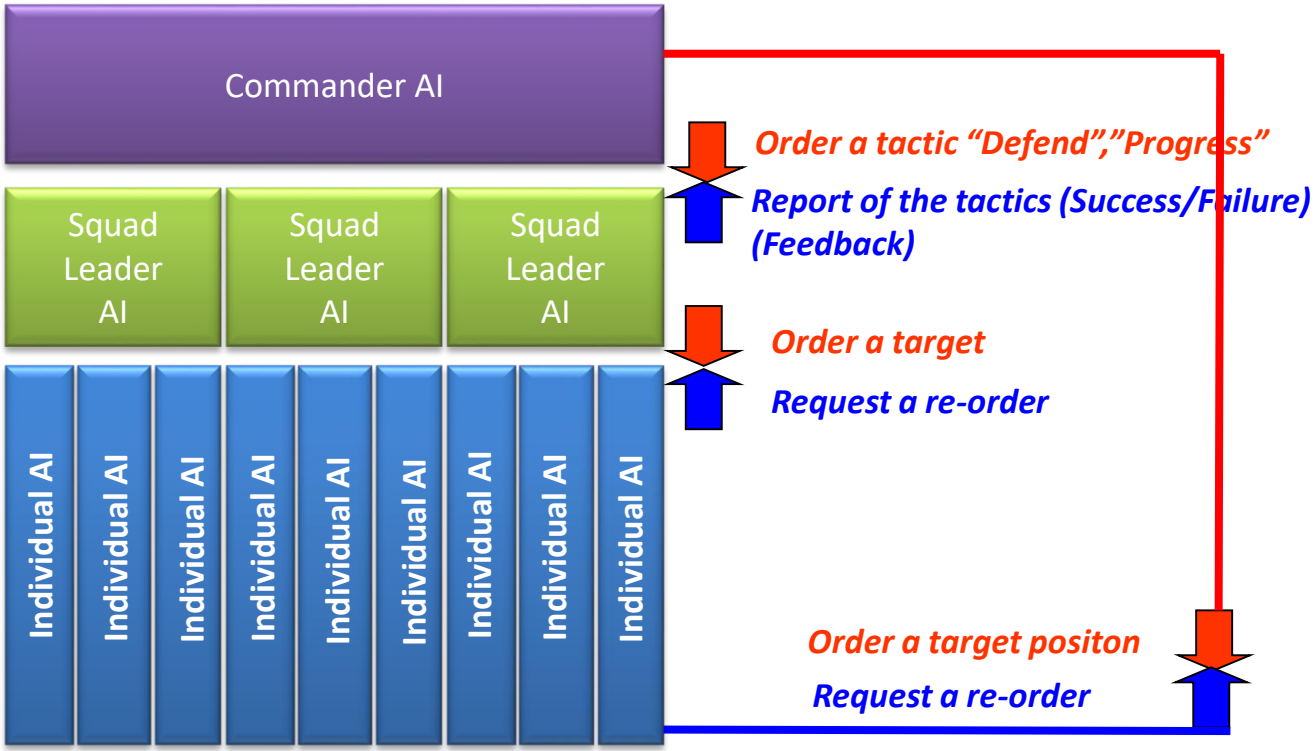
By iteration of applying methods , Task Network is generated.



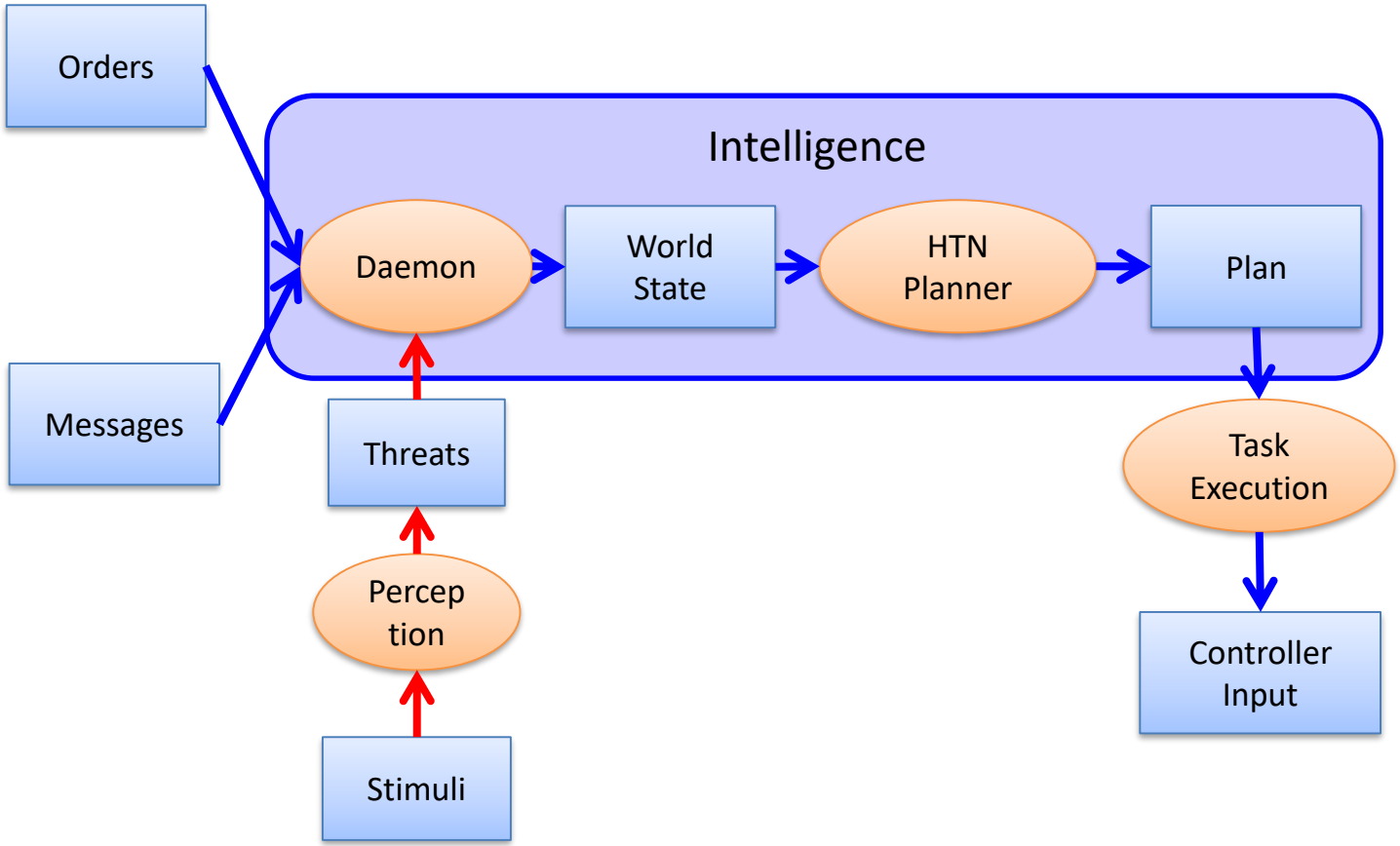
Killzone 2’s AI

Alex Champandard, Tim Verweij, Remco Straatman, "Killzone 2 Multiplayer Bots",
http://files.aigamedev.com/coverage/GAIC09_Killzone2Bots_StraatmanChampandard.pdf

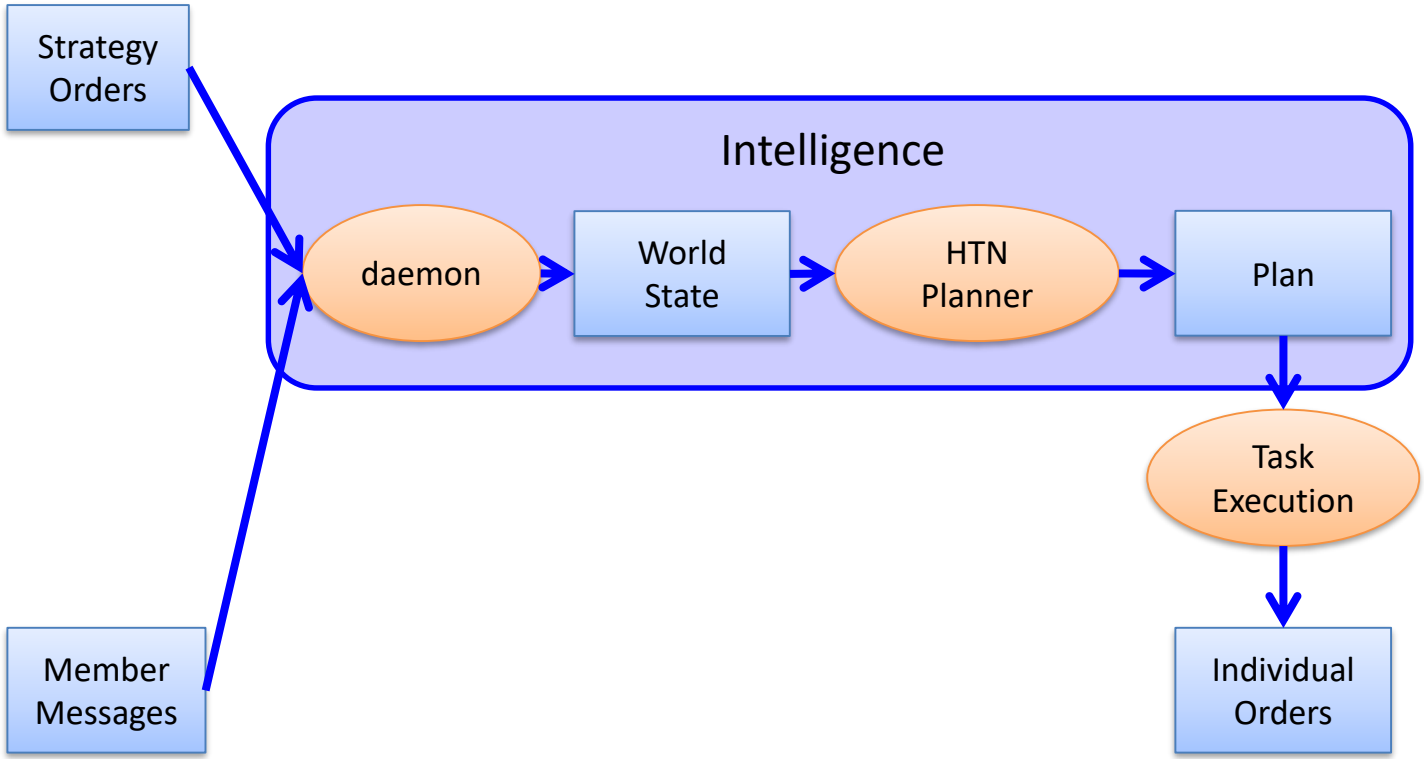
Organization in KILLZONE 2's AI team

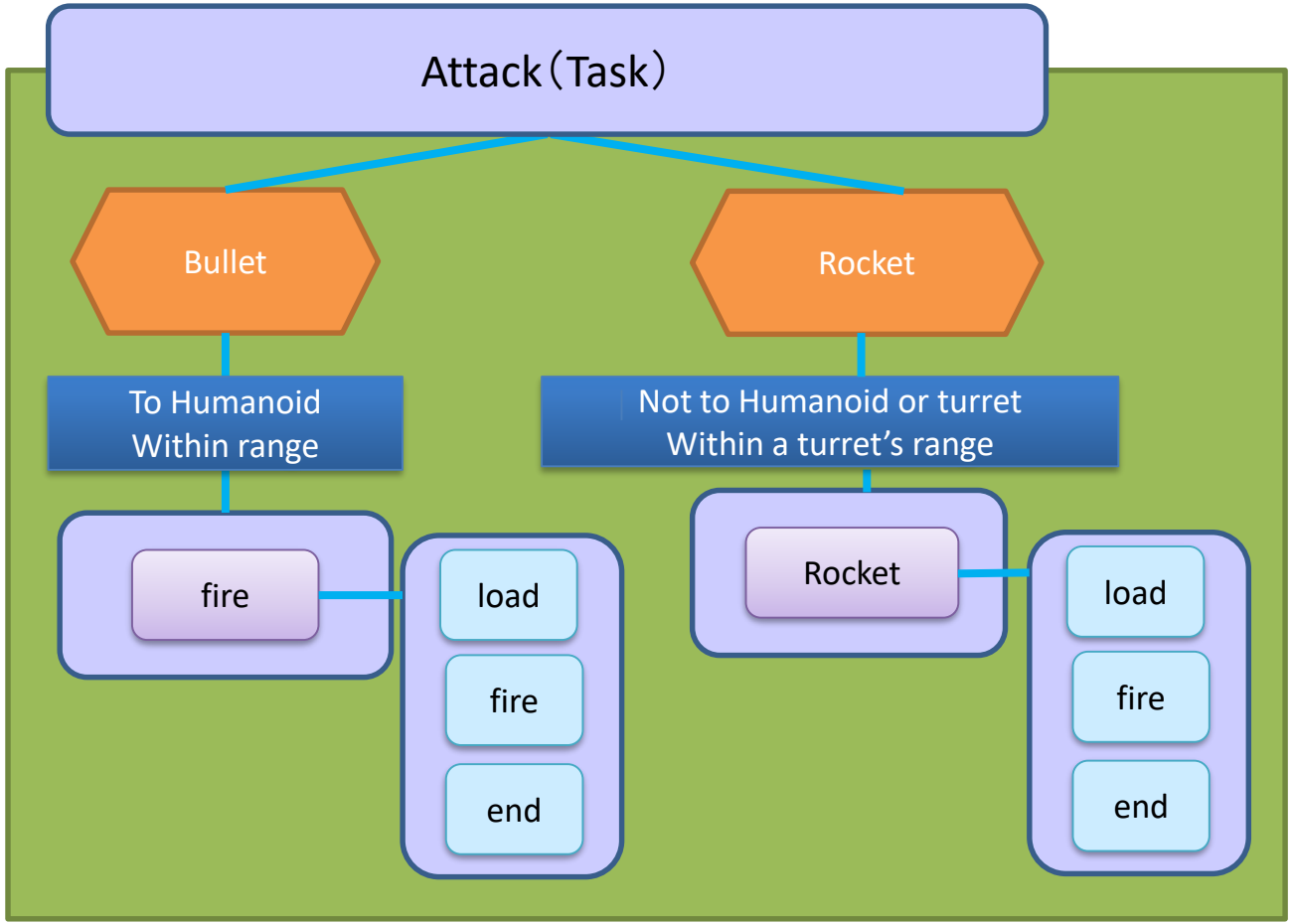


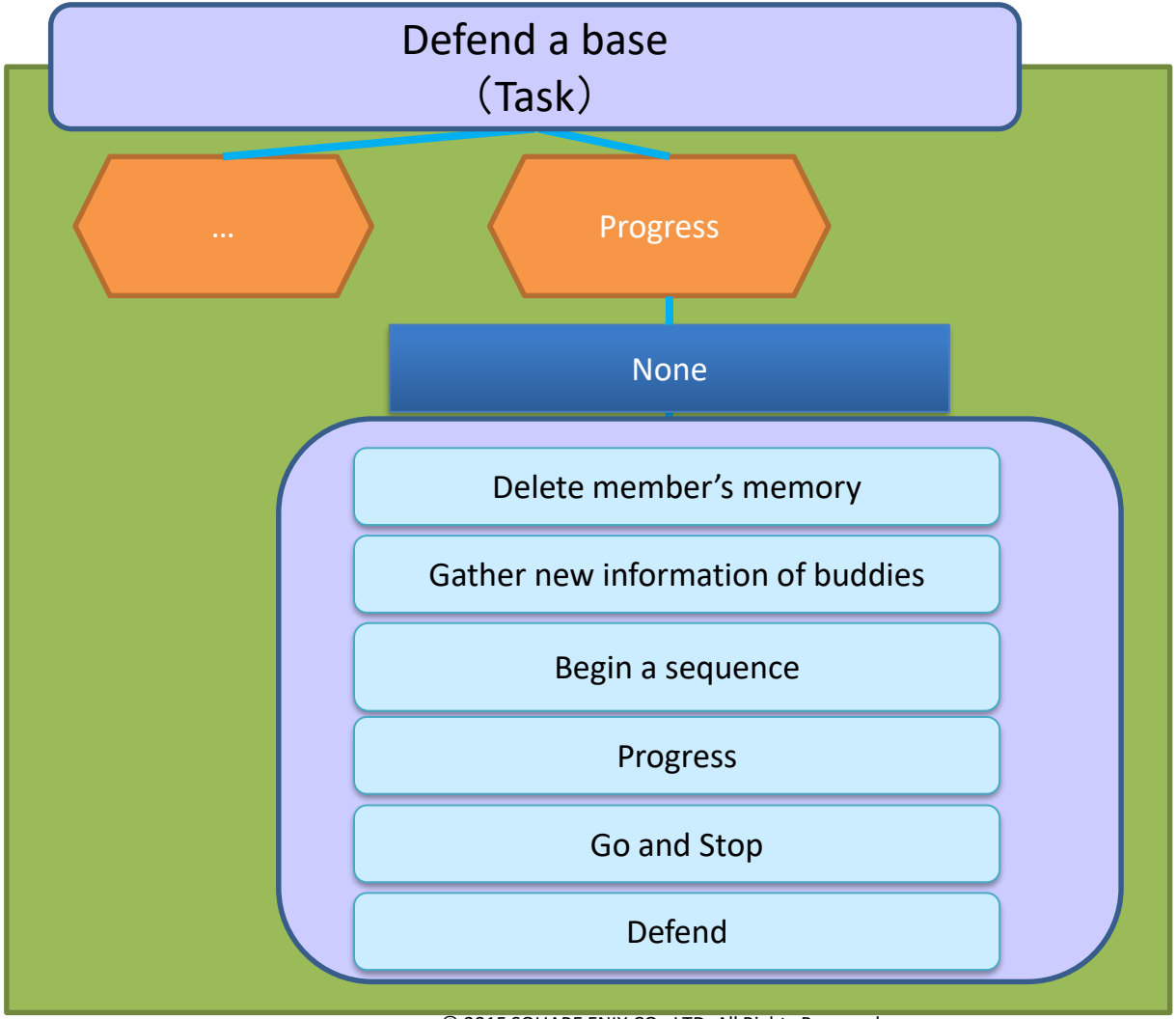
Agent Architecture of a member (Individual AI)

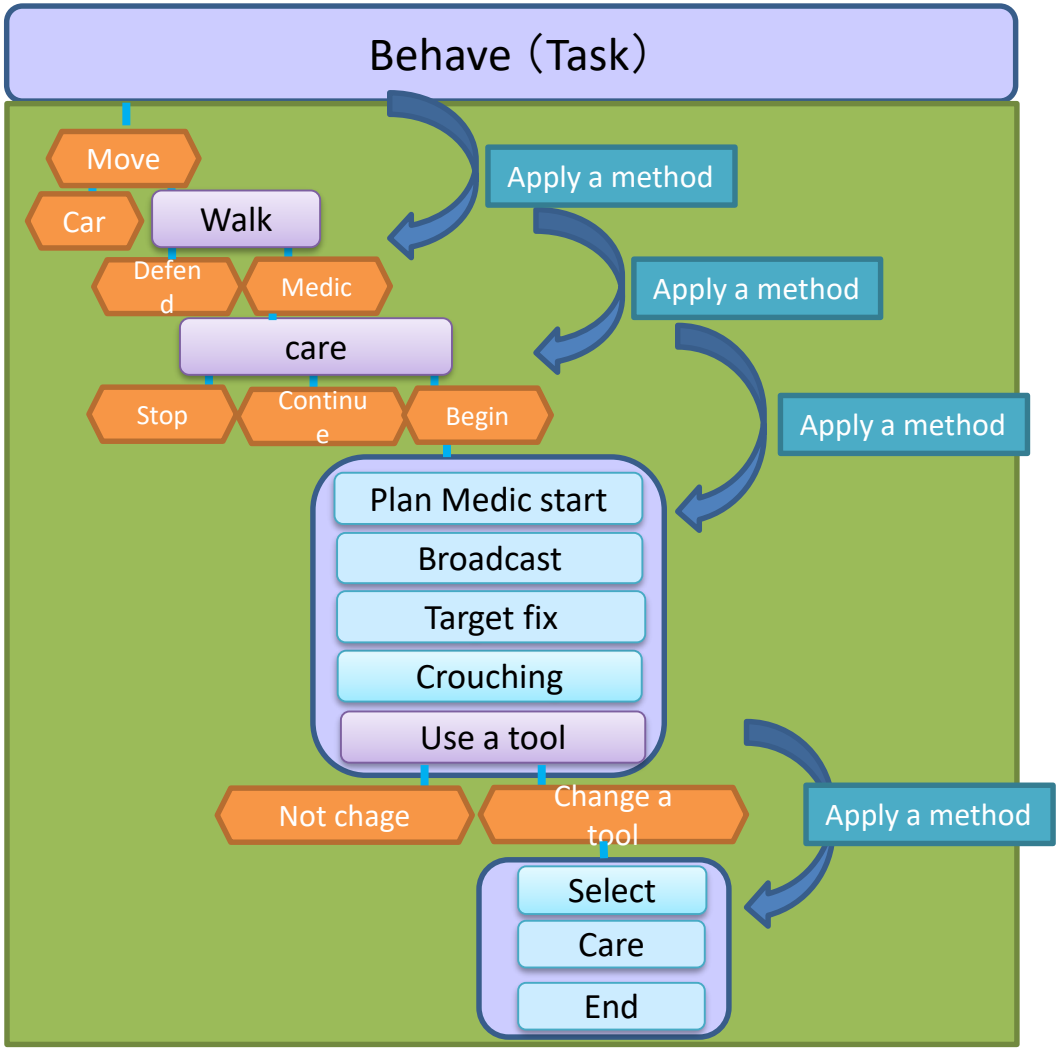


Agent Architecture of a Squad leader





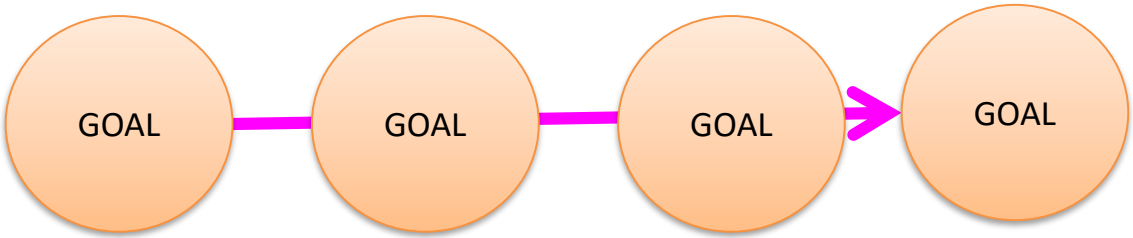




Goal-based AI

Describing the world and AI state

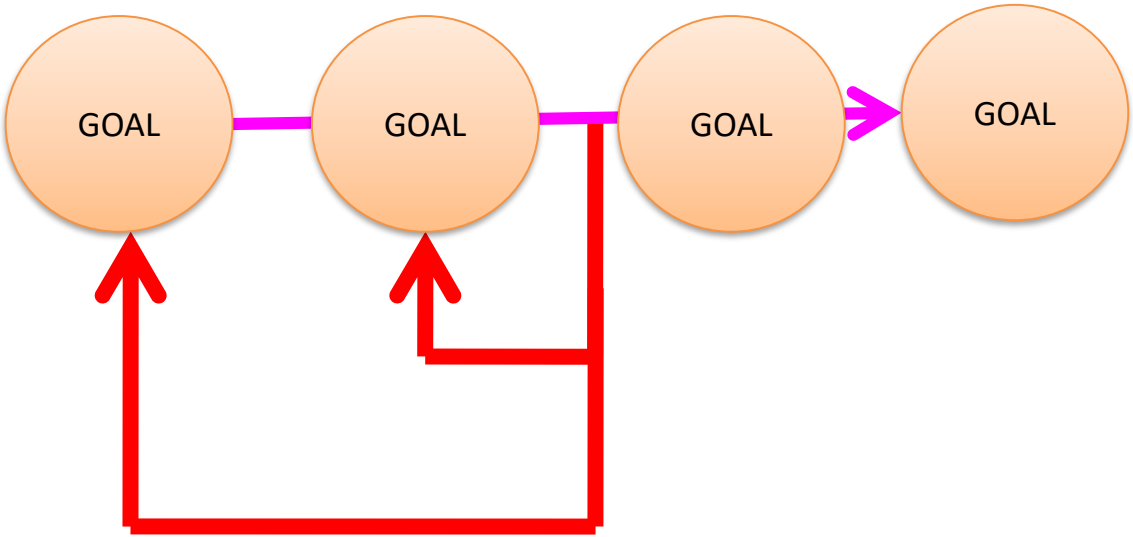
Goal-based AI



Goal- based AI is the policy that a goal is the first.

To achieve the goal, AI makes a plan, behaviors and changes them according to the changes of the game situation.

Goal-based AI

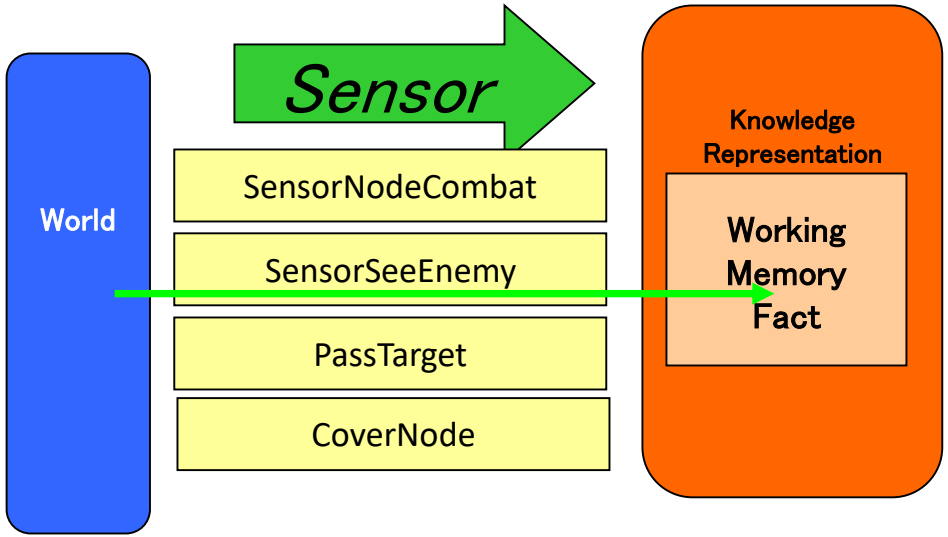


AI keeps checking whether the goal is achieved or not to feed back.

Goal-Oriented Action Planning in F.E.A.R.

Agent Architecture Considerations for Real-Time Planning in Games (AIIDE 2005)
http://web.media.mit.edu/~jorkin/AIIDE05_Orkin_Planning.ppt

F.E.A.R COM ’s sensor

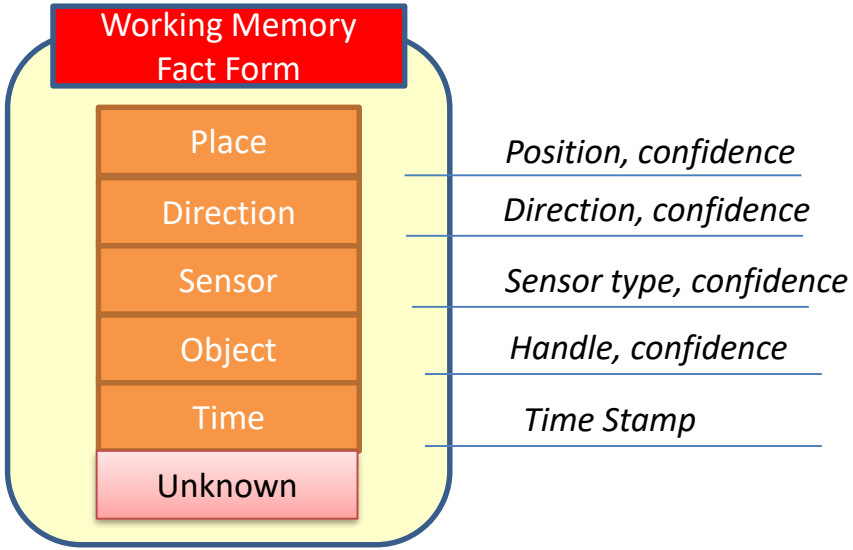


SensorNodeCombat	Finding the point to fight
SensorSeeEnemy	Checking Line of sight to the enemy
PassTarget	Finding a safe pass to tactical point
CoverNode	Finding a point to hide

Agent Architecture Considerations for Real-Time Planning in Games (AIIDE 2005)
http://web.media.mit.edu/~jorkin/AIIDE05_Orkin_Planning.ppt

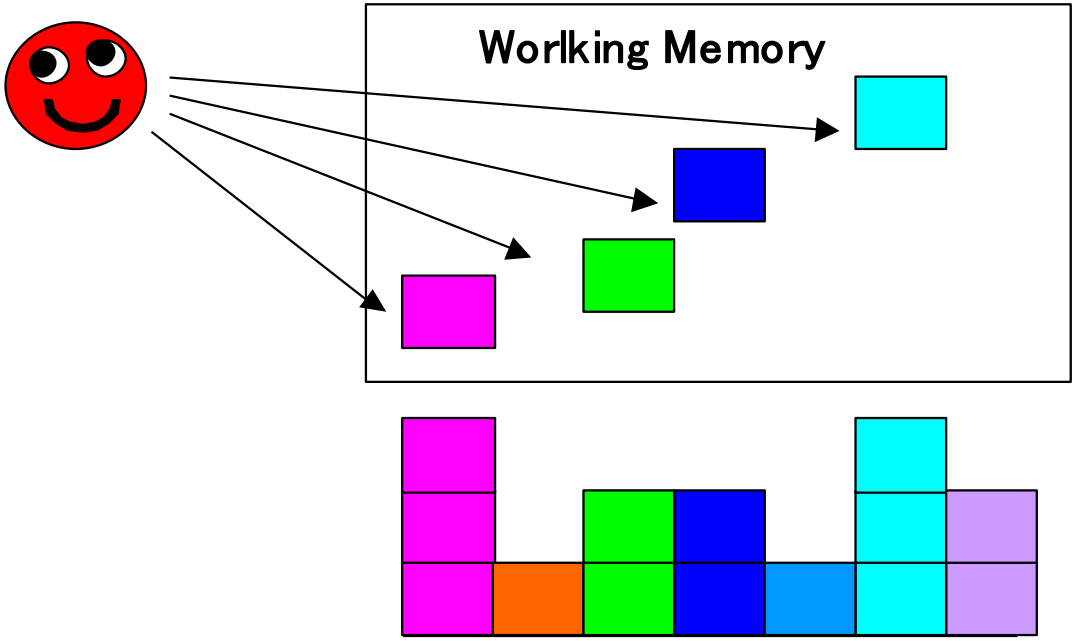
Working Memory Fact

All facts are described in the same format.



Agent Architecture Considerations for Real-Time Planning in Games (AIIDE 2005)
http://web.media.mit.edu/~jorkin/AIIDE05_Orkin_Planning.ppt

AI stored all facts in its working memory



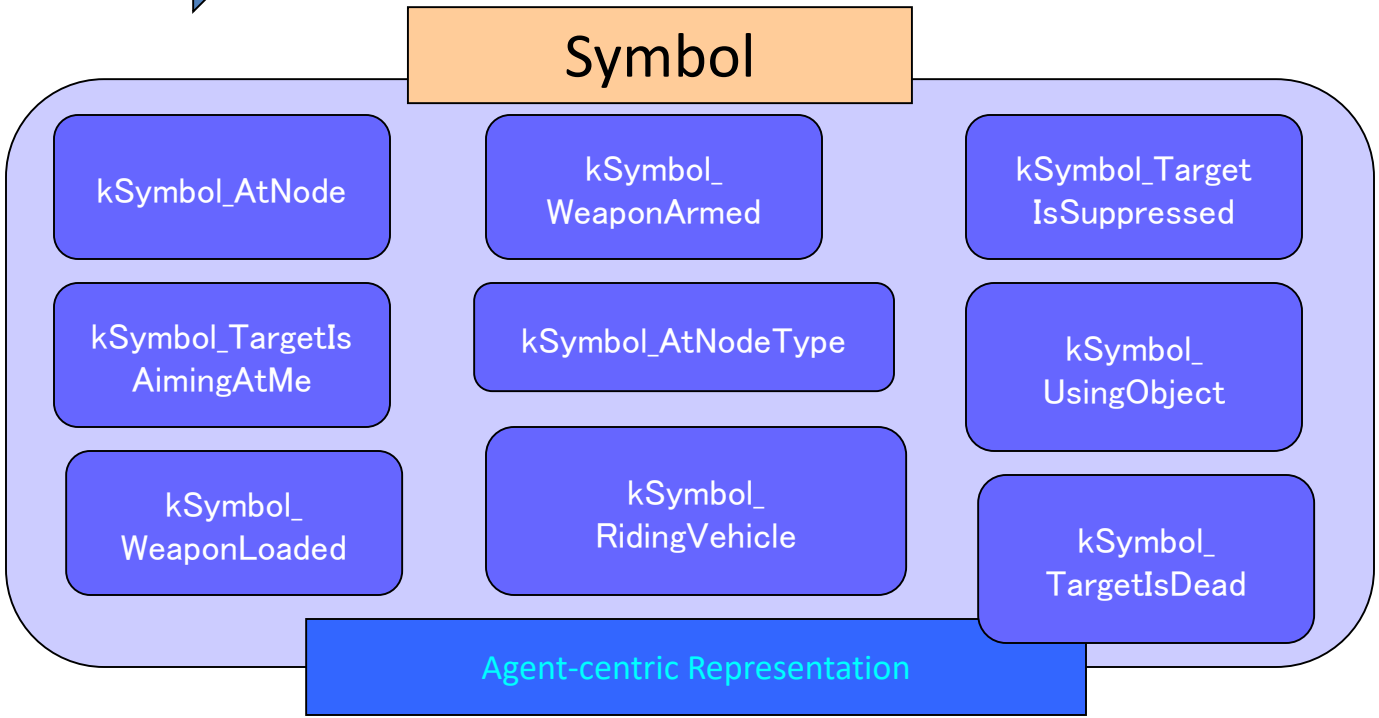
The facts to the same target are stacked on the same list.

Agent Architecture Considerations for Real-Time Planning in Games (AIIDE 2005)
http://web.media.mit.edu/~jorkin/AIIDE05_Orkin_Planning.ppt

Preparation for Planning

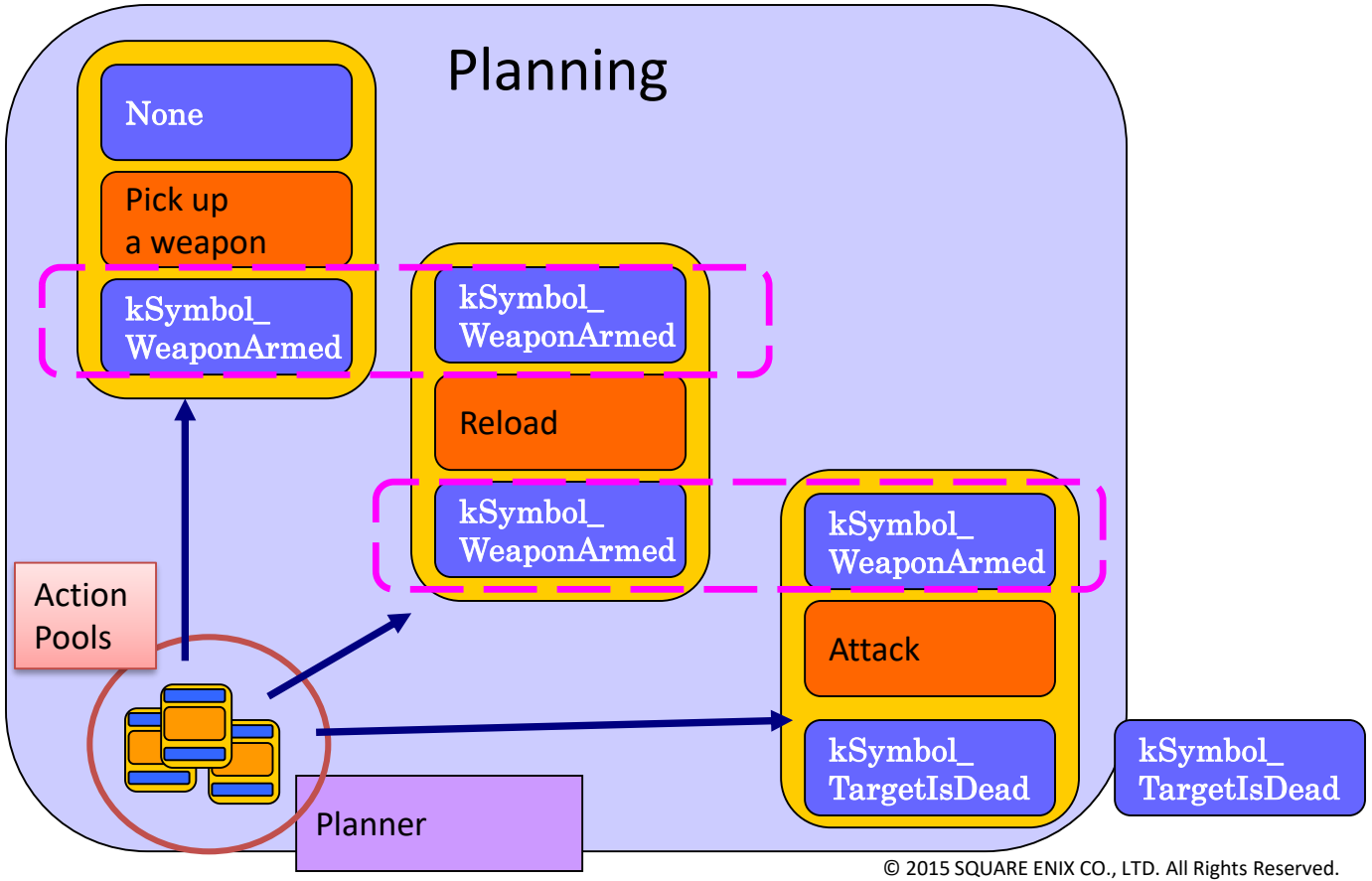
Let's represent the world AI recognize more simply.

The World is represented by only 20 symbols .



Jeff Orkin, "3 States and a Plan: The AI of F.E.A.R.",
http://web.media.mit.edu/~jorkin/gdc2006_orkin_jeff_fear.zip

Planning by Chaining Example

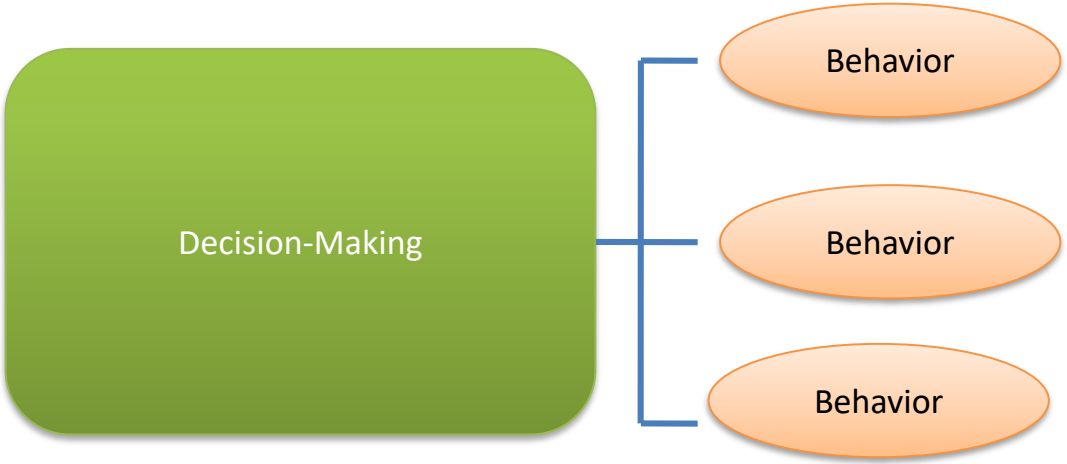


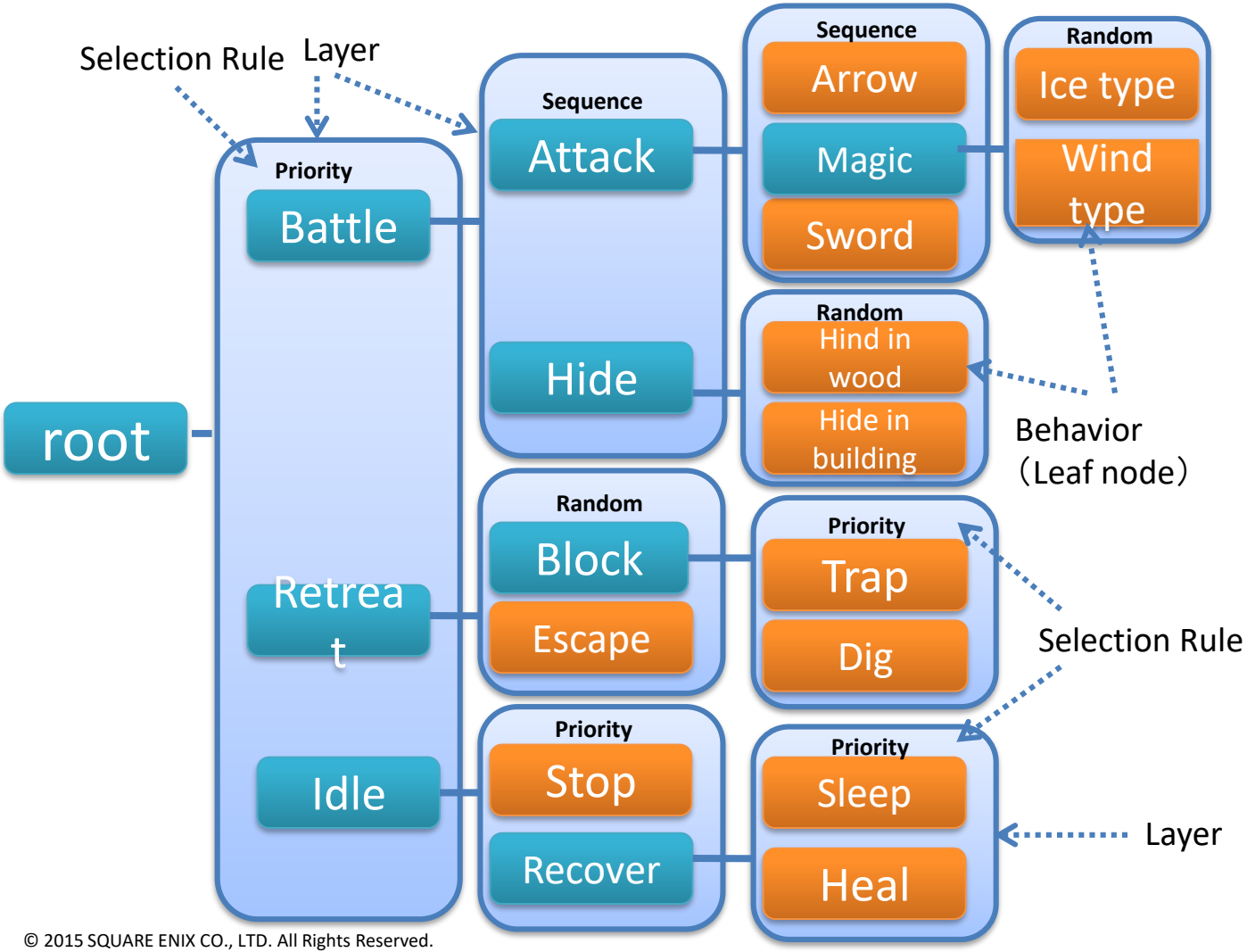
Behavior-based AI

A behavior represent not an animation detail but a physical action.

Behavior-based AI

A behavior-based AI constructs its thinking by using some behaviors.

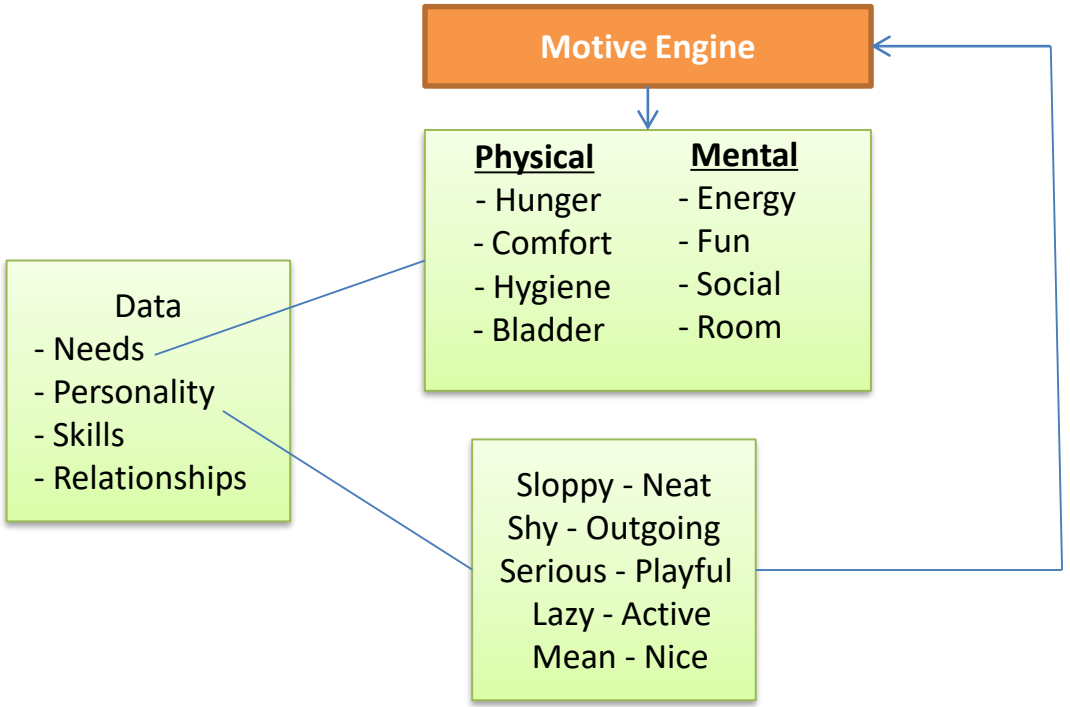




Utility-based AI

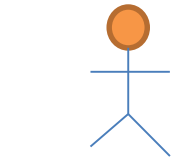
- Utility-based AI simulates a world's model, and assign a numerical value to a utility of action.
- Utility-based AI selects one tactic by estimating all tactics.

Motive Engine in The Sims



Ken Forbus, "Simulation and Modeling: Under the hood of The Sims" (NorthWerstern University)
http://www.cs.northwestern.edu/%7Eforbus/c95-gd/lectures/The_Sims_Under_the_Hood_files/frame.htm

最適な行動を選択する



Hunger	+20
Comfort	-12
Hygiene	-30
Bladder	**-75**
Energy	+80
Fun	+40
Social	+10
Room	- 60
Mood	**+18**

Toilet

- Urinate (+40 Bladder)
- Clean (+30 Room)
- Unclog (+40 Room)

Mood +26

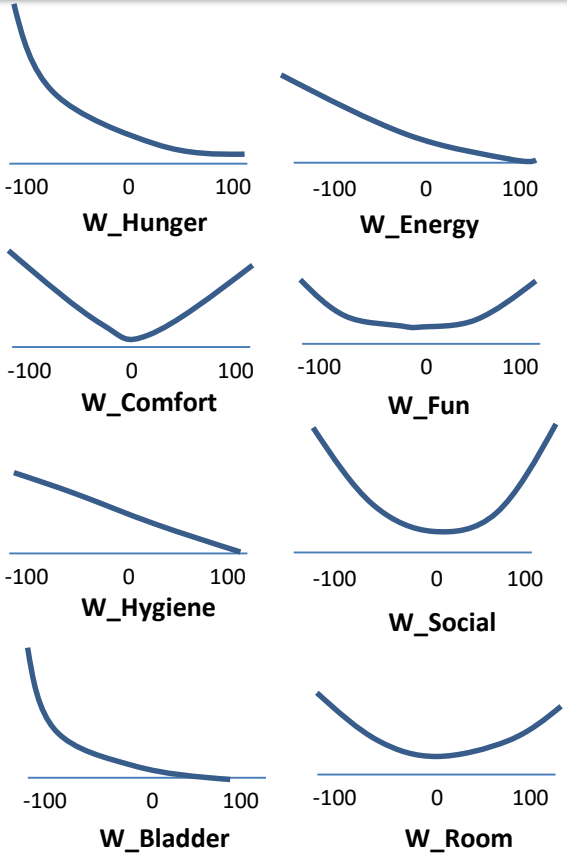
Bathtub

- Take Bath (+40 Hygiene) (+30 Comfort)
- Clean (+20 Room)

Mood +20

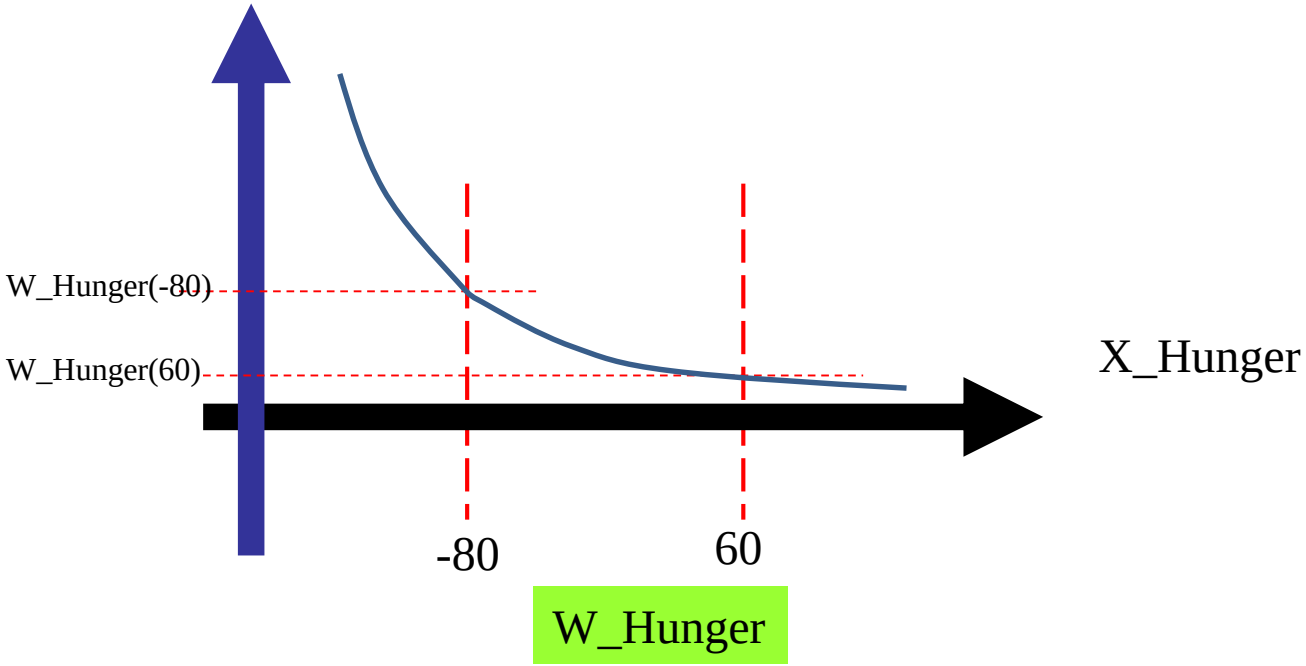
[Principle] Select from all actions the best action which makes mood value maximum.

What is mood ?

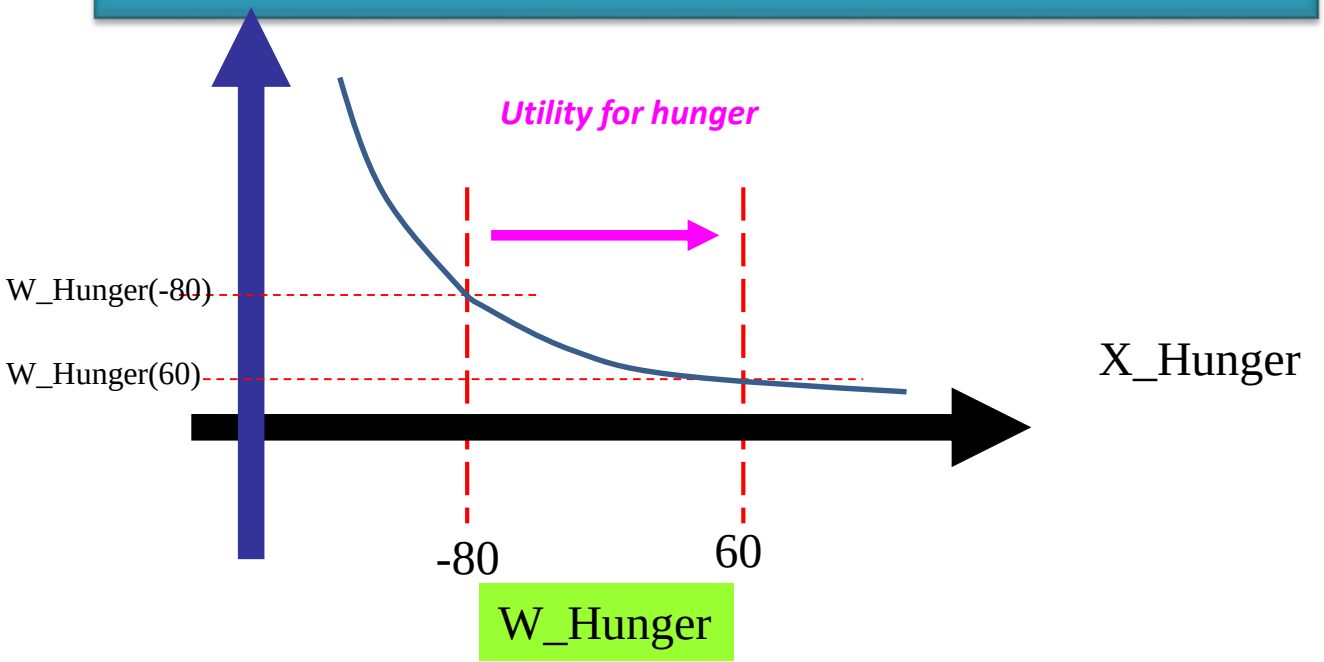


Mood = W_Hunger(X_Hunger) * X_Hunger + W_Engergy(X_Energy) * X_Energy + ...

How to calculate utility ?



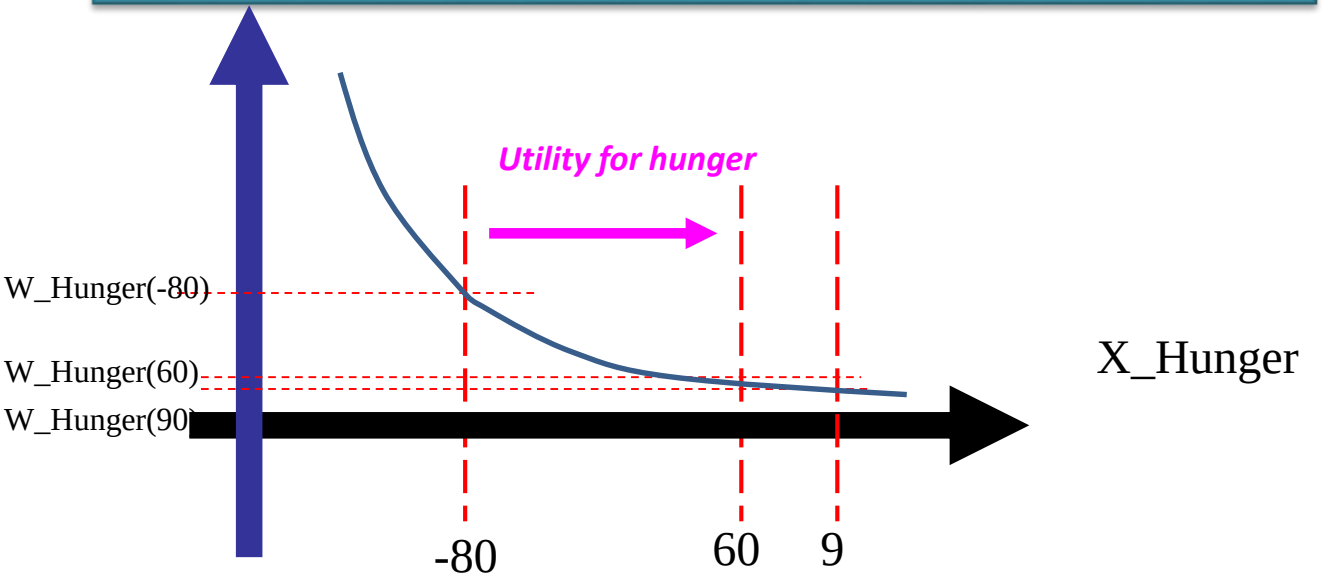
How to calculate utility ?



Hunger degree at -80 = W_Hunger(-80)*(-80)
Hunger degree at 60 = W_Hunger(60)*(60)

Δ = W_Hunger(60)*(60) - W_Hunger(-80)*(-80)

Law of diminishing marginal utility



$\Delta(-80 \rightarrow 60) = W\_Hunger(60)*(60) - W\_Hunger(-80)*(-80)$

$\Delta(60 \rightarrow 90) = W\_Hunger(90)*(90) - W\_Hunger(60)*(60)$

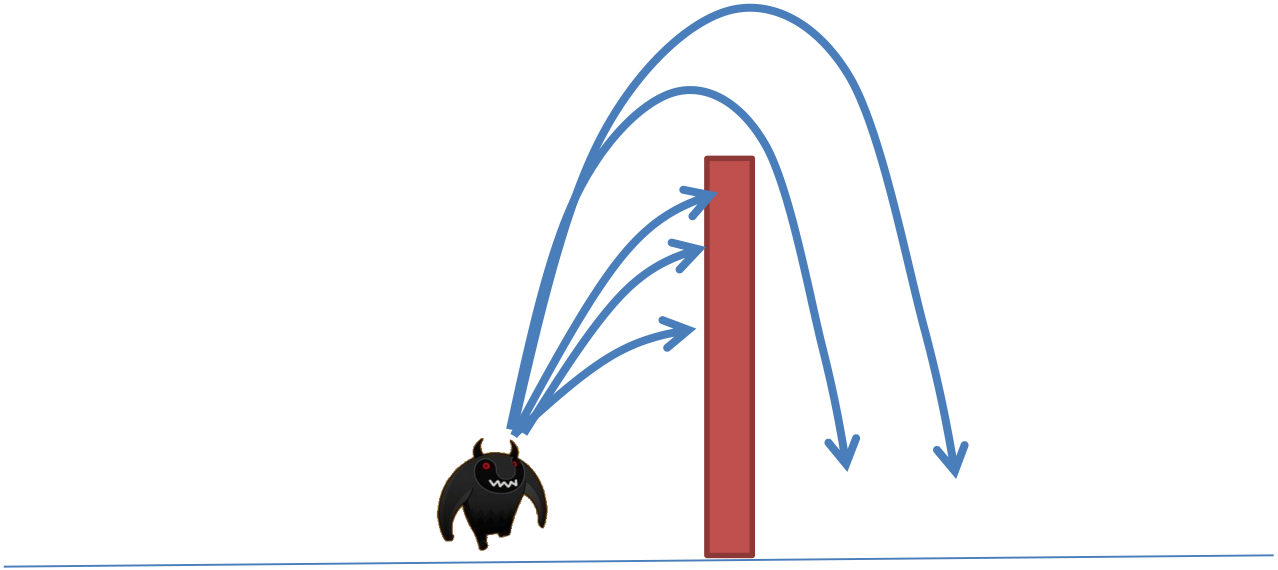
$\Delta(-80 \rightarrow 60)$ is much larger than $\Delta(60 \rightarrow 90)$

Utility from unsatisfied state to satisfied state is much greater than that from satisfied state to more satisfied state .

Simulation-based AI

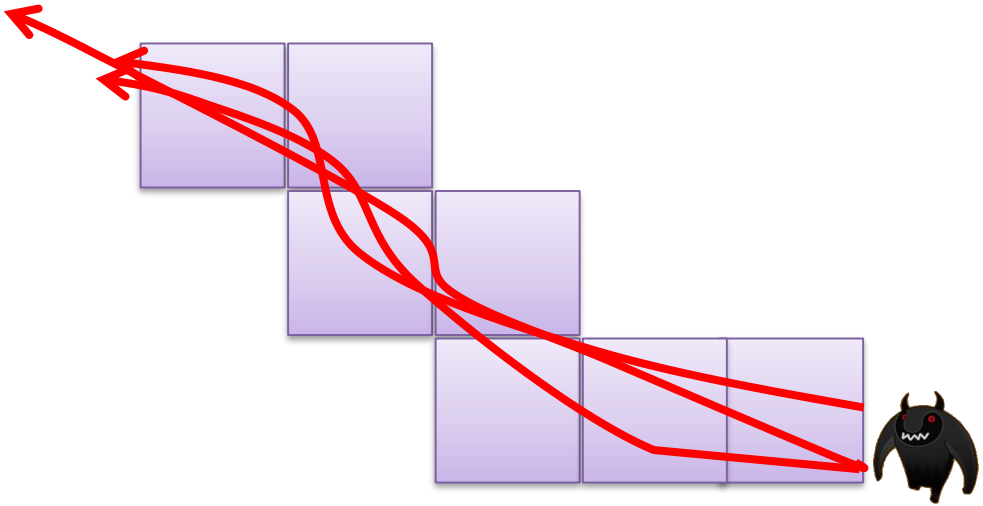
- For a character, simulation is equal to imagination.
- When modelling the situation is difficult, simulation is a good way to find the best solution.
- A simulation is executed by the game rules.

Simulation-based AI



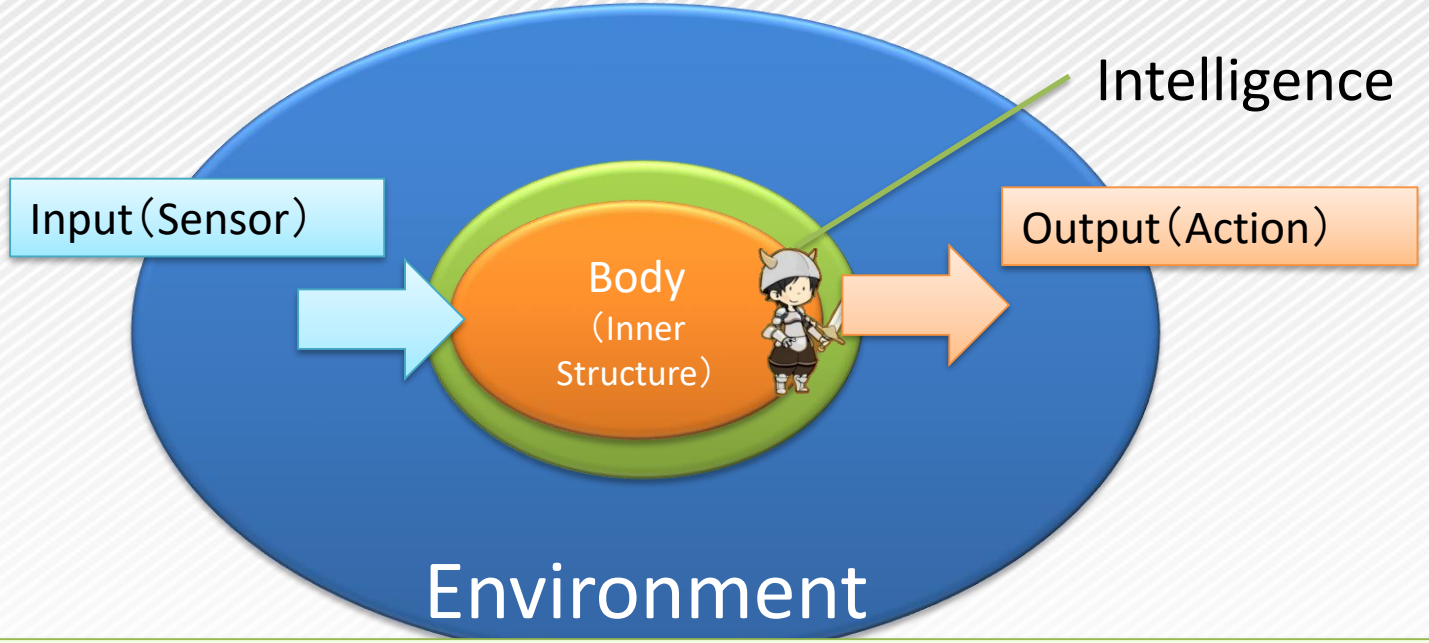
To go over a wall, by iterating a jumping simulation, a good case is found.

Simulation-based AI

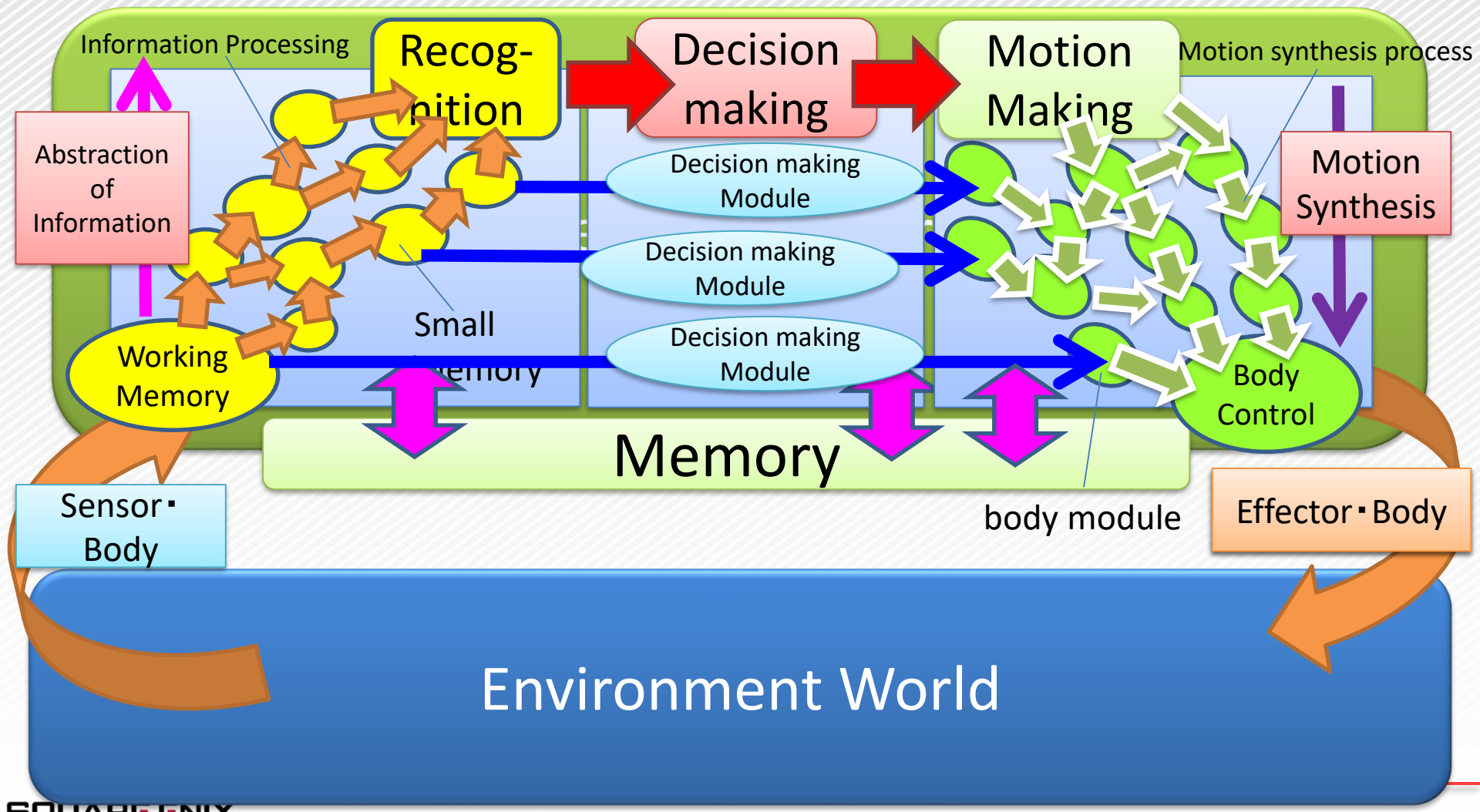


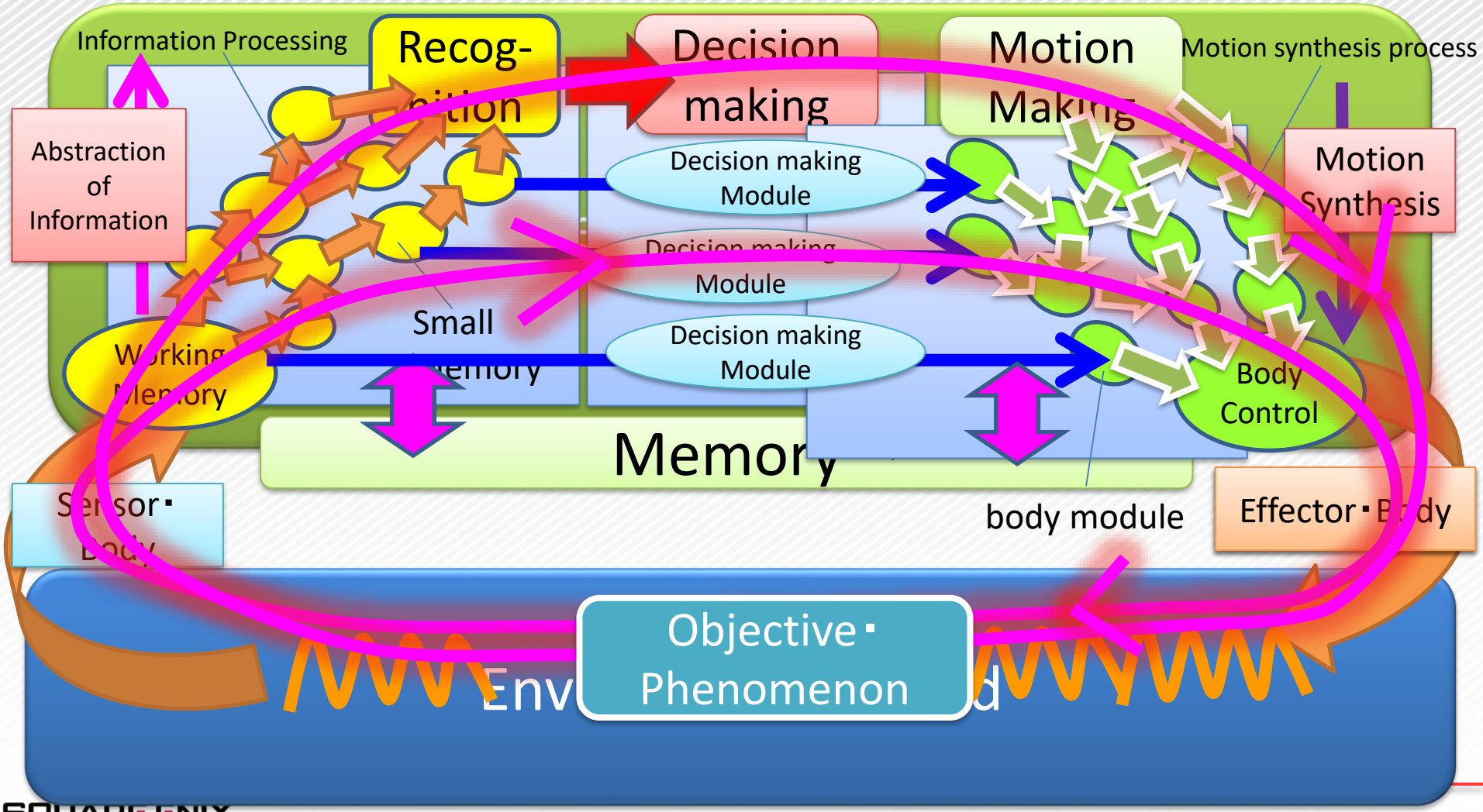
To find the best orbit to go through in a complex terrain, simulation is good way to test many combinations of velocity and acceleration.

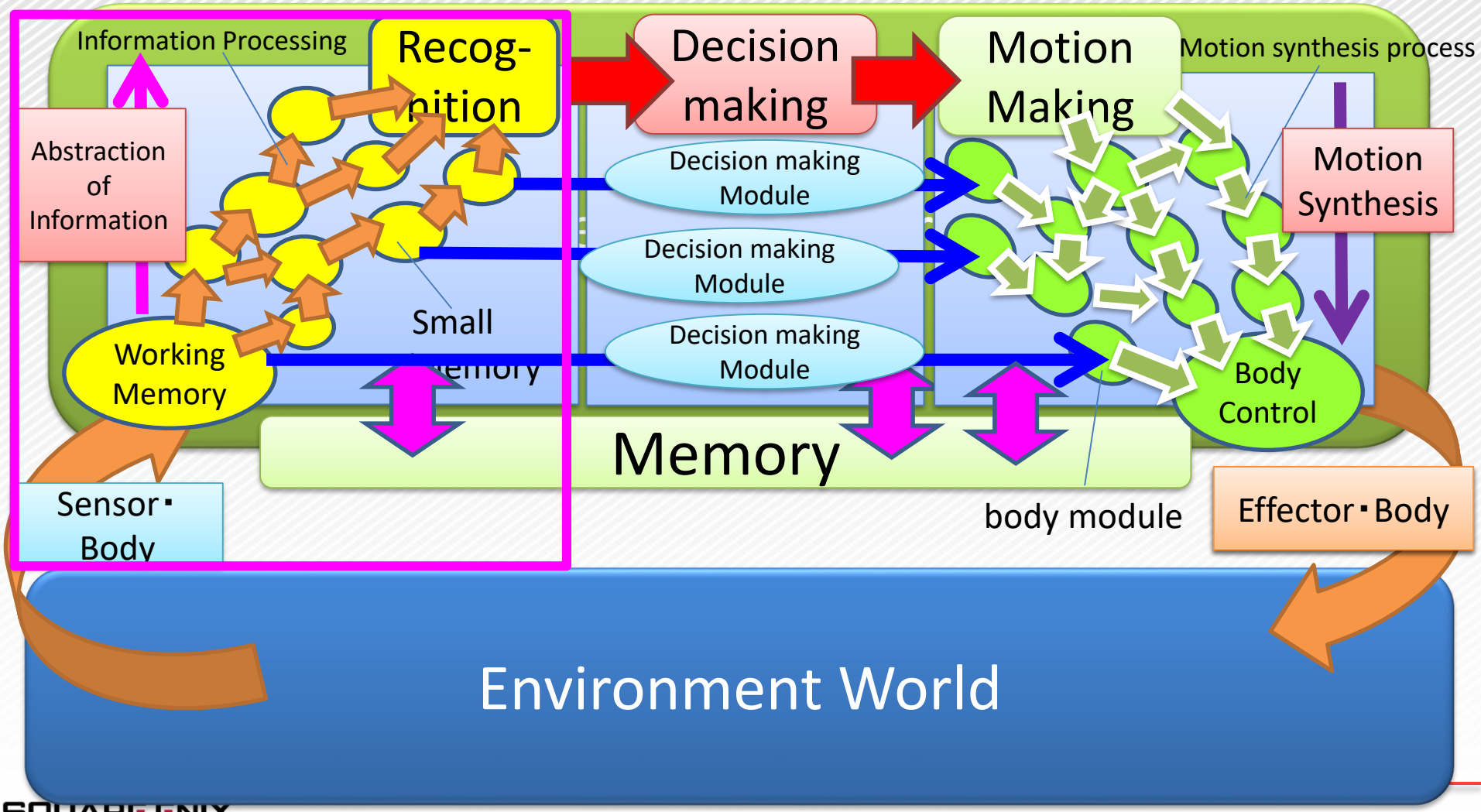
What is intelligence？



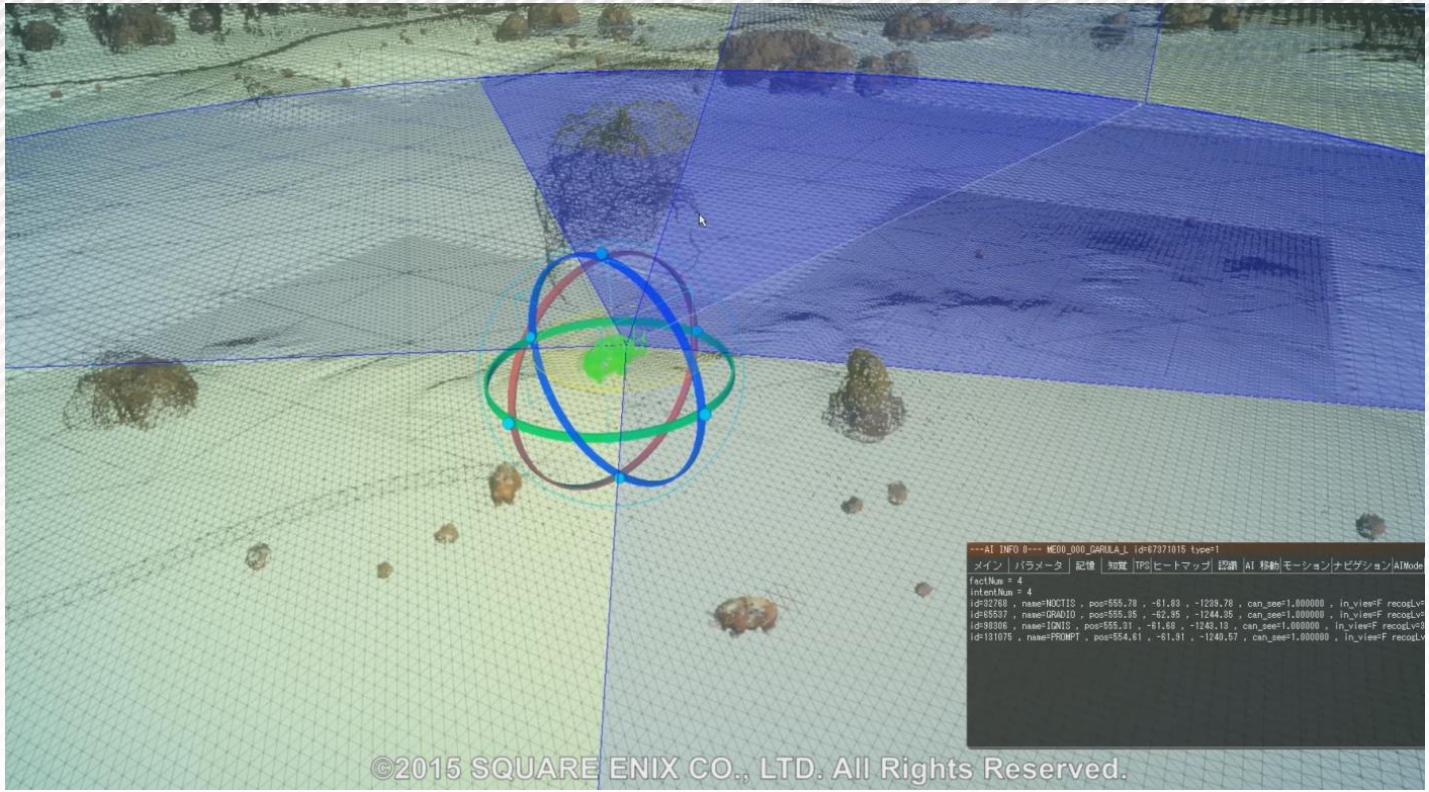
Artificial Intelligence＝ dynamically makes an AI’s action in harmony with artificial environment.







Vison Sensor (Field of View)



Vison Sensor (Field of View) (movie)

Vison sensor (target selection rule's condition)

- target selection rule's condition

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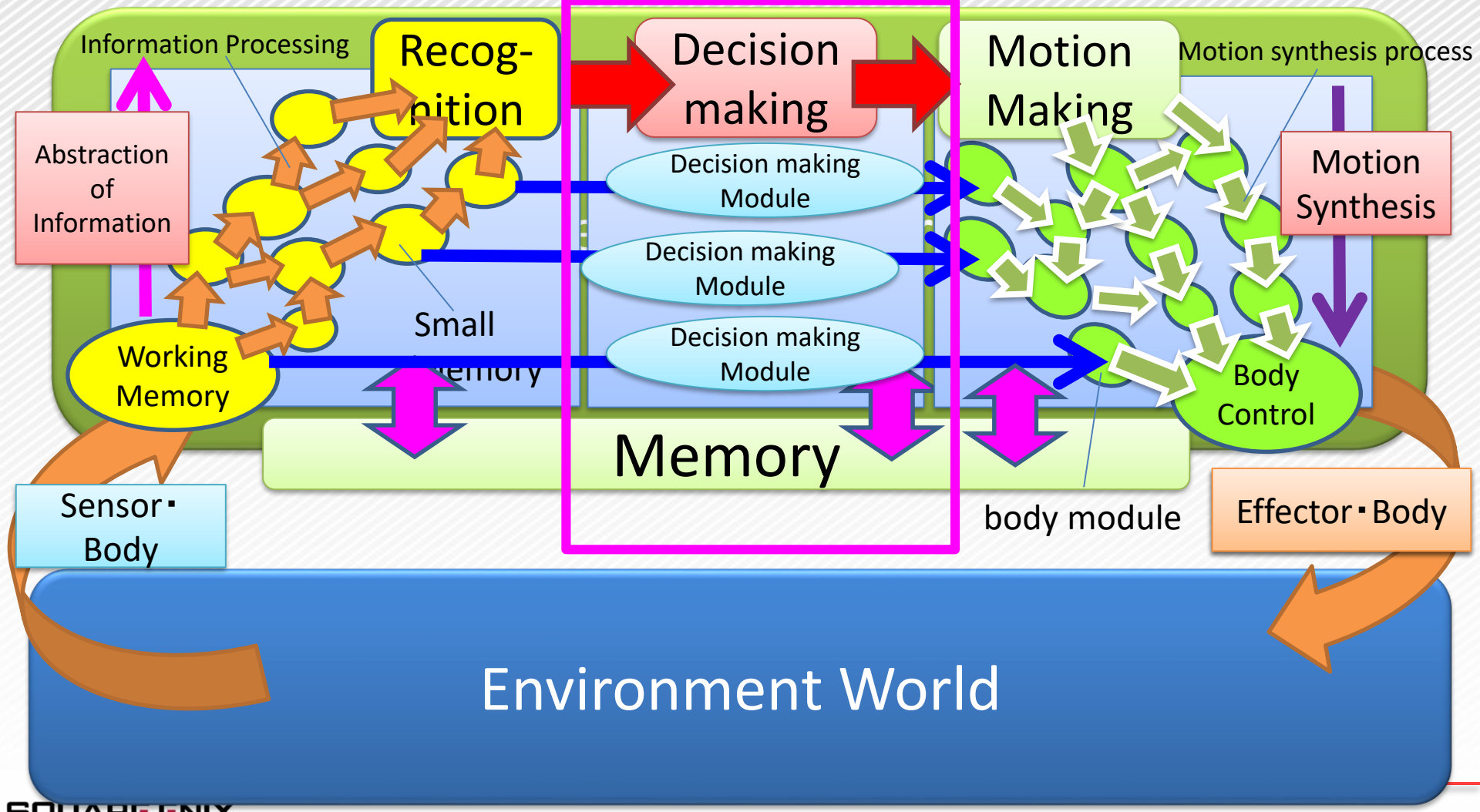
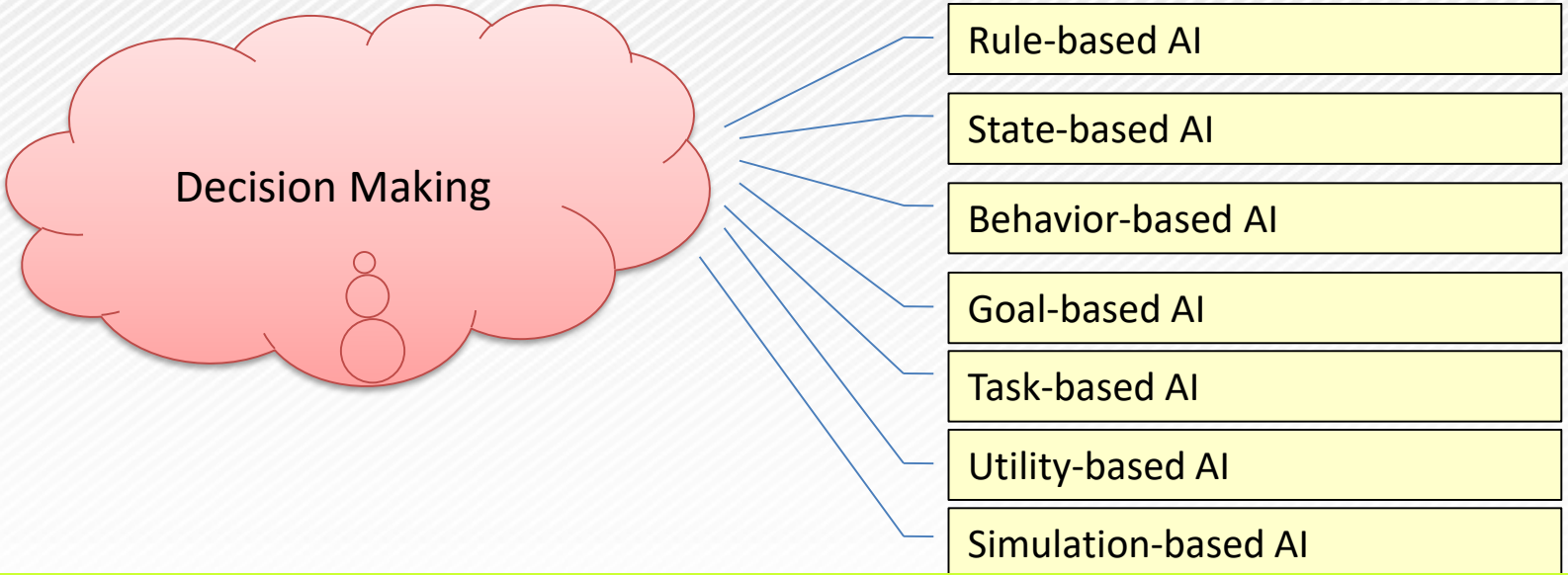
;;コメント		サーチラベル	ファイルタイプ	優先度判定タイプ	優先度決定時の基準座標タイプ	基準座標タイプ（センサーには影響無	基準角度タイプ（センサーには影響無	勢力関係	アクタータイプ	最少認知段階（この段階以上を対象）	HP割合最低（百分率）	HP割合最高（百分率）	ステータスフィルタ	修飾語 － 誰を（に）	修飾語 － どうして（されて）いる	範囲割合 最小（0.0 － 1.0	範囲割合 最大（0.0 － 1.0	最小距離Lv	最大距離Lv
ME07_TRIAL_BEHE_NORMAL_01	体験版ベヒ - 仲間狙いモード	ME07_TRIAL_BEHE_NORMAL		DISTANCE_ASC	DEFAULT	SELF	SELF_BODY	OPPONENT			0.0		ALIVE						MIDDLE
ME07_TRIAL_BEHE_NORMAL_02		ME07_TRIAL_BEHE_NORMAL		DISTANCE_ASC	DEFAULT	SELF	SELF_BODY	OPPONENT			0.0		ALIVE						MIDDLE
ME07_TRIAL_BEHE_NORMAL_03		ME07_TRIAL_BEHE_NORMAL		DISTANCE_ASC	DEFAULT	SELF	SELF_BODY	OPPONENT			0.0		ALIVE						ALL
ME07_TRIAL_BEHE_NORMAL_04		ME07_TRIAL_BEHE_NORMAL		DISTANCE_ASC	DEFAULT	SELF	SELF_BODY	OPPONENT					ALIVE						ALL



Decision Making Model

Decision Making is generally a very complex high-degree process.
But for digital game there are 7 simple decision making algorithms.



「(something)-based AI」means that an algorithm uses (something) as a unit.

Decision Making Model

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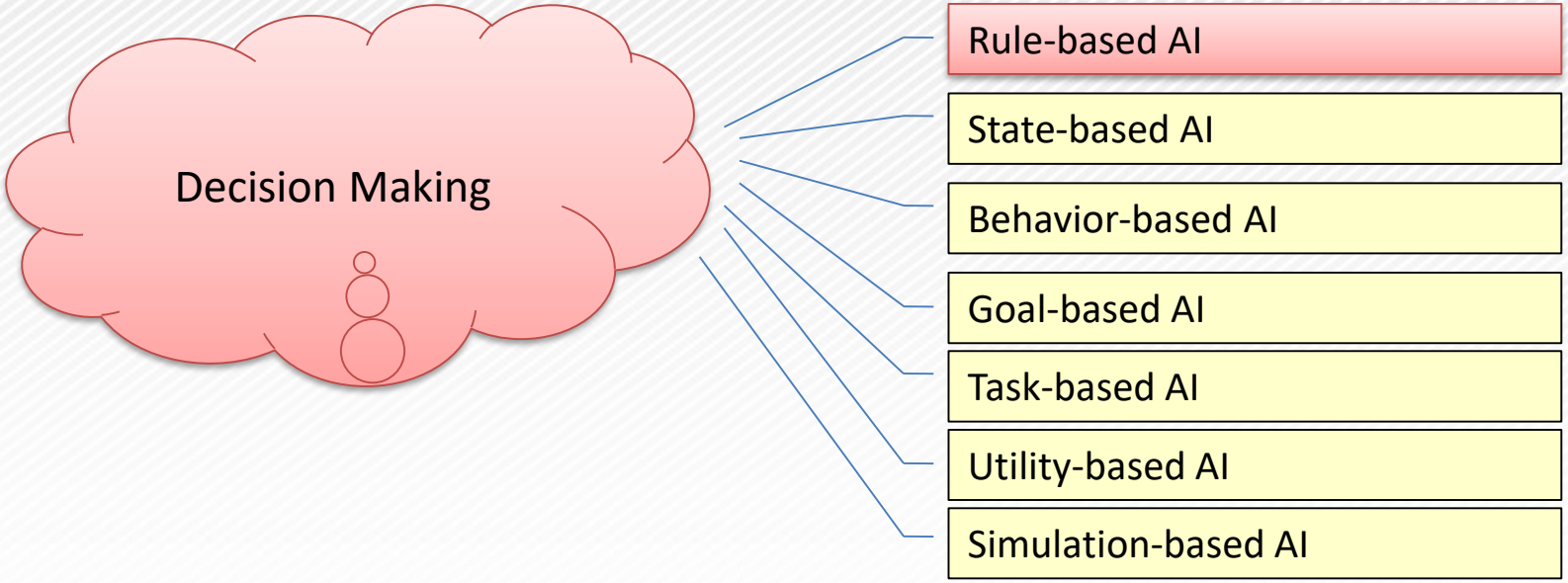

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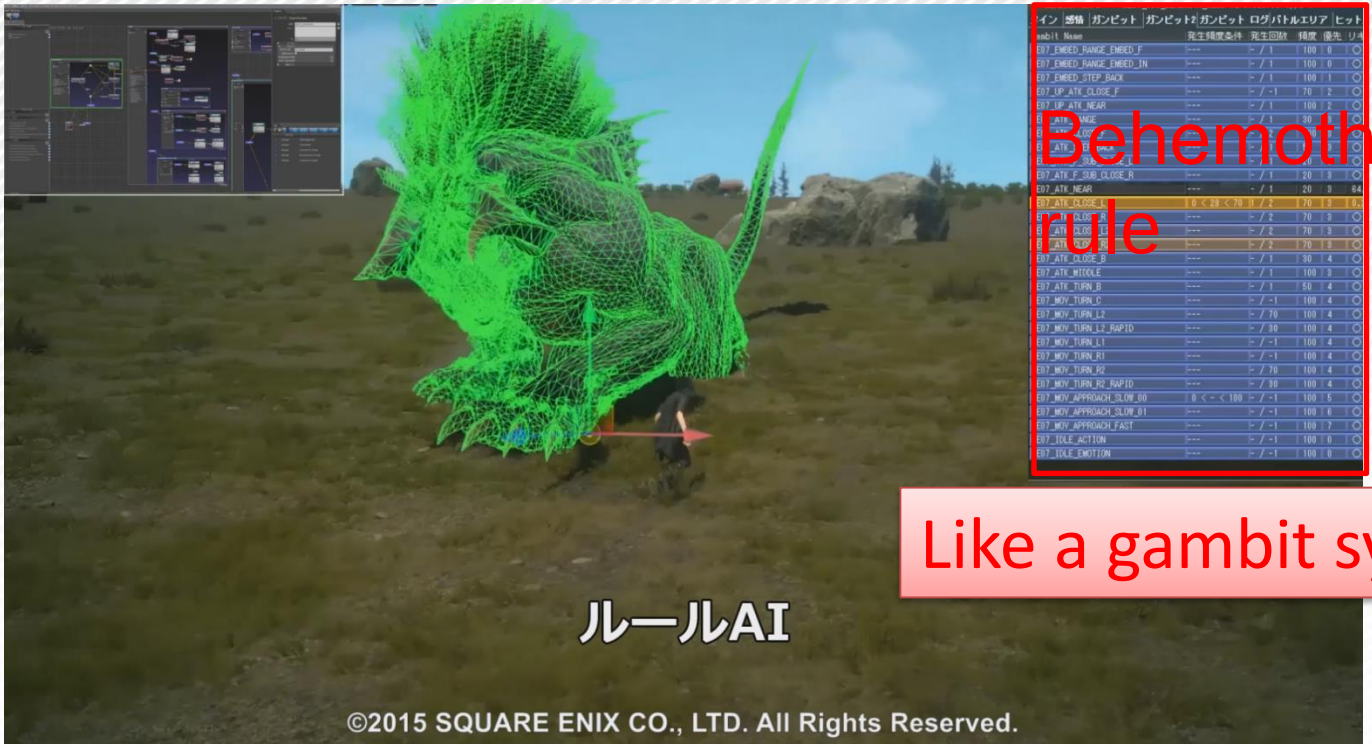
Rule-based AI System



Like a gambit system

Rule-based AI System (Movie)

Decision Making Model

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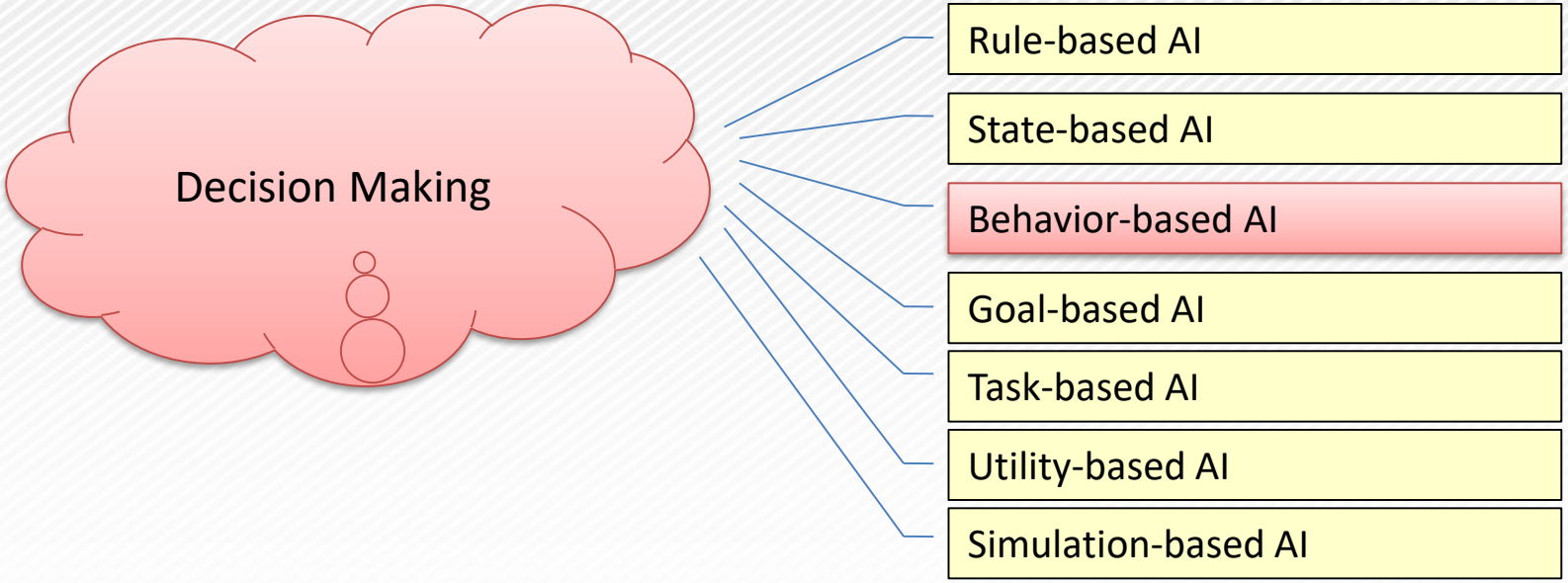

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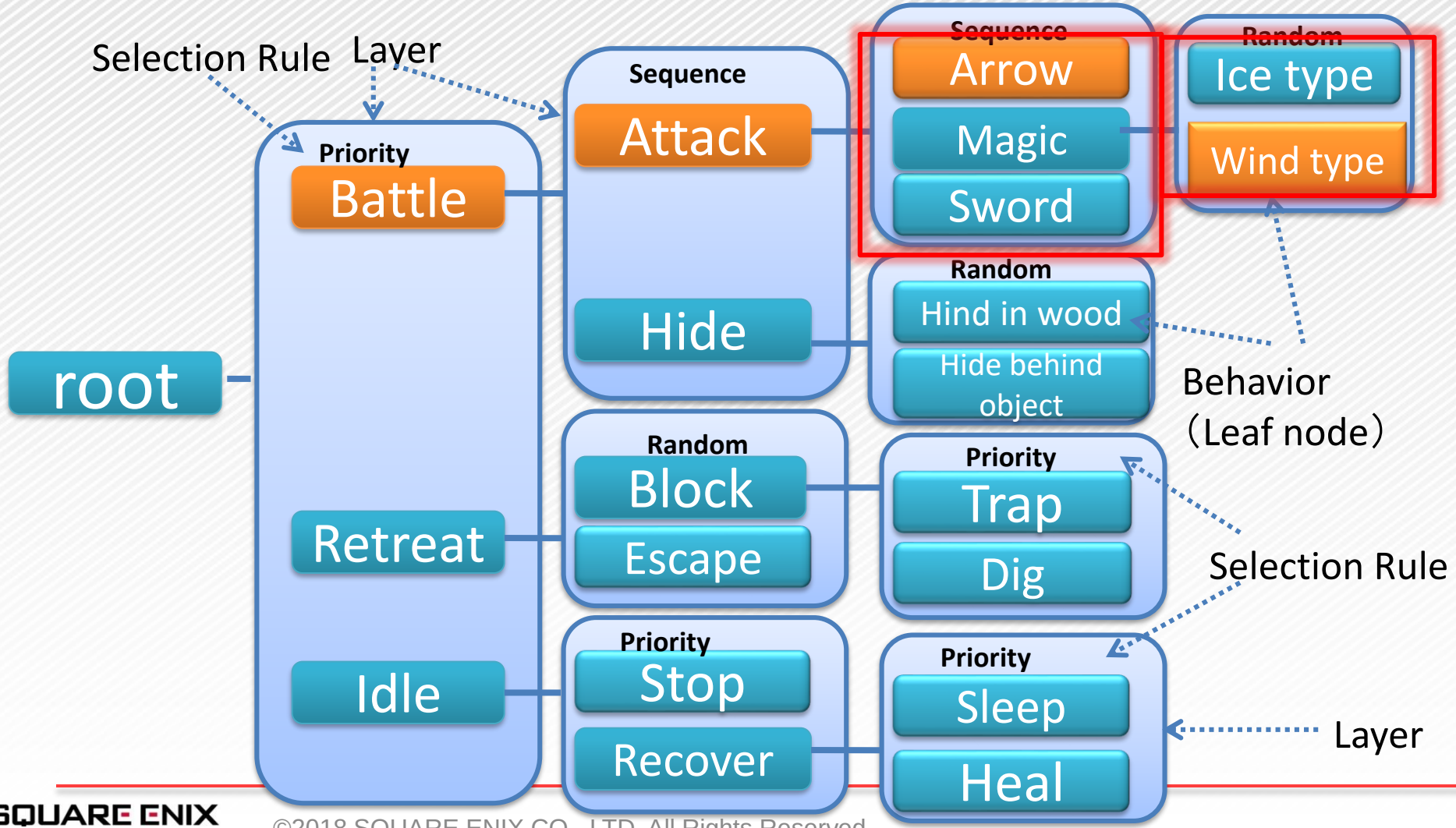
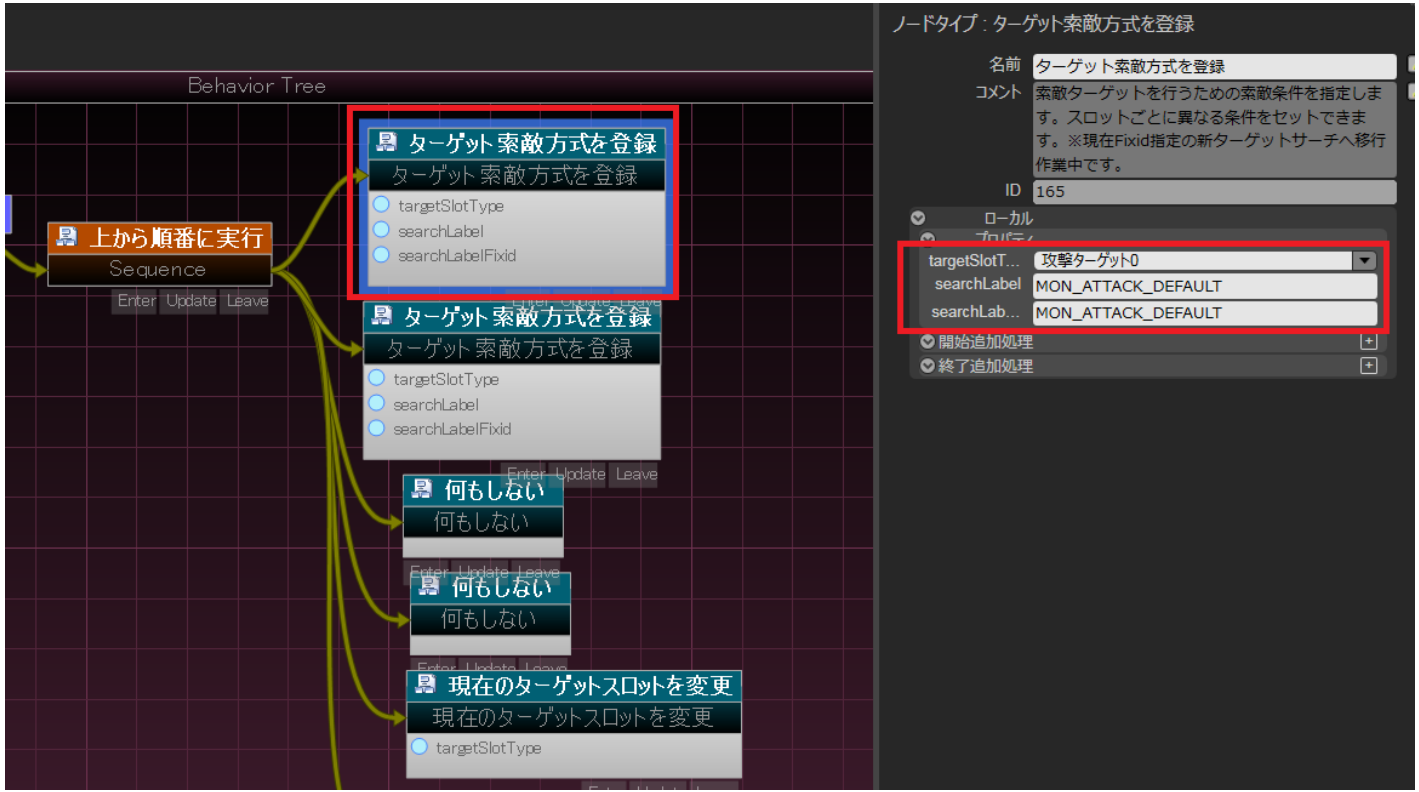


Behavior Tree Tool



Decision Making Model

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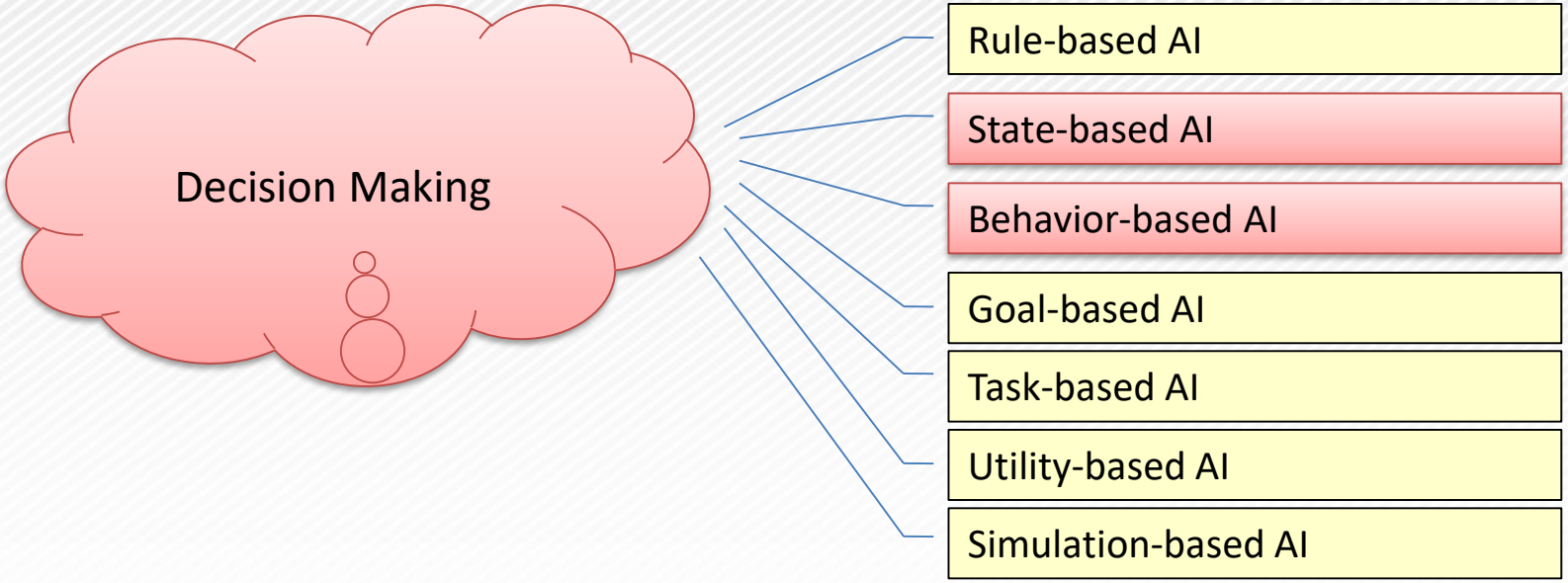
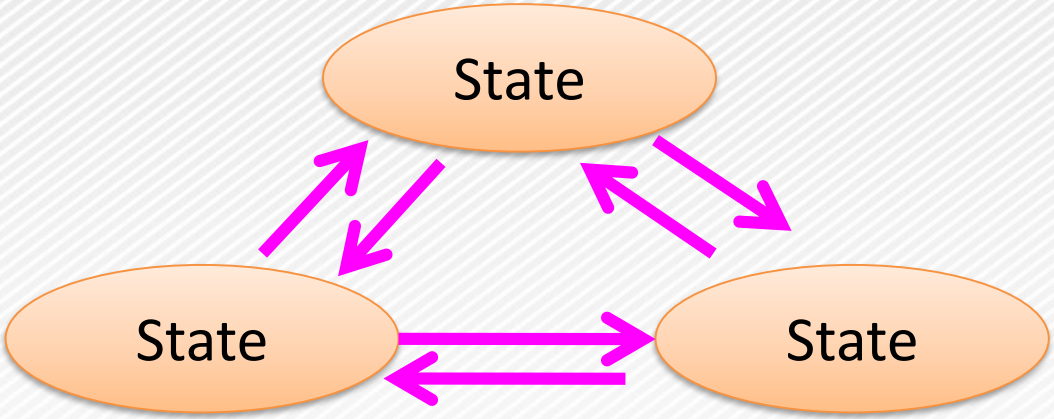


「(something)-based AI」means that an algorithm uses (something) as a unit.

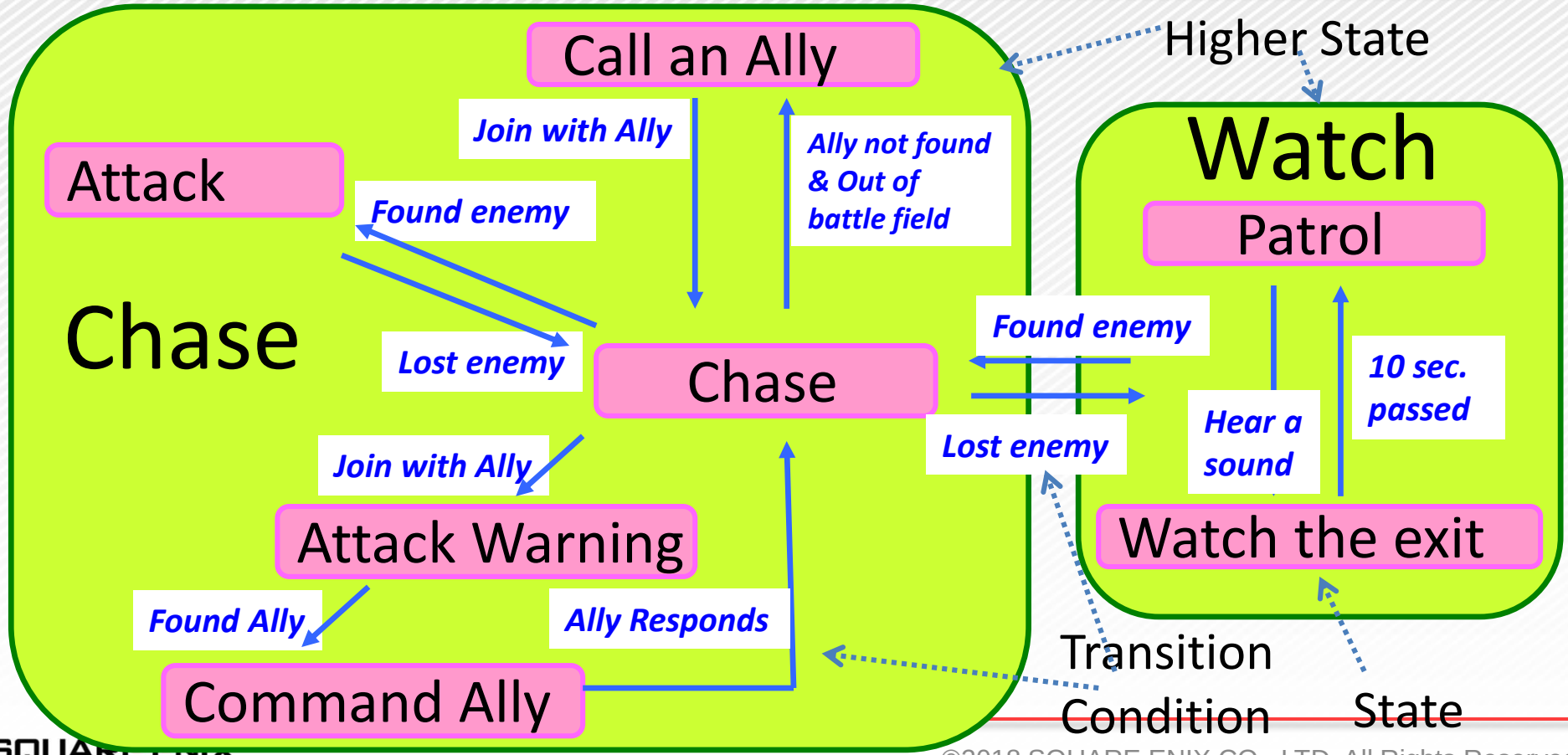
State Machine



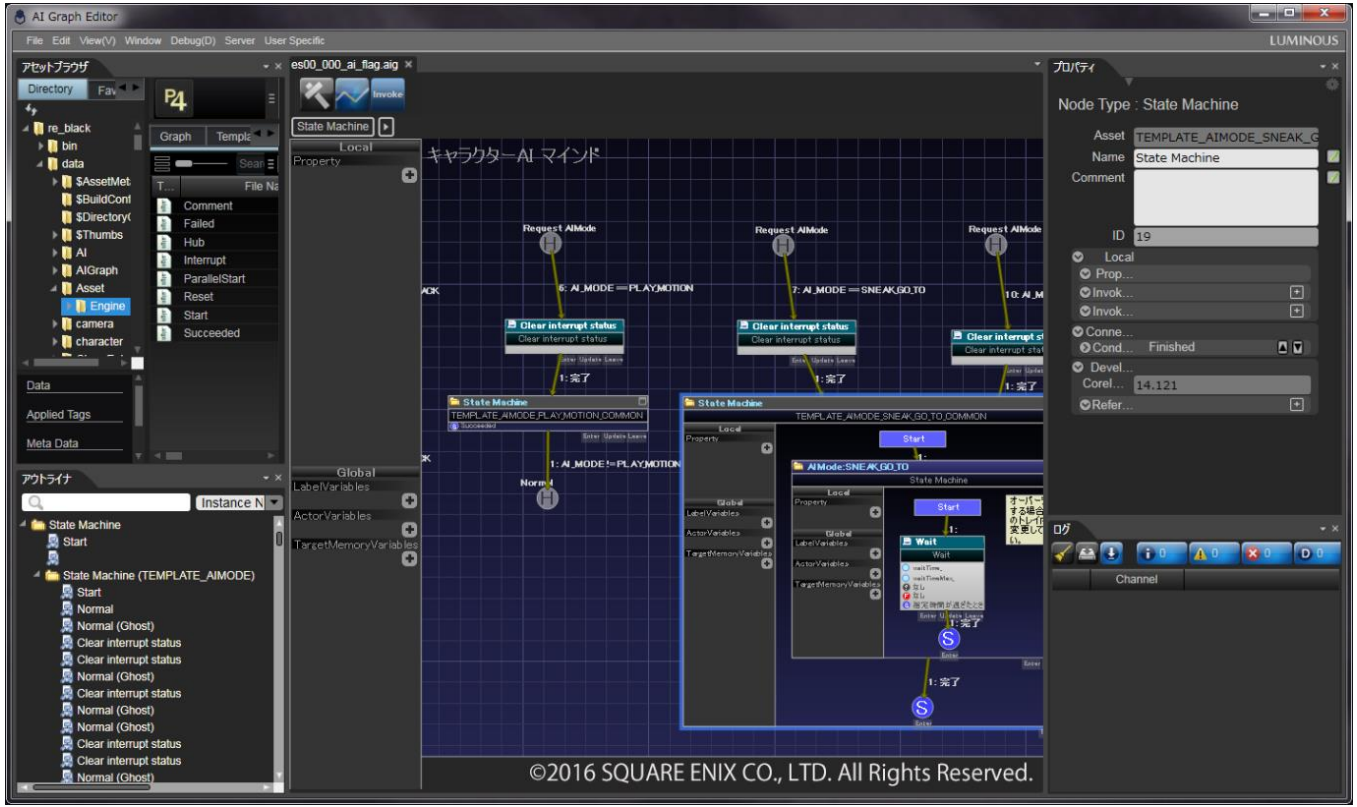
State Machine（Finite State Machine）

AI’s instruction is described in a state, and changes in the world and AI are described in a transition condition.
A state machine has a loop structure but does not have feedback dynamics.

Hierarchical State Machine



State Machine



Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button

Chapter 4.3

SQUARE ENIX ORIGINAL AI SYSTEM

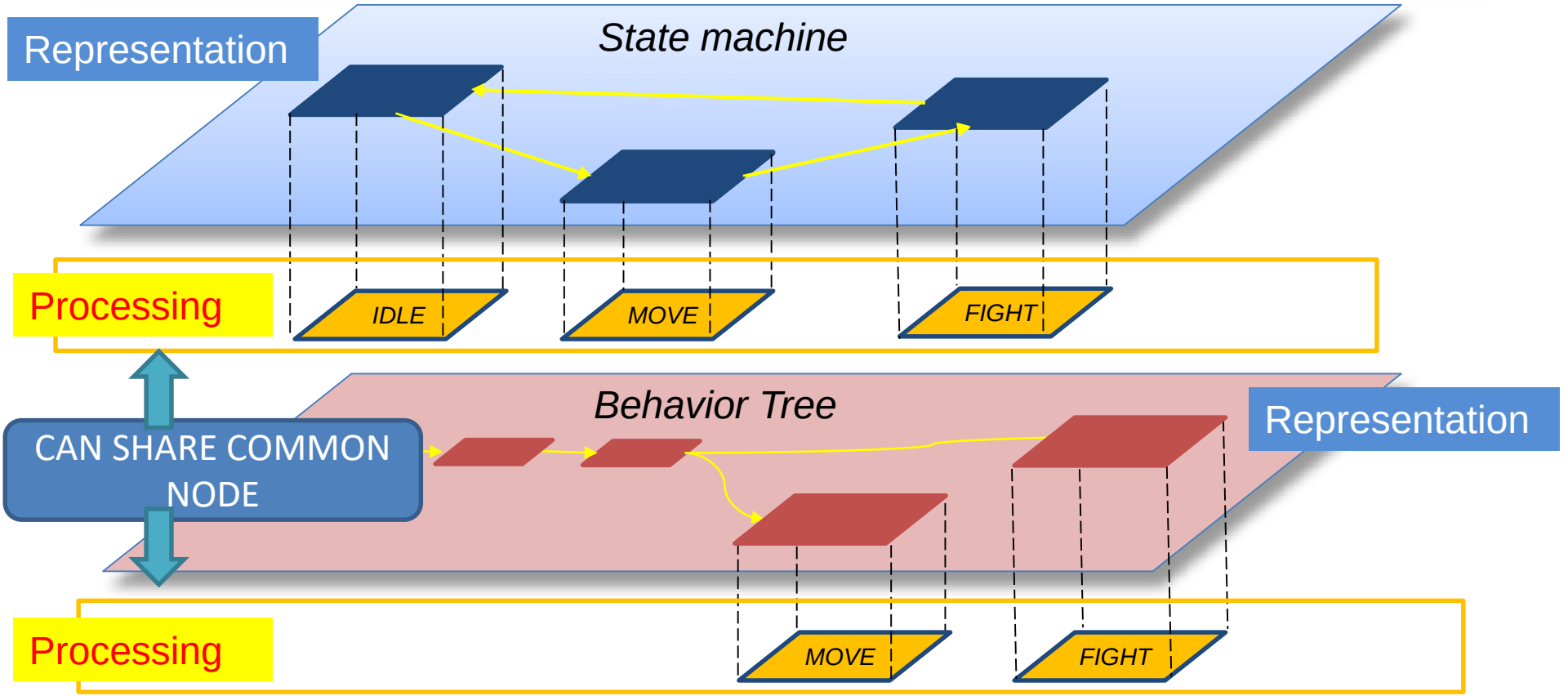
4.3 AI GRAPH

State machine compared to Behavior tree

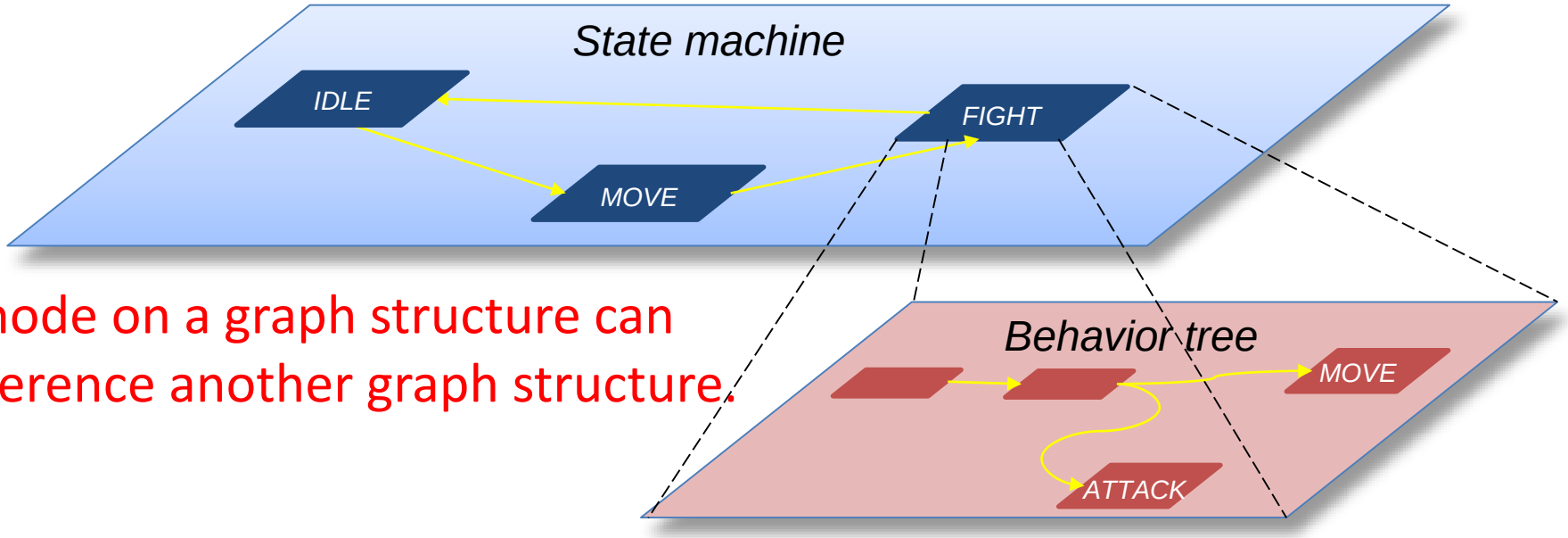
- State machine＝ Steady control step by step
- Behavior tree ＝ Adapt behavior fluently

We want to use both good points

Hybrid node format

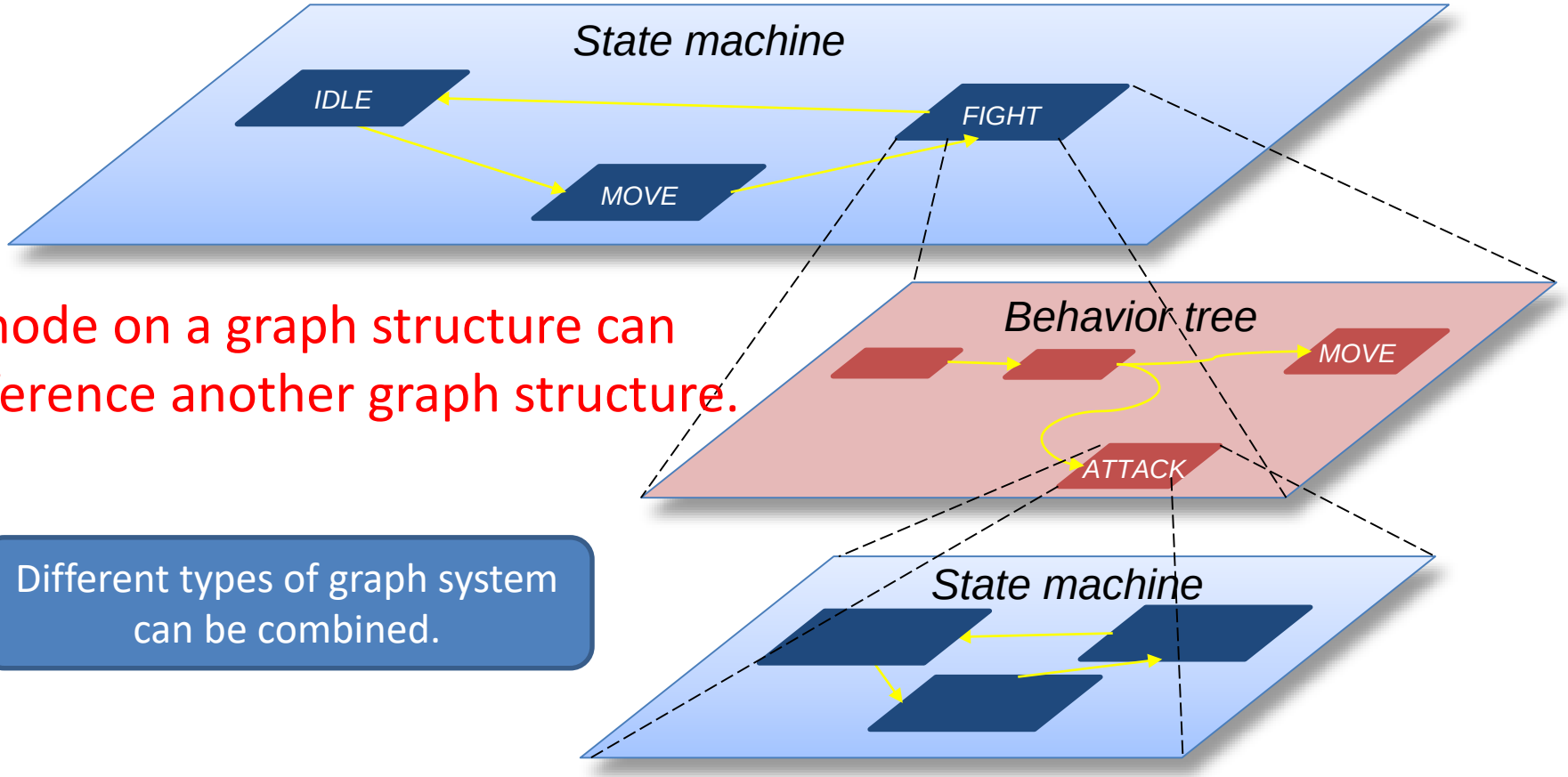


AI Graph has a Hierarchical Layered Architecture



A node on a graph structure can reference another graph structure.

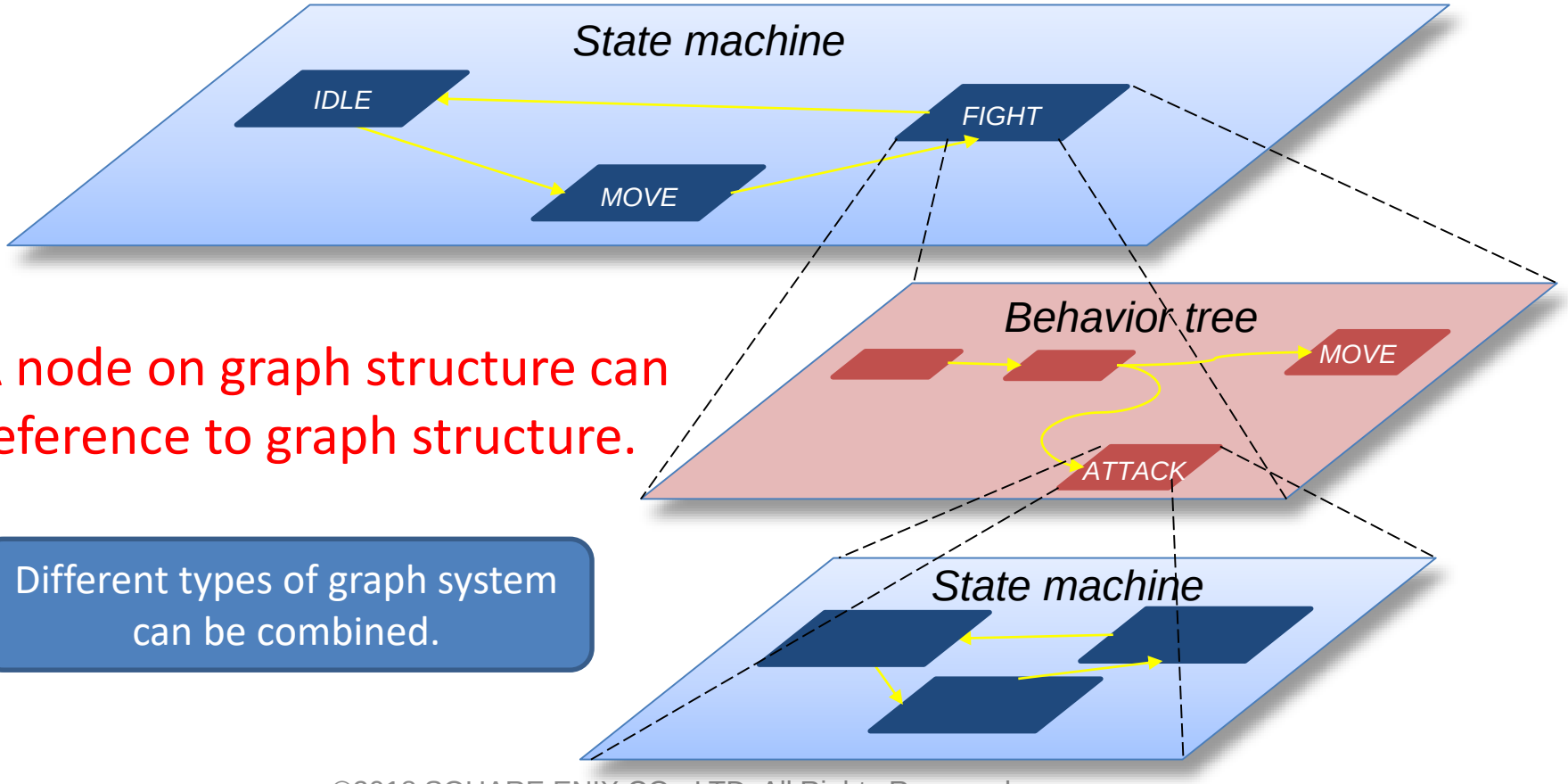
AI Graph Hierarchical Layered Architecture



A node on a graph structure can reference another graph structure.

Different types of graph system can be combined.

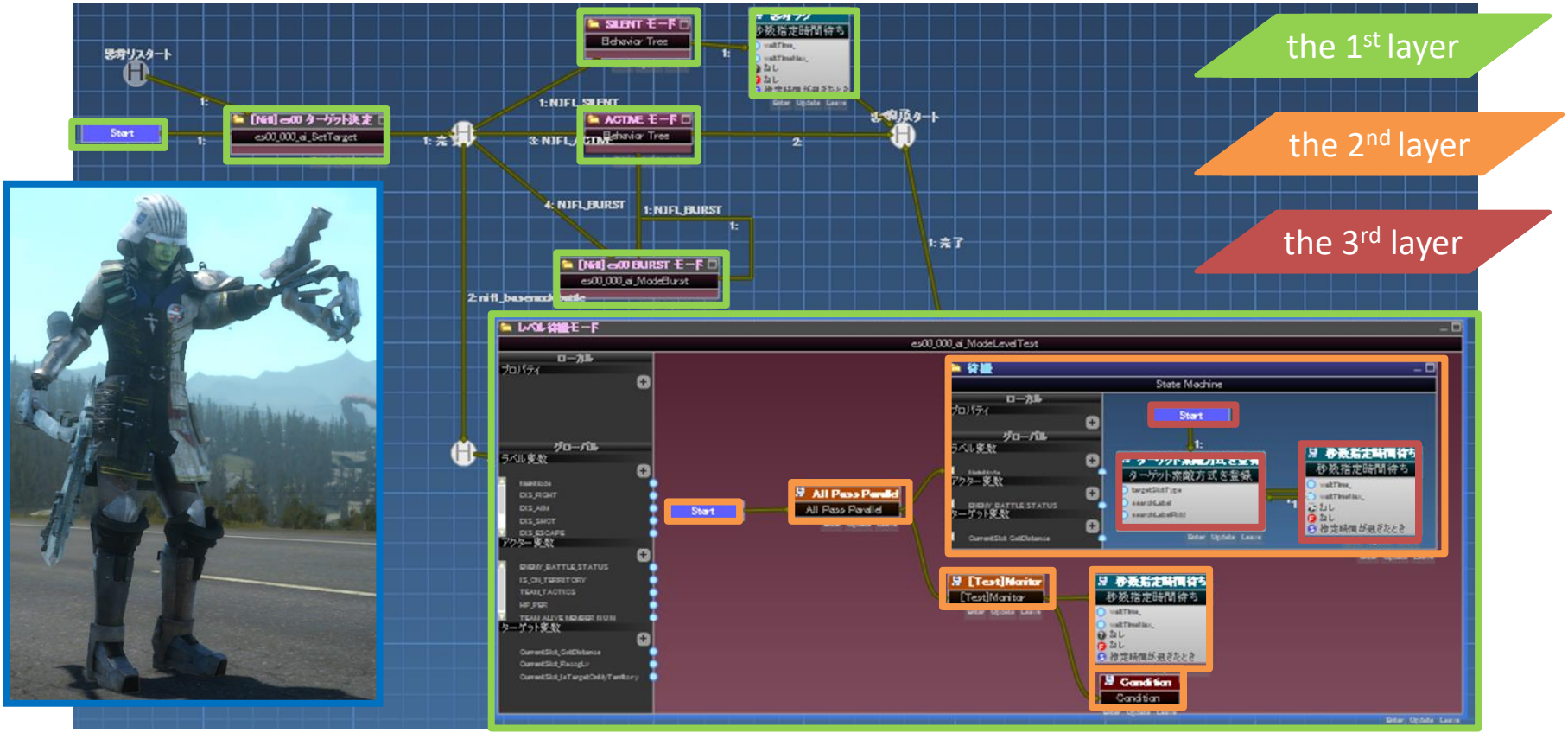
AI Graph Hierarchical Layered Architecture



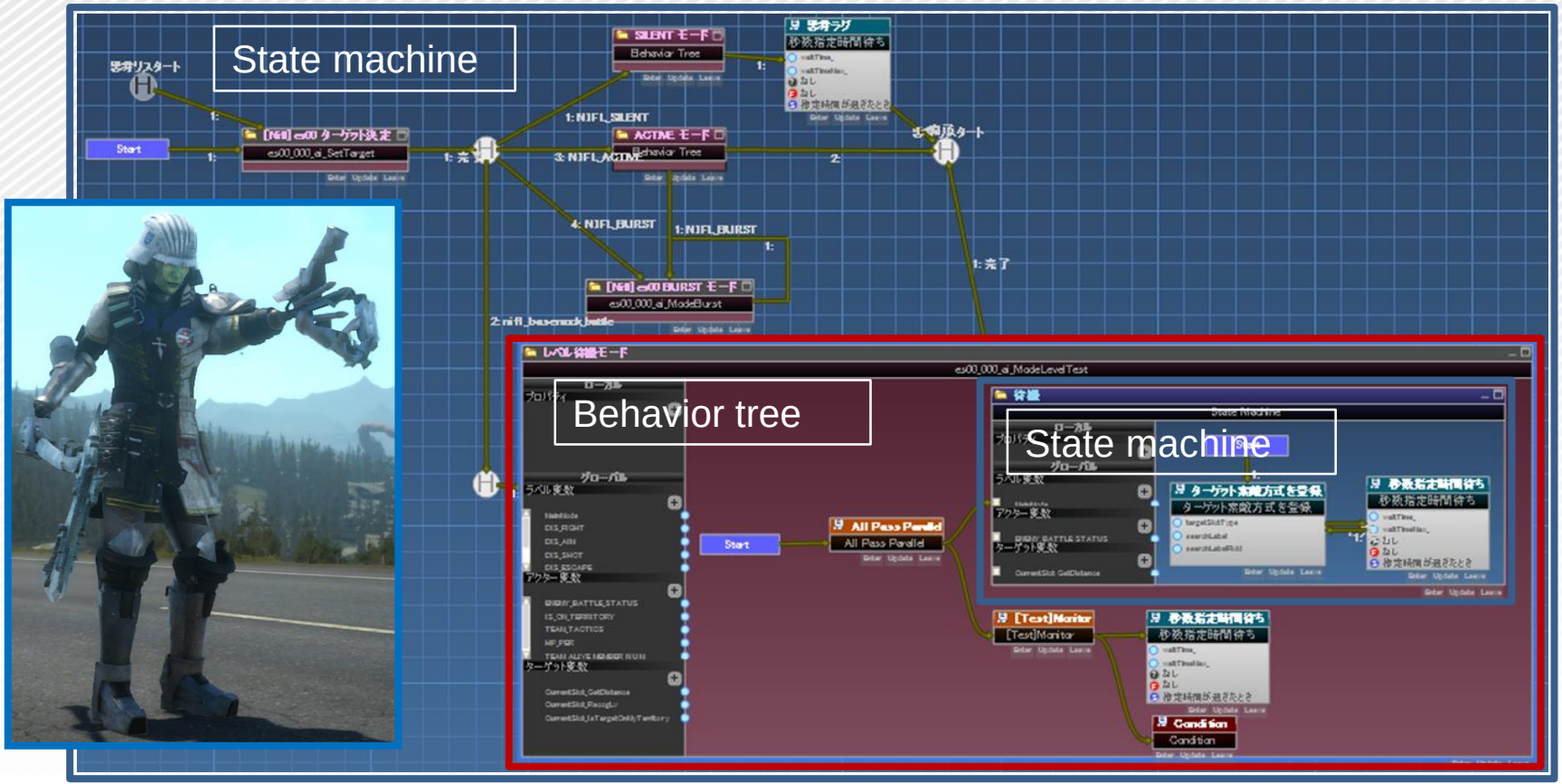
A node on graph structure can reference to graph structure.

Different types of graph system can be combined.

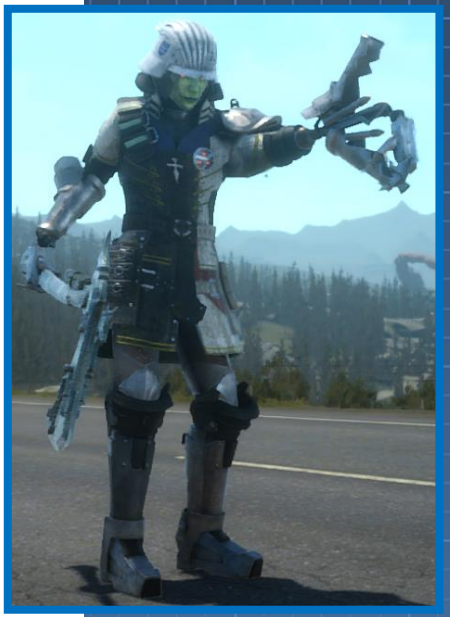
Scalability by Hierarchy



AI Graph Hierarchical Layered Architecture

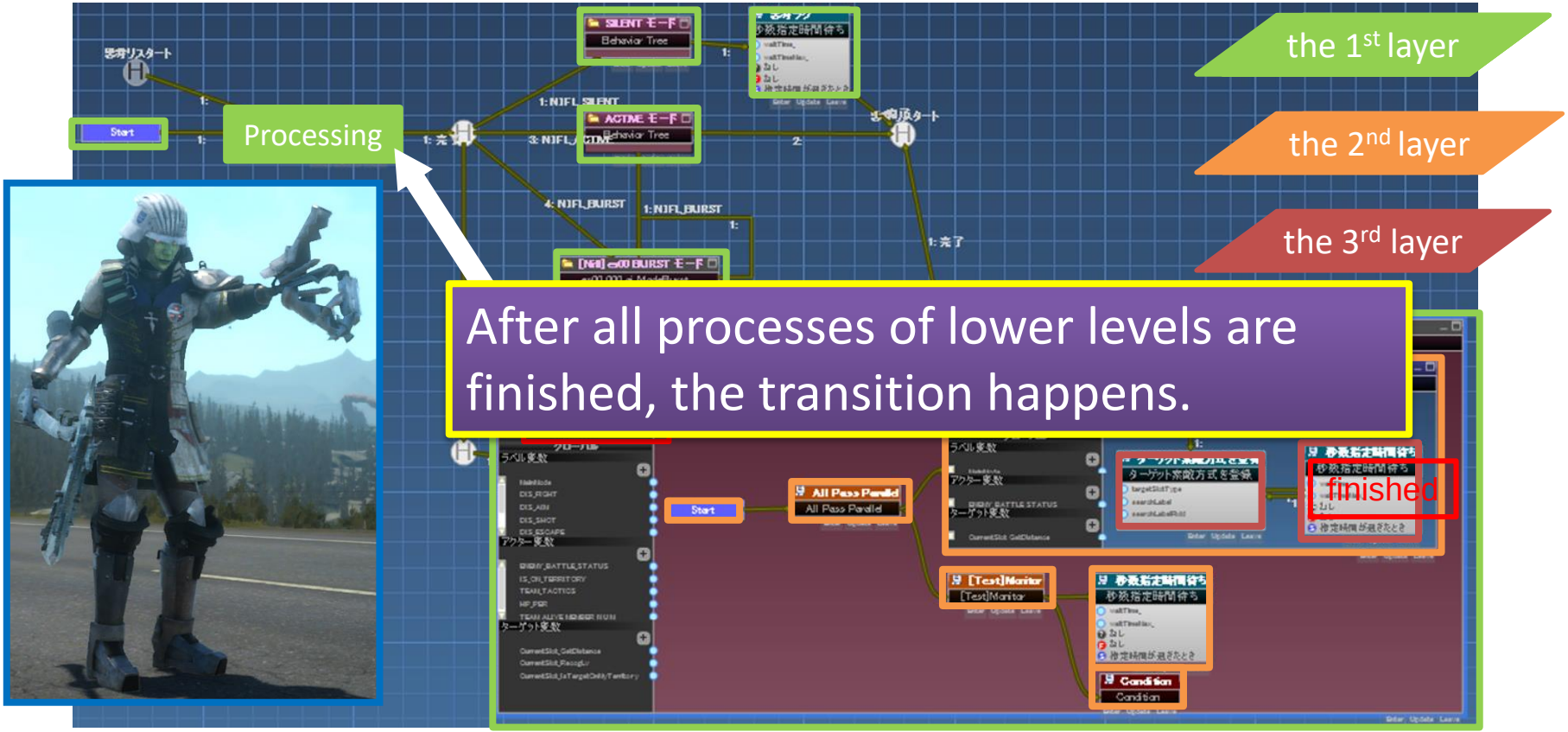


AI Graph Hierarchical Layered Architecture



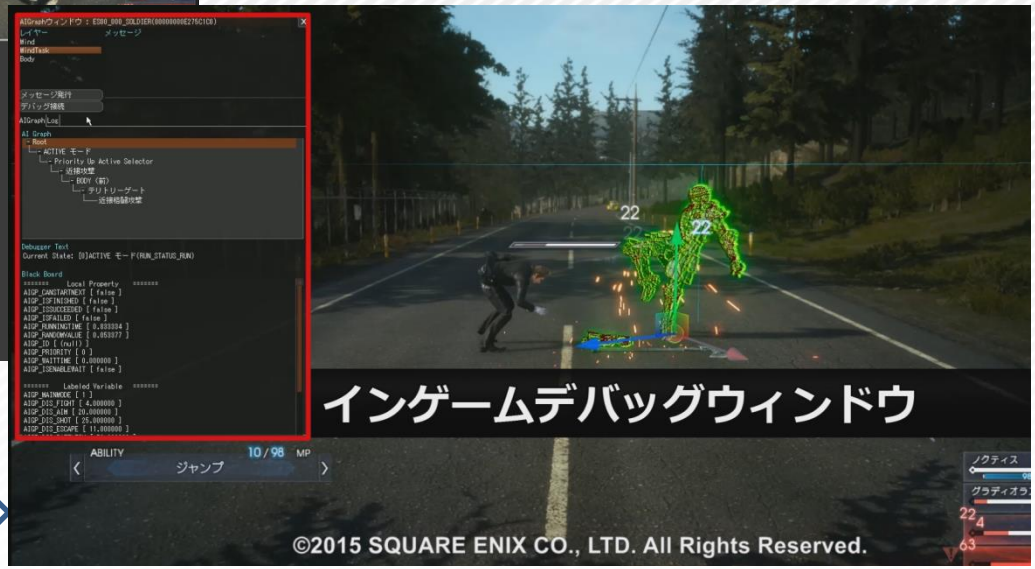
State machine and behavior tree can use the same common node.

Scalability by Hierarchy



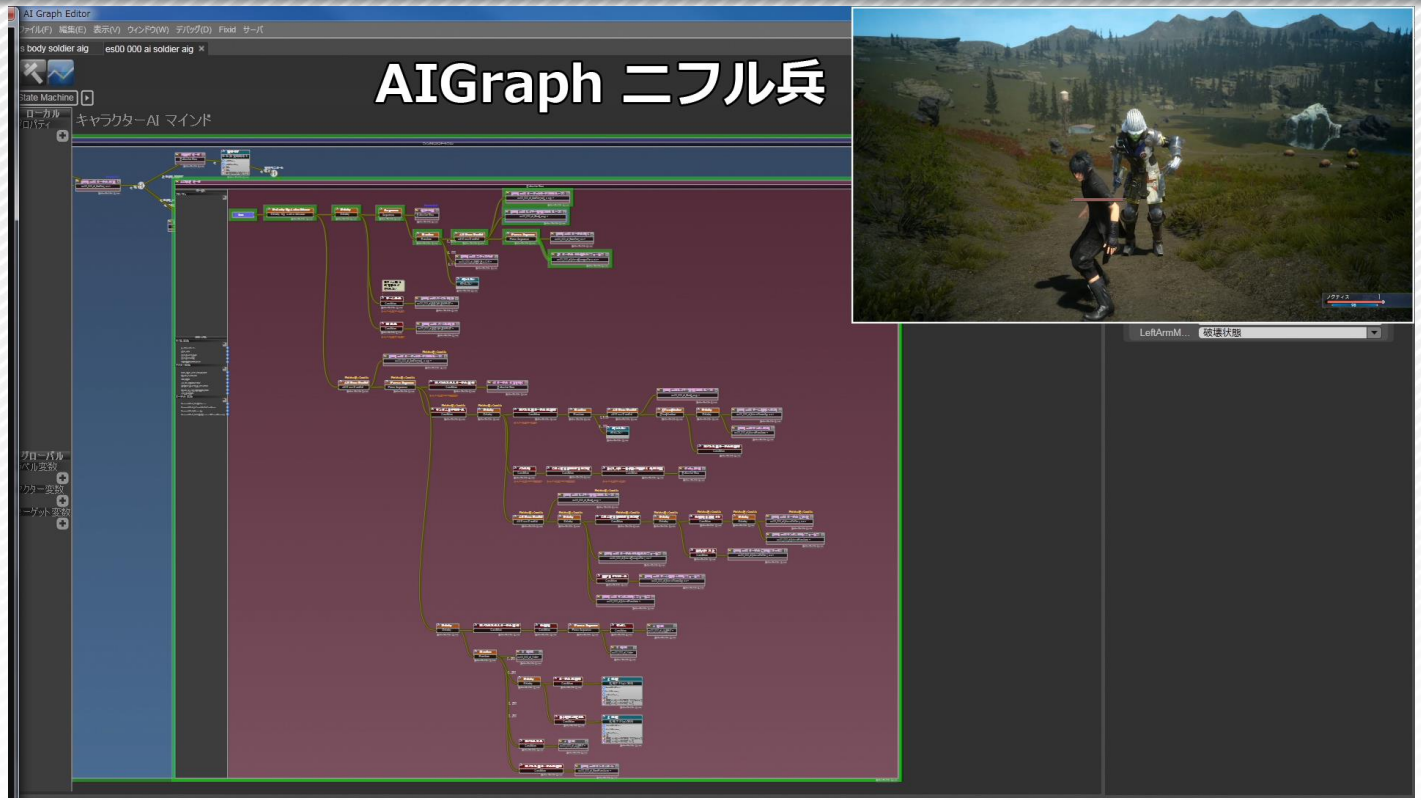
Visual node debugger and In-game debug window

Visual node debugger displays current status of nodes.



In-game debug window display detailed logs.

Visual node debugger and In-game debug window (movie)



Chapter 4.3

SQUARE ENIX ORIGINAL AI SYSTEM

4.3 AI GRAPH

Blackboard architecture

Parallel thinking

Overriding

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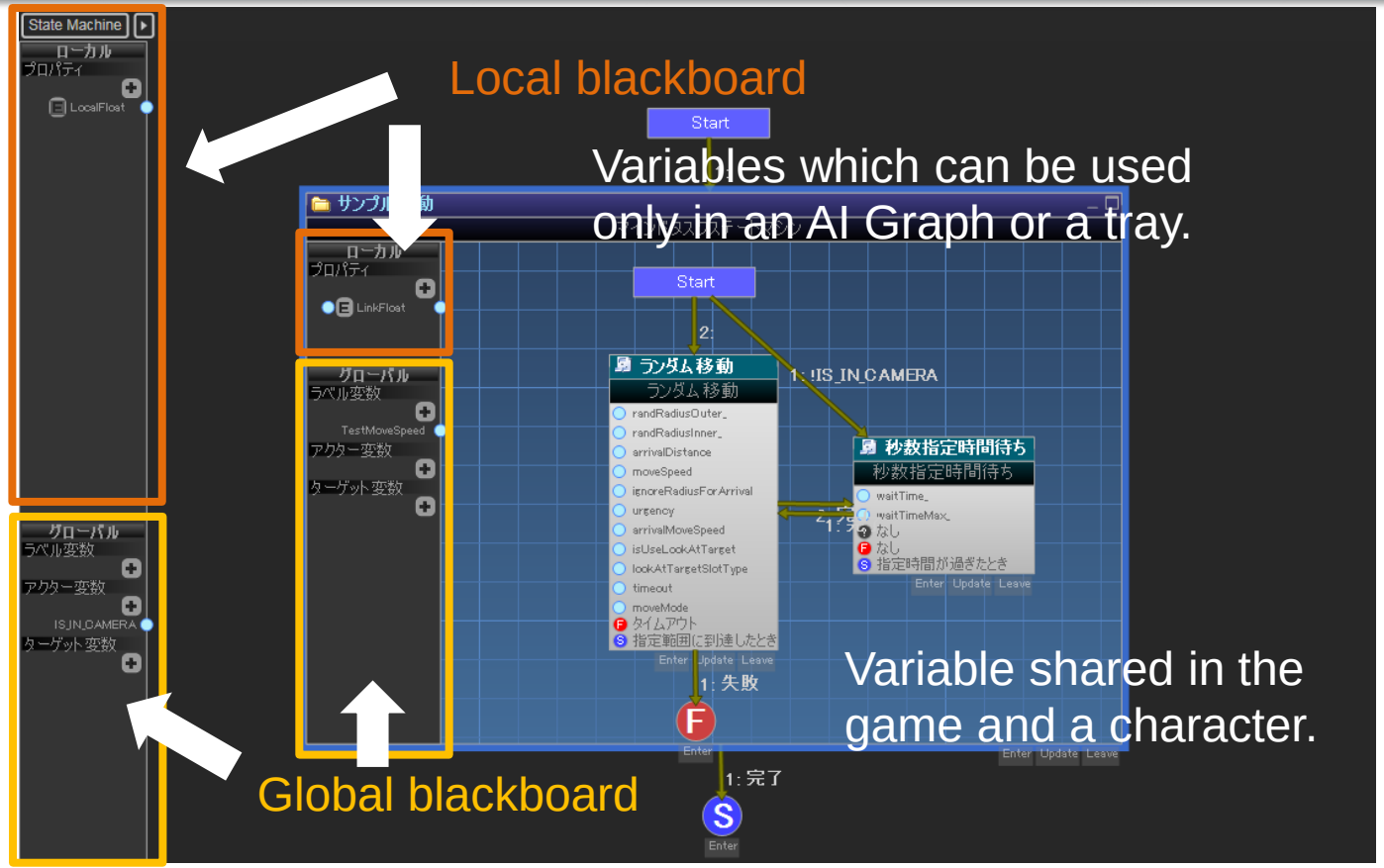
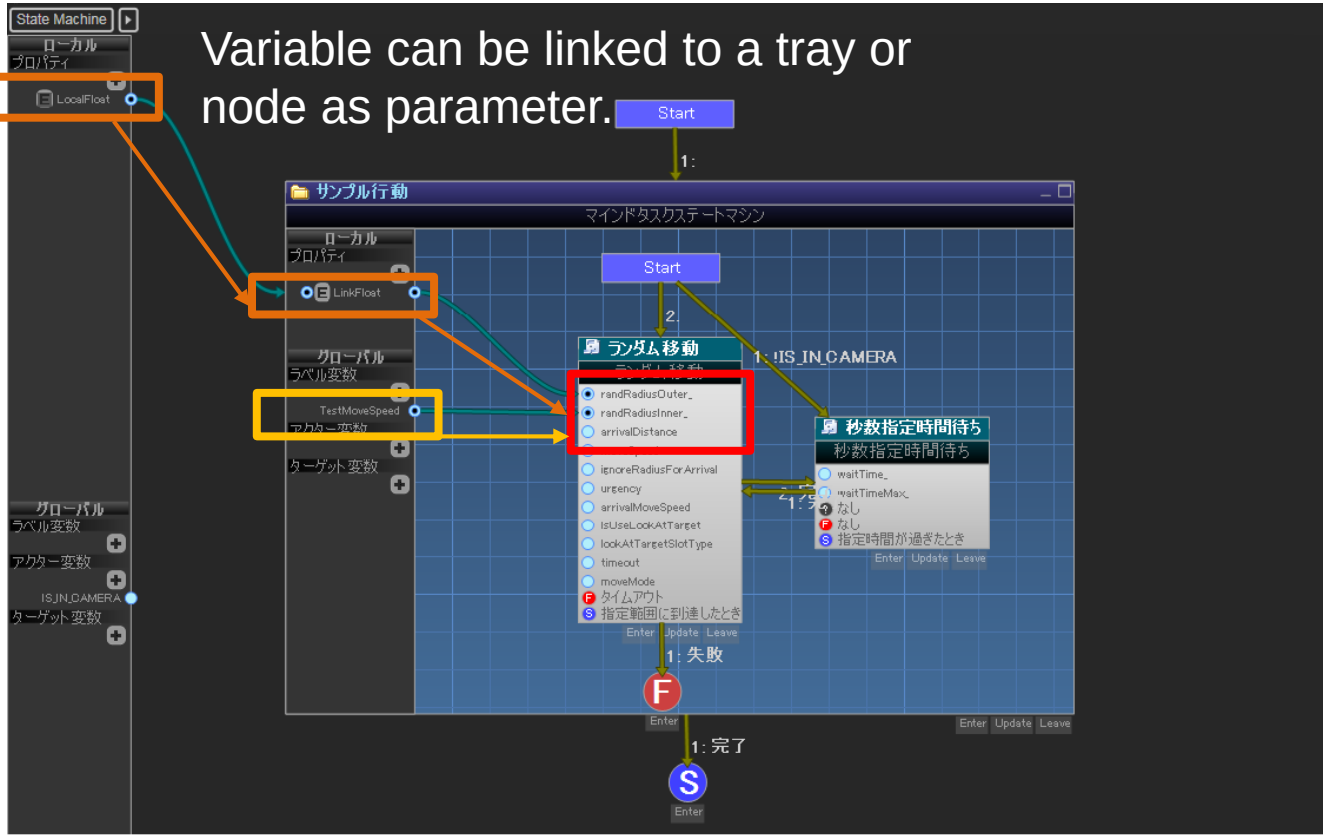
Blackboard in AI Graph



Blackboard in AI Graph



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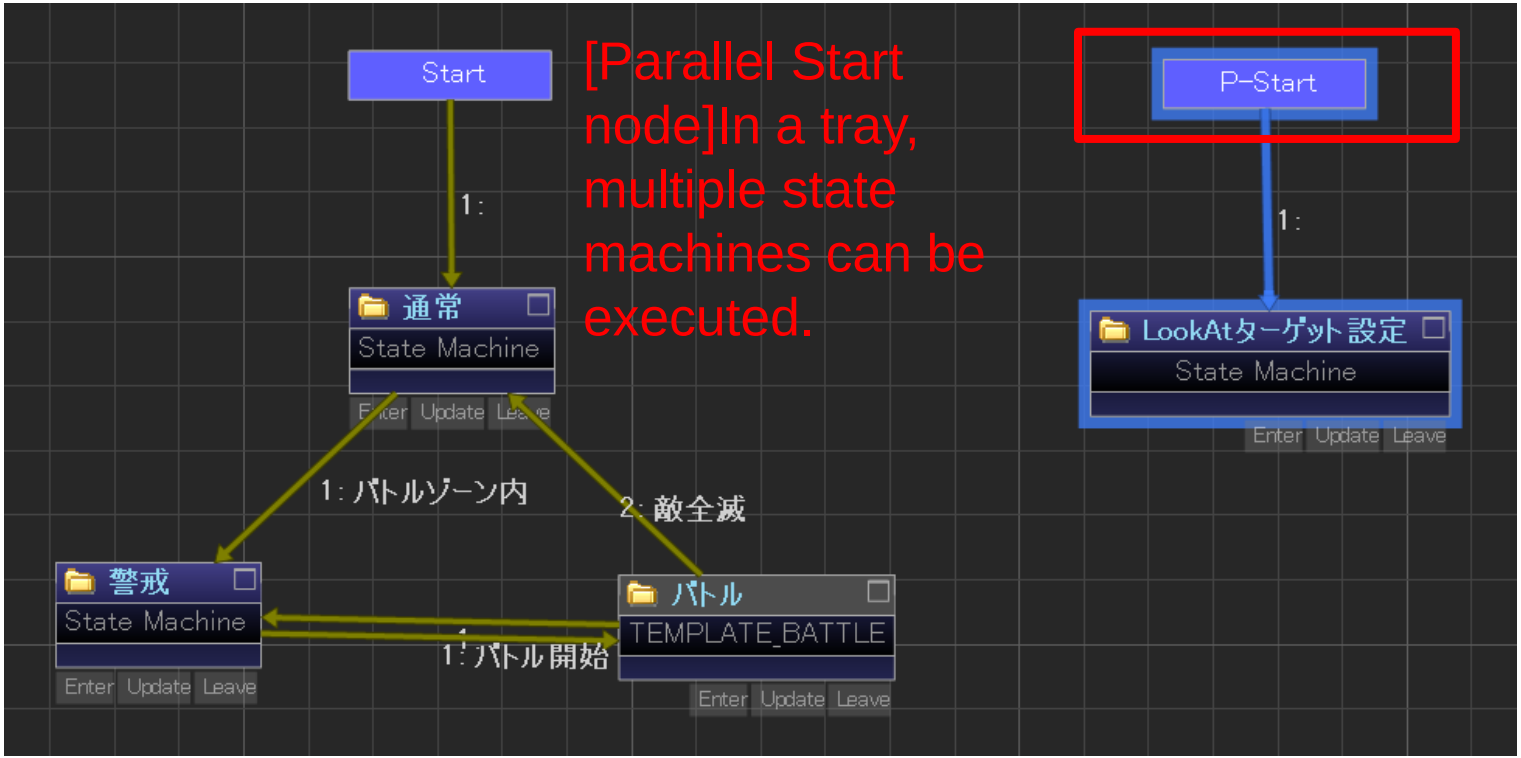
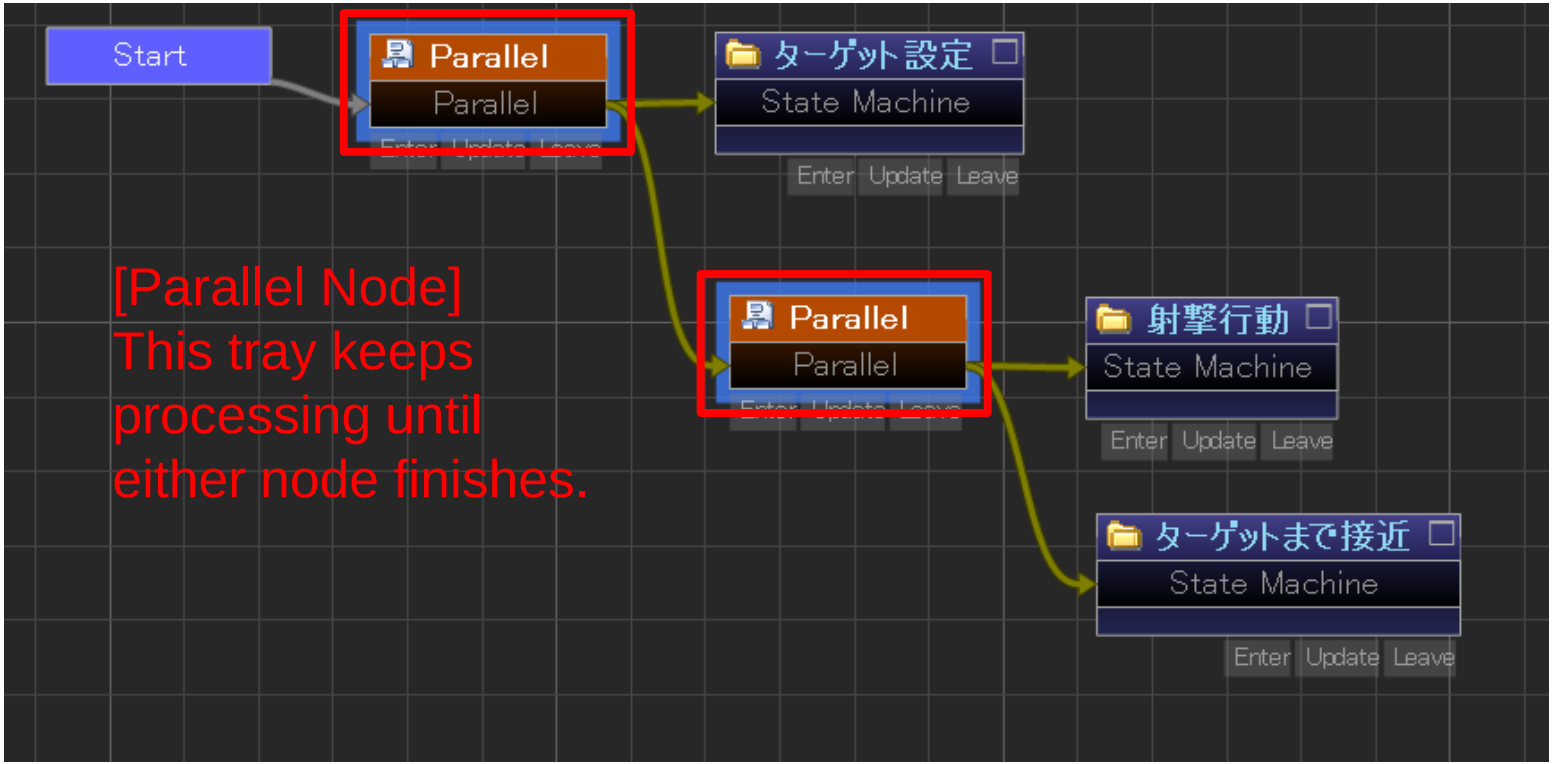
Parallel thinking

- State machine case

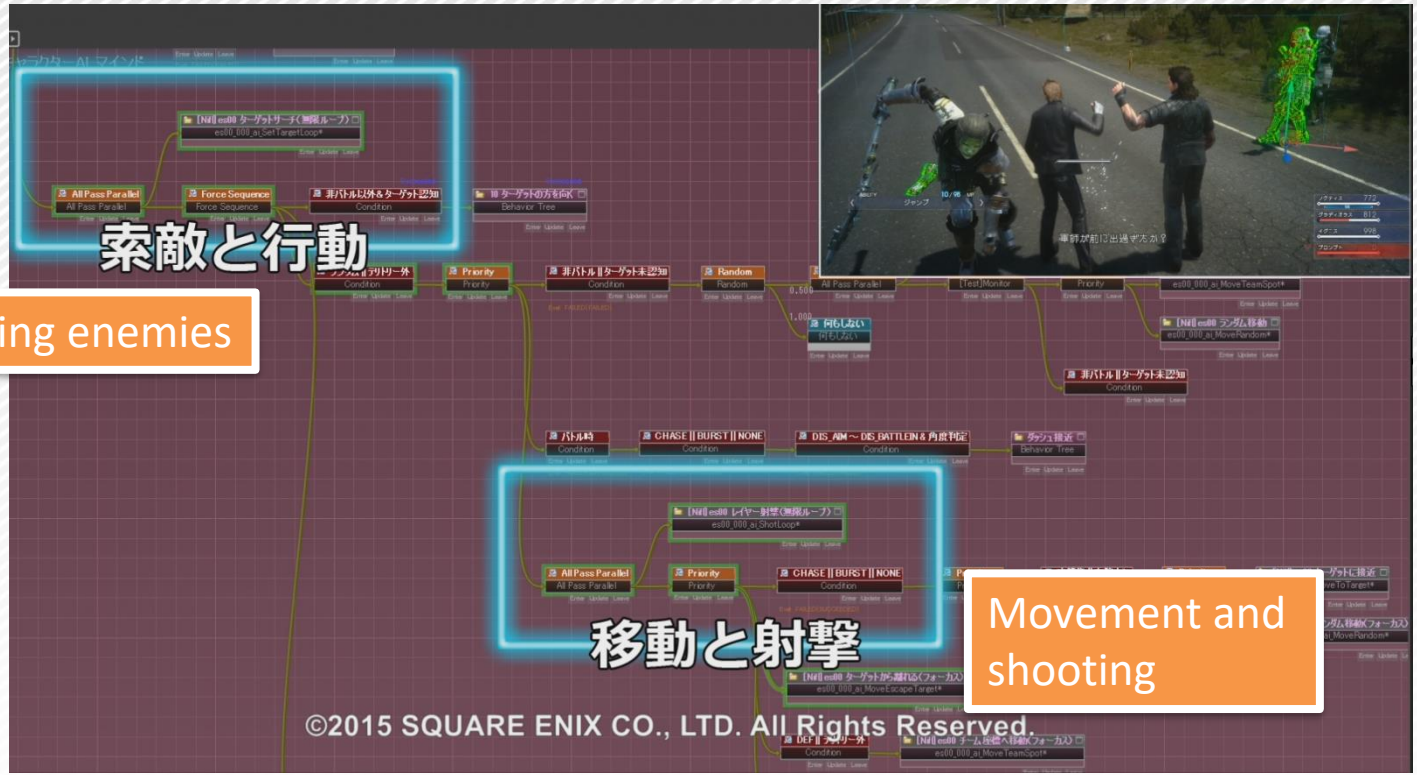


Parallel thinking

- Behavior tree case

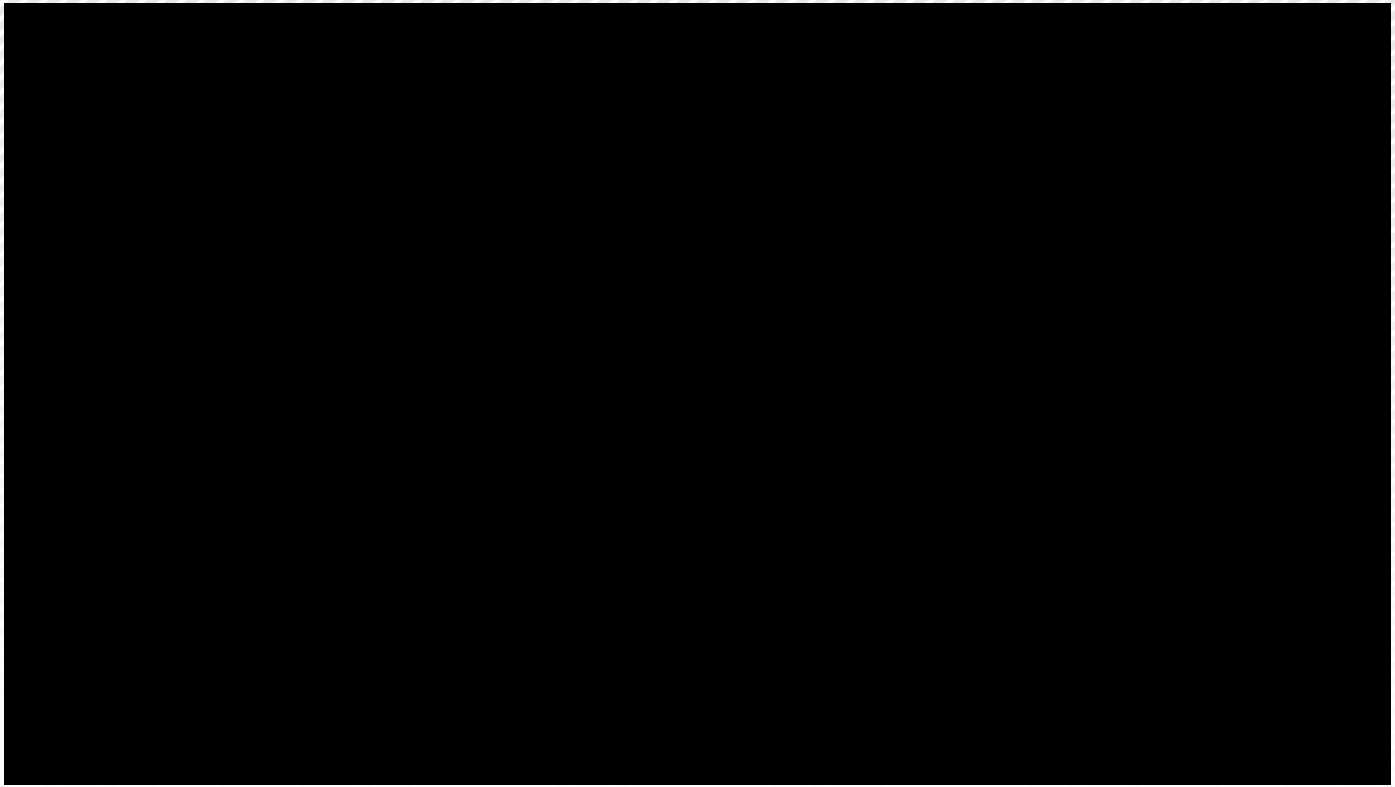


Parallel thinking



Parallel thinking on a behavior tree.

Parallel thinking (movie)



Chapter 4.3

SQUARE ENIX ORIGINAL AI SYSTEM

4.3 AI GRAPH

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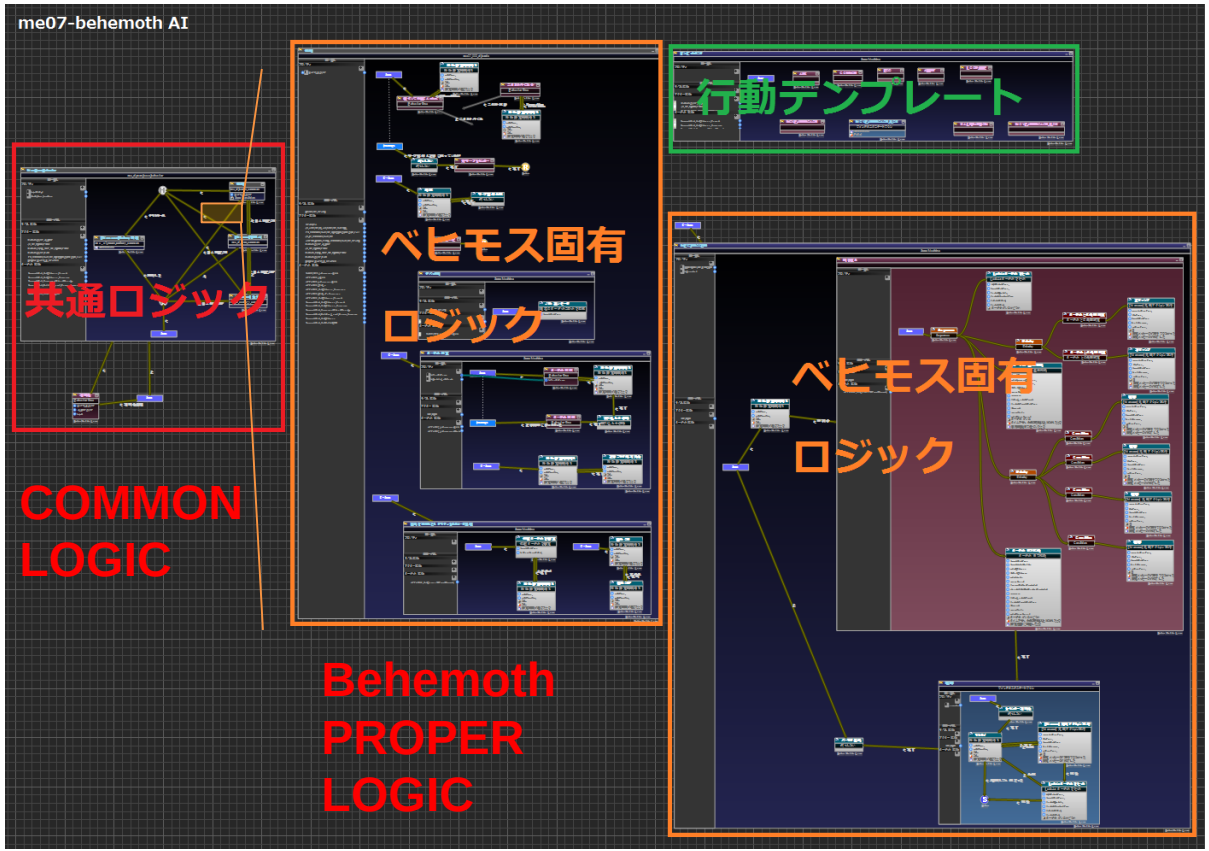
Overriding

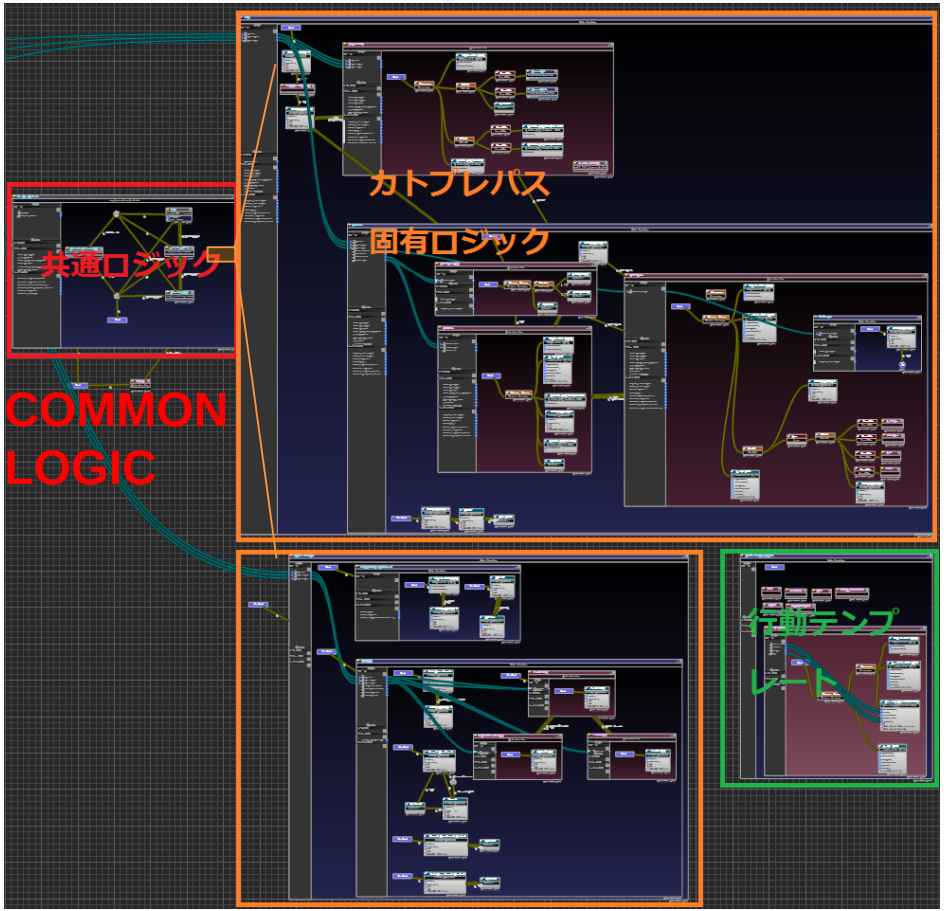
AI Graph override

Me07 behemoth

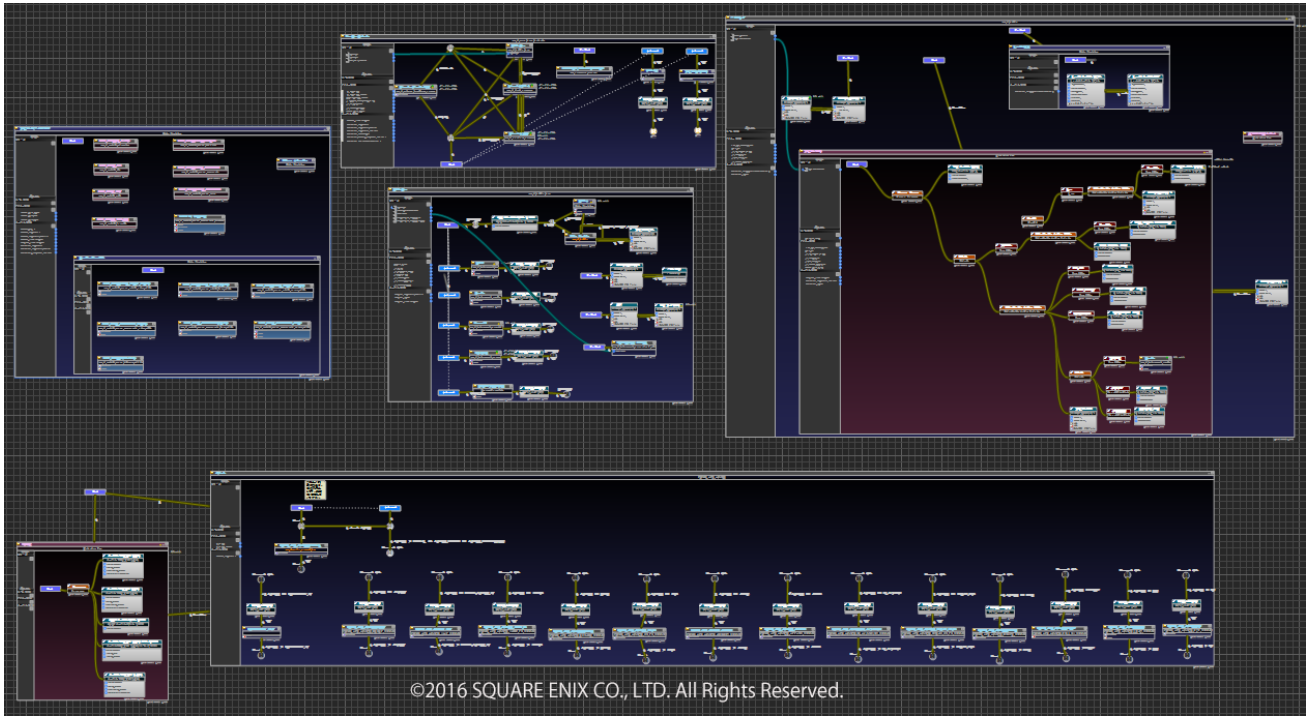


AI Graph override

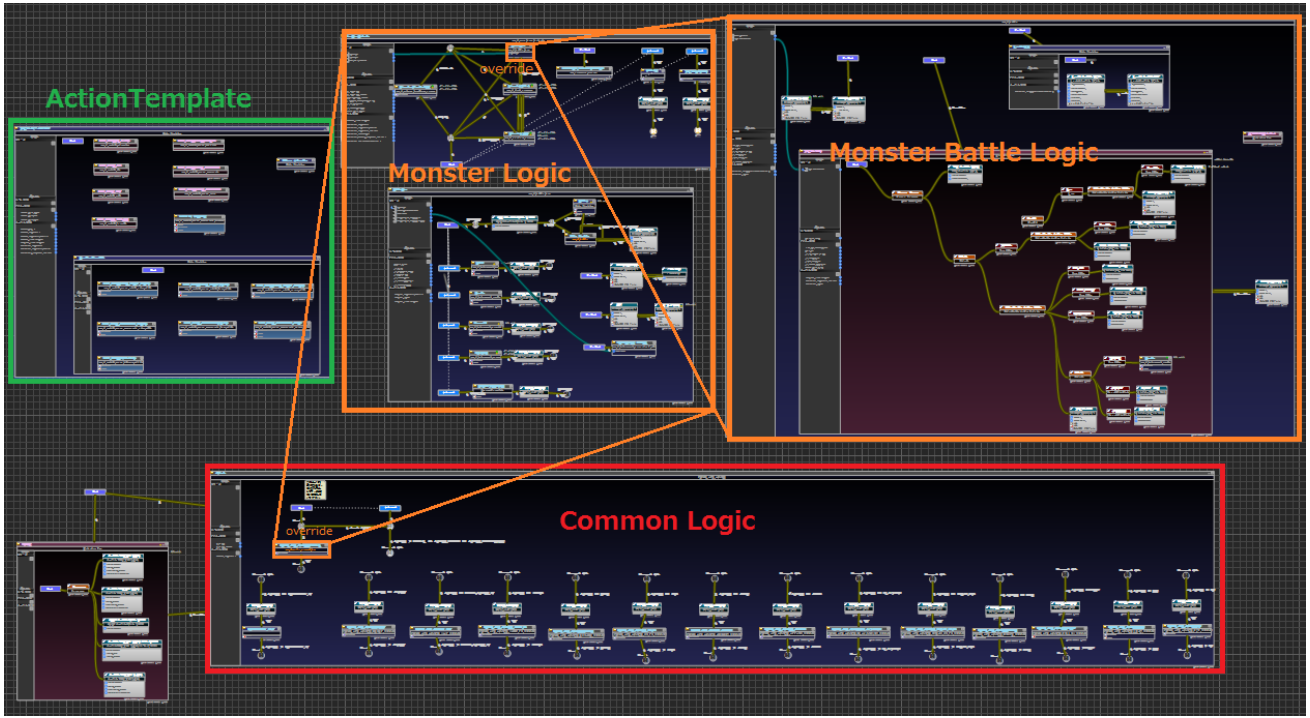
Me04 Catoblepas

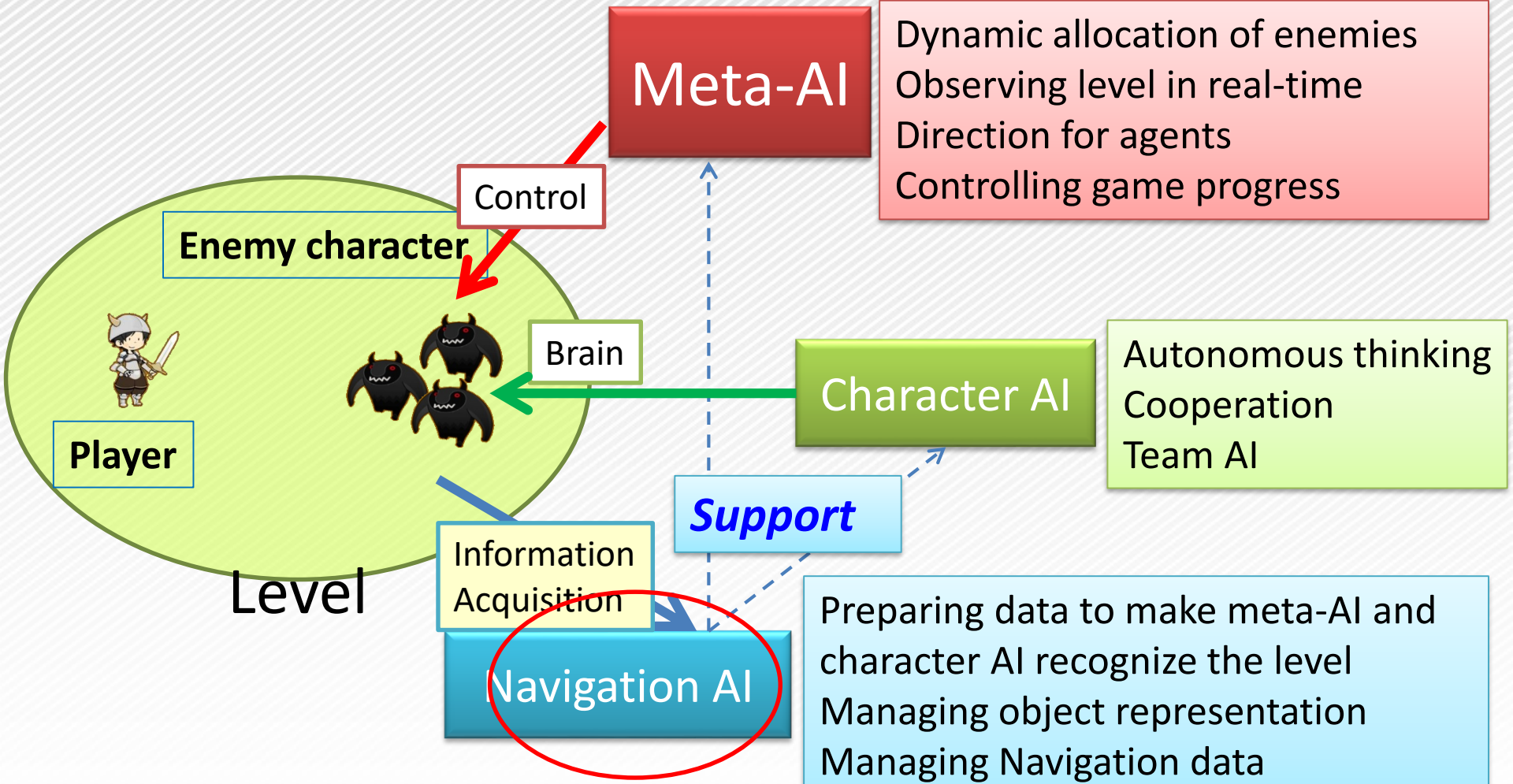


AI Graph Override



AI Graph Override





Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button ▶

Difference between Meta-AI and AI-Director

- Meta AI (Will Wright, The Sims, 2000)

  AI that controls a whole game situation by giving an order to NPCs, putting new objects on a level, and changing a terrain dynamically.

  (Will Wright, "AI : A Design Perspective", AIIDE 2005)

  https://www.aaai.org/Library/AIIDE/aiide05contents.php

- AI Director (LEFT 4 DEAD, 2008)

  AI that directs a battle by allocating NPCs dynamically.

  (Michael Booth. "Replayable Cooperative Game Design: Left 4 Dead."GDC 2009)

  http://www.valvesoftware.com/company/publications.html

Chapter 3

META AI (AI DIRECTOR)

Adjusting the game world to the player

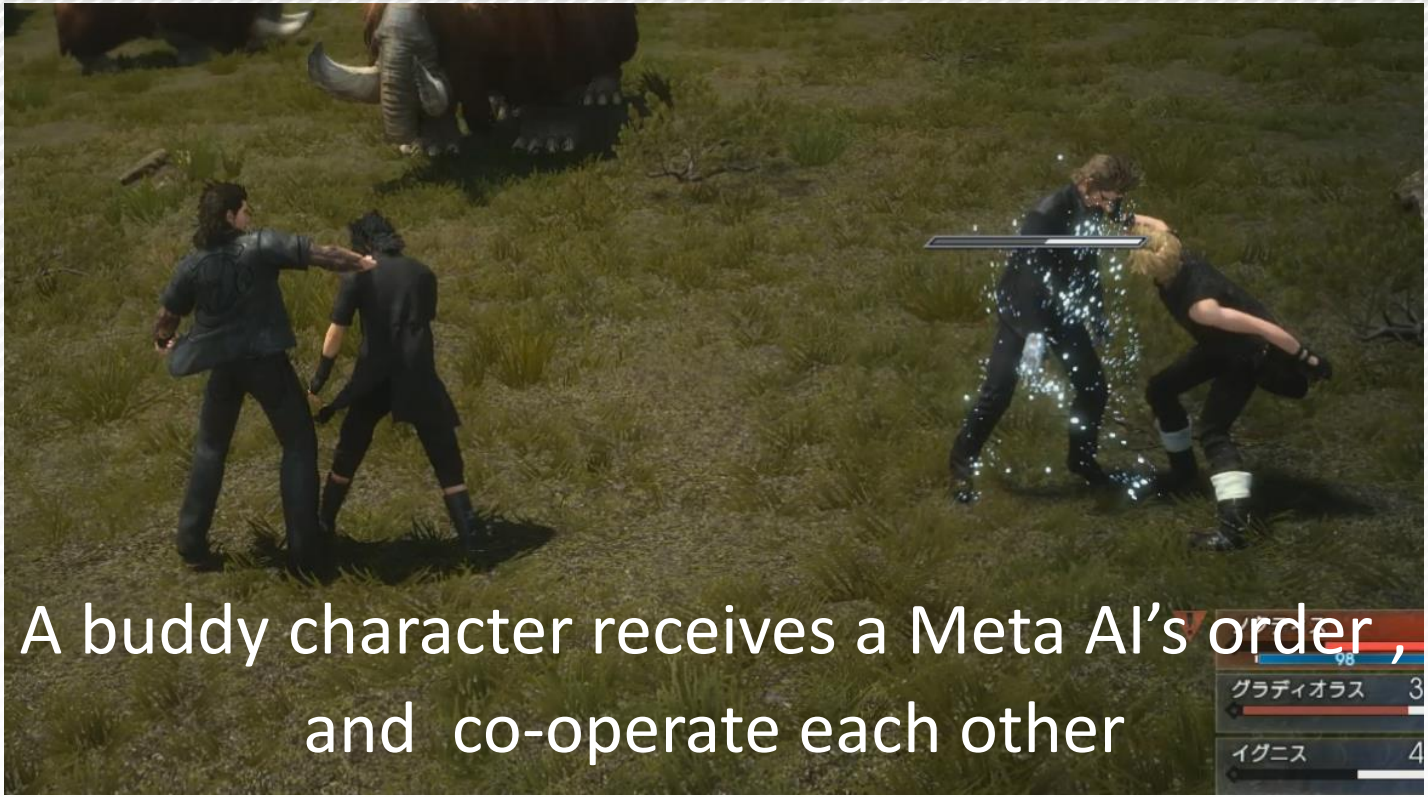
Meta-AI

For an example, Meta-AI issues an order to a buddy character to rescue a play character .

Meta-AI

This shows the cooperation of buddies directed by Meta AI.

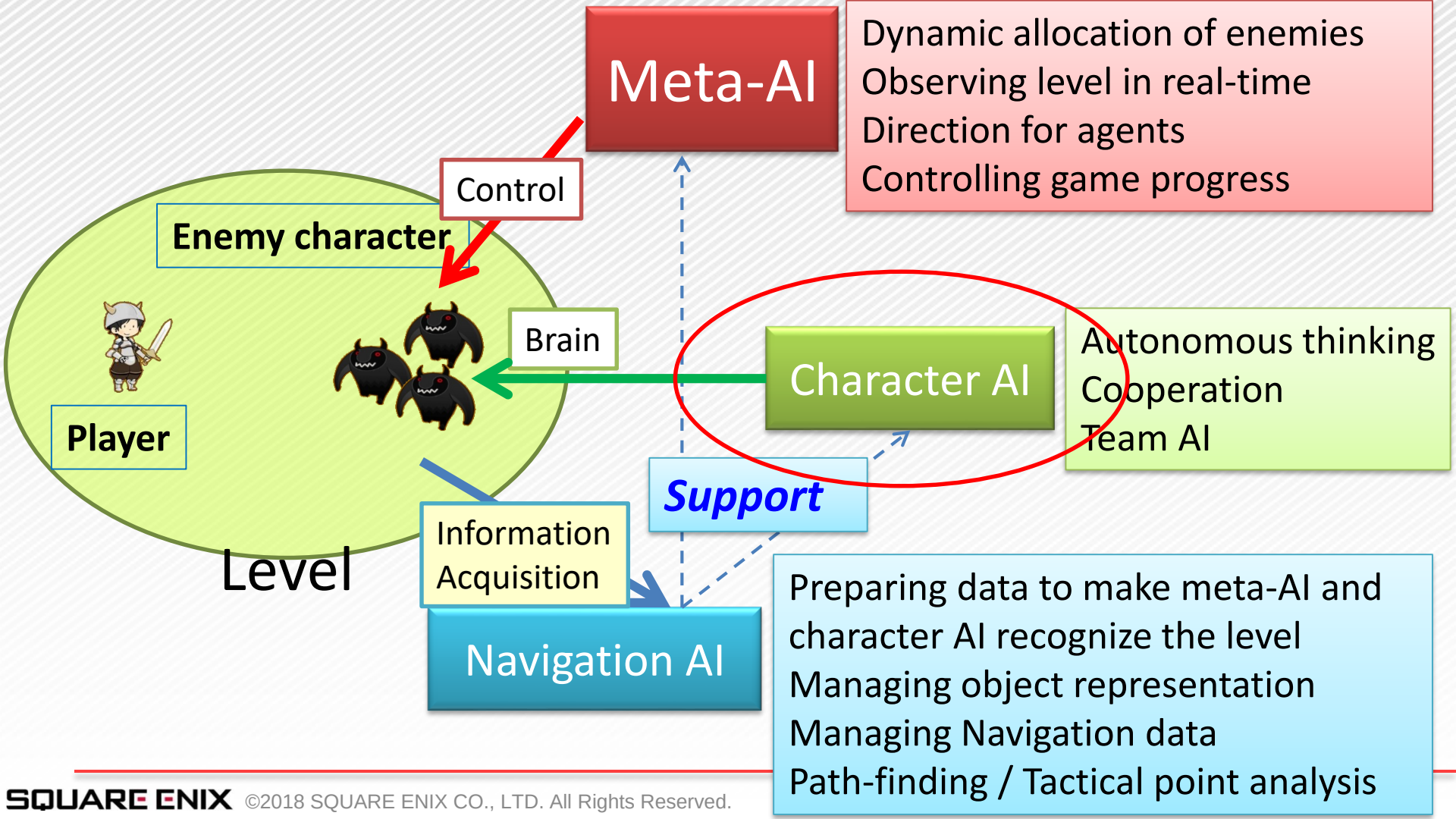
Meta-AI



A buddy character receives a Meta AI's order ,
and co-operate each other

Meta-AI (movie)

This shows the cooperation of buddies directed by Meta AI.



Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button ▶

Contents

Theme

- ***What information*** is necessary for an animal to move naturally in an environment ?

Theme

To make a game character act not as a controlled puppet but as an autonomous agent in an environment,

Objective information *is not necessary,*

But,

Subjective world *that the game character has is necessary.*

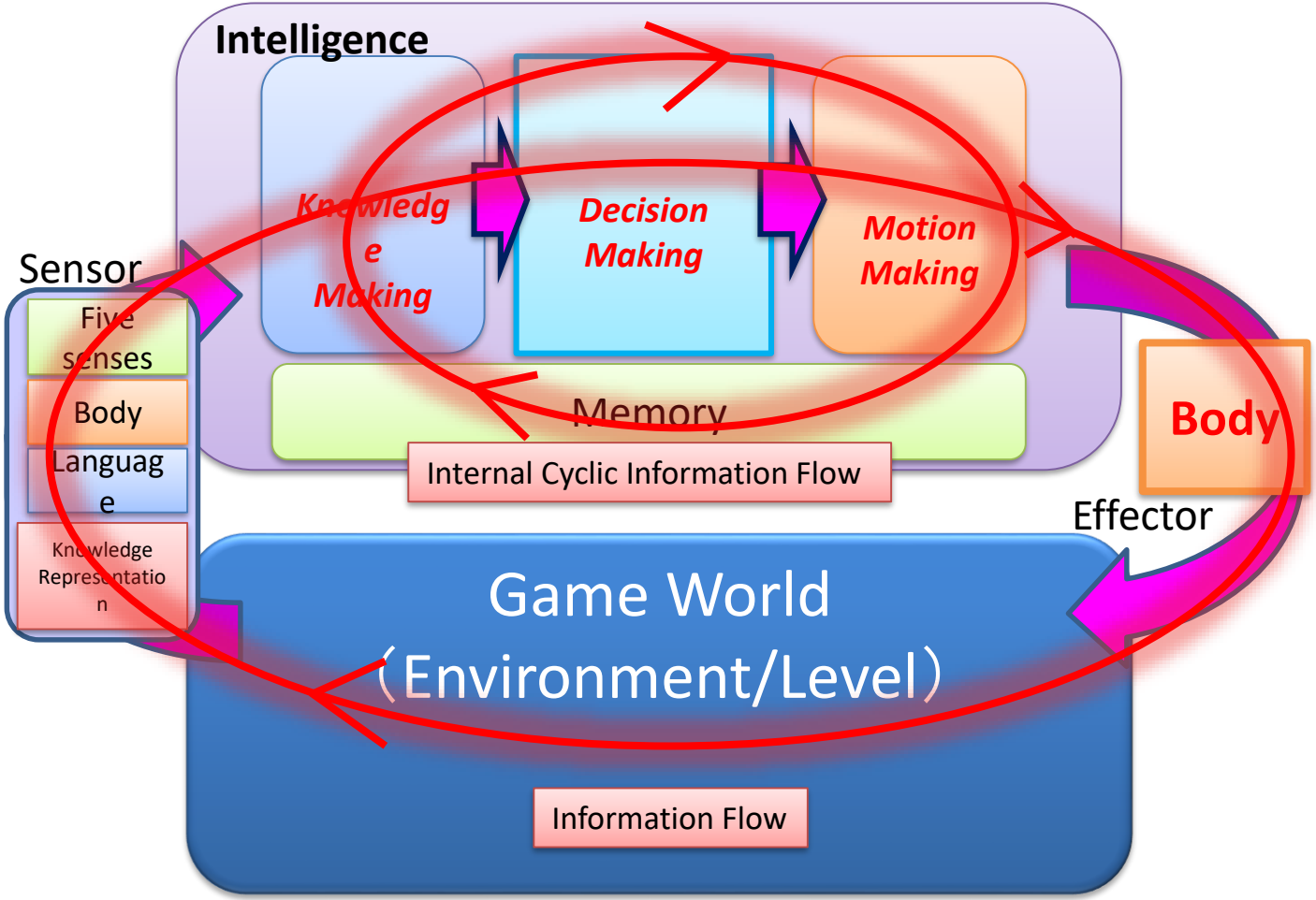
Making a game character's subjective world.

Question

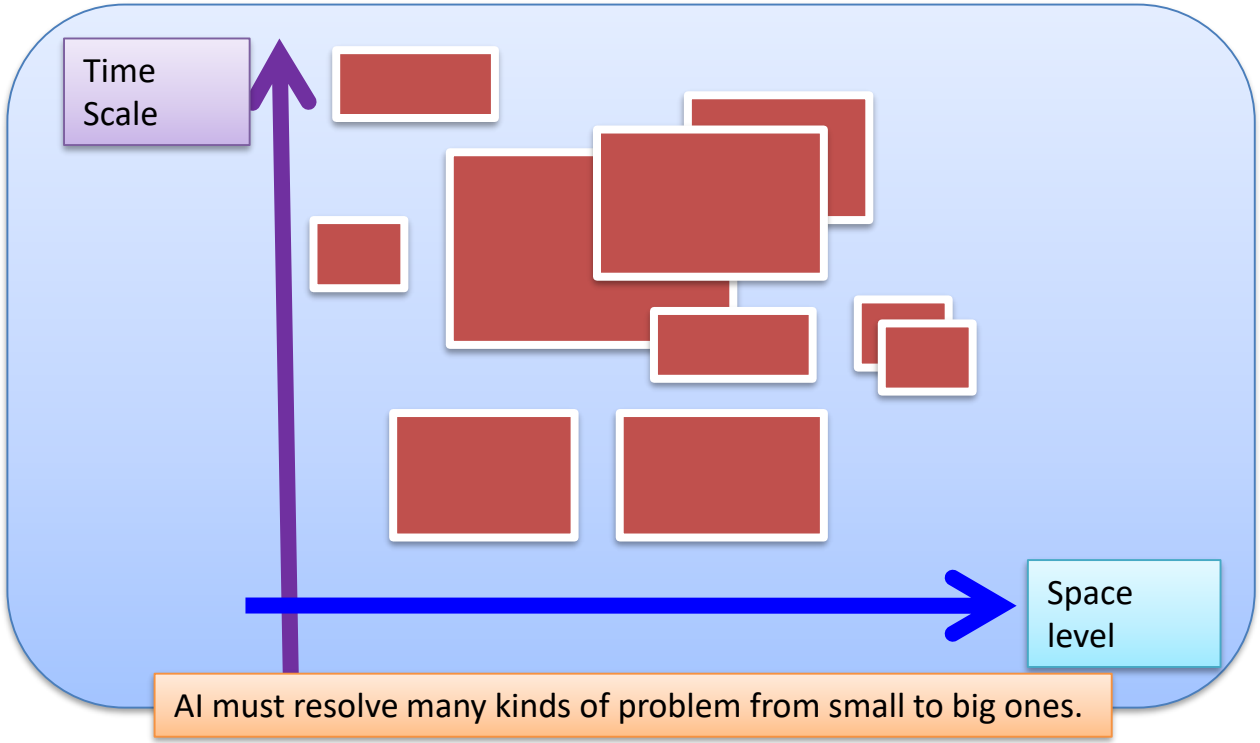
What is difference between
an animal's eye and a camera eye ?

5.0.1

WHAT DOES A LIVING THING SEE?

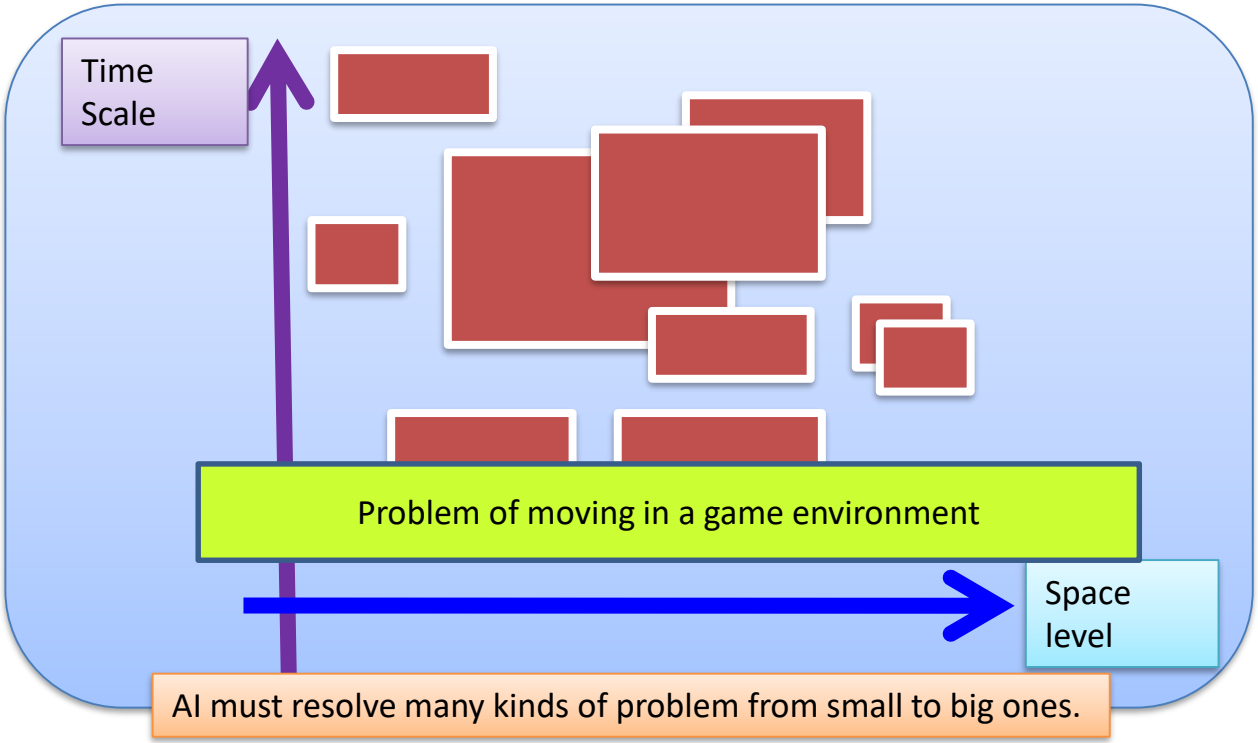


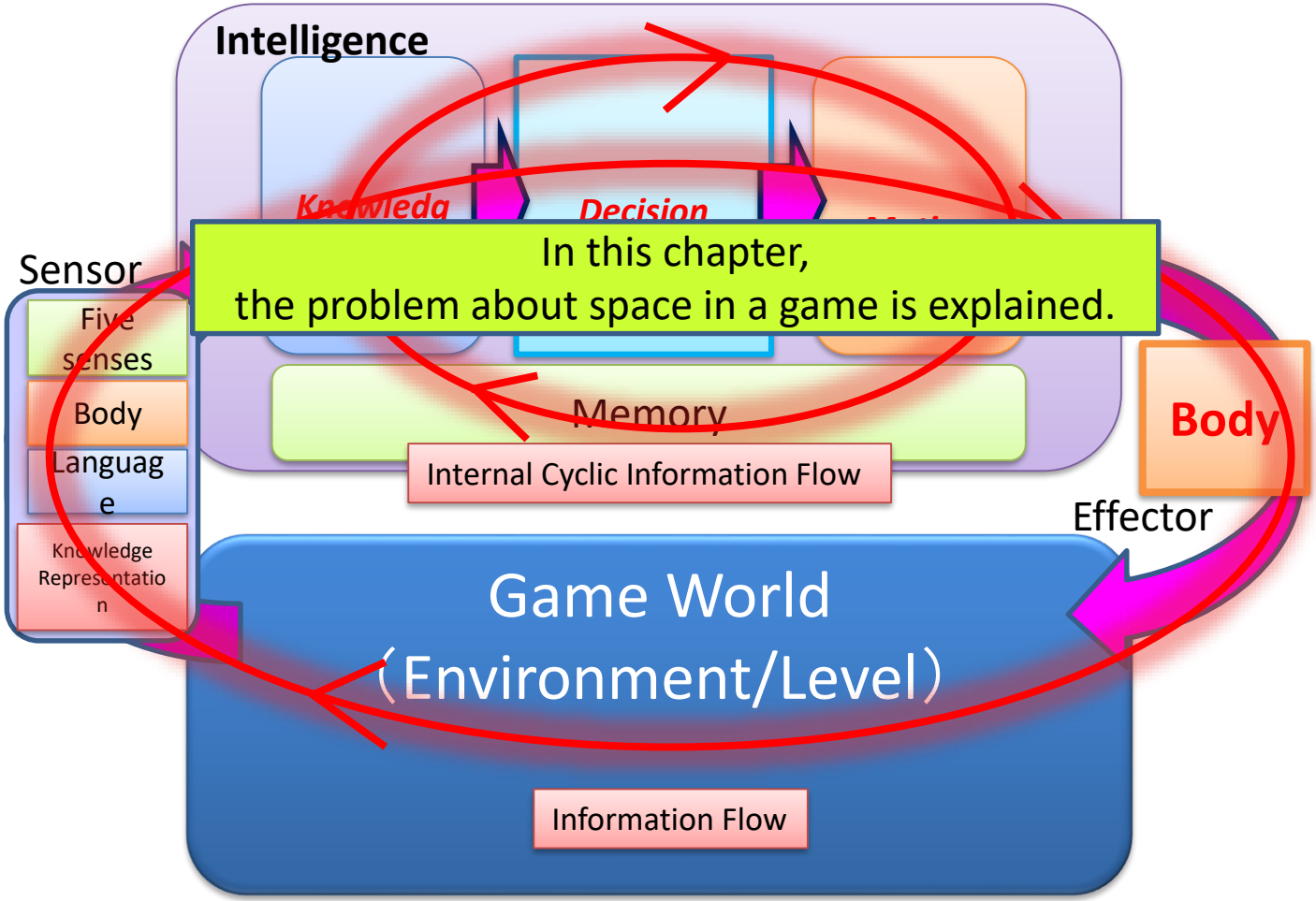
Problem Domain

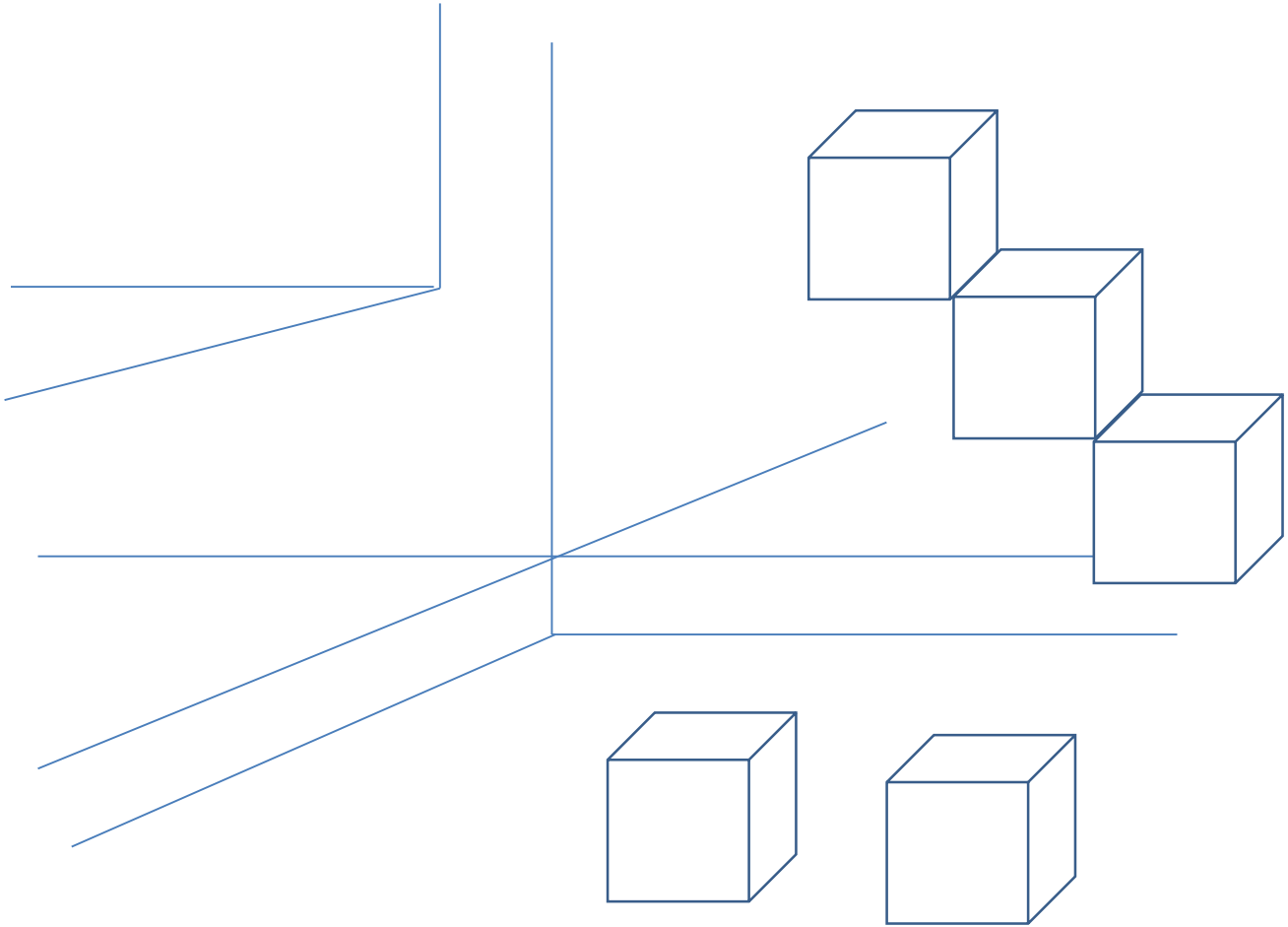


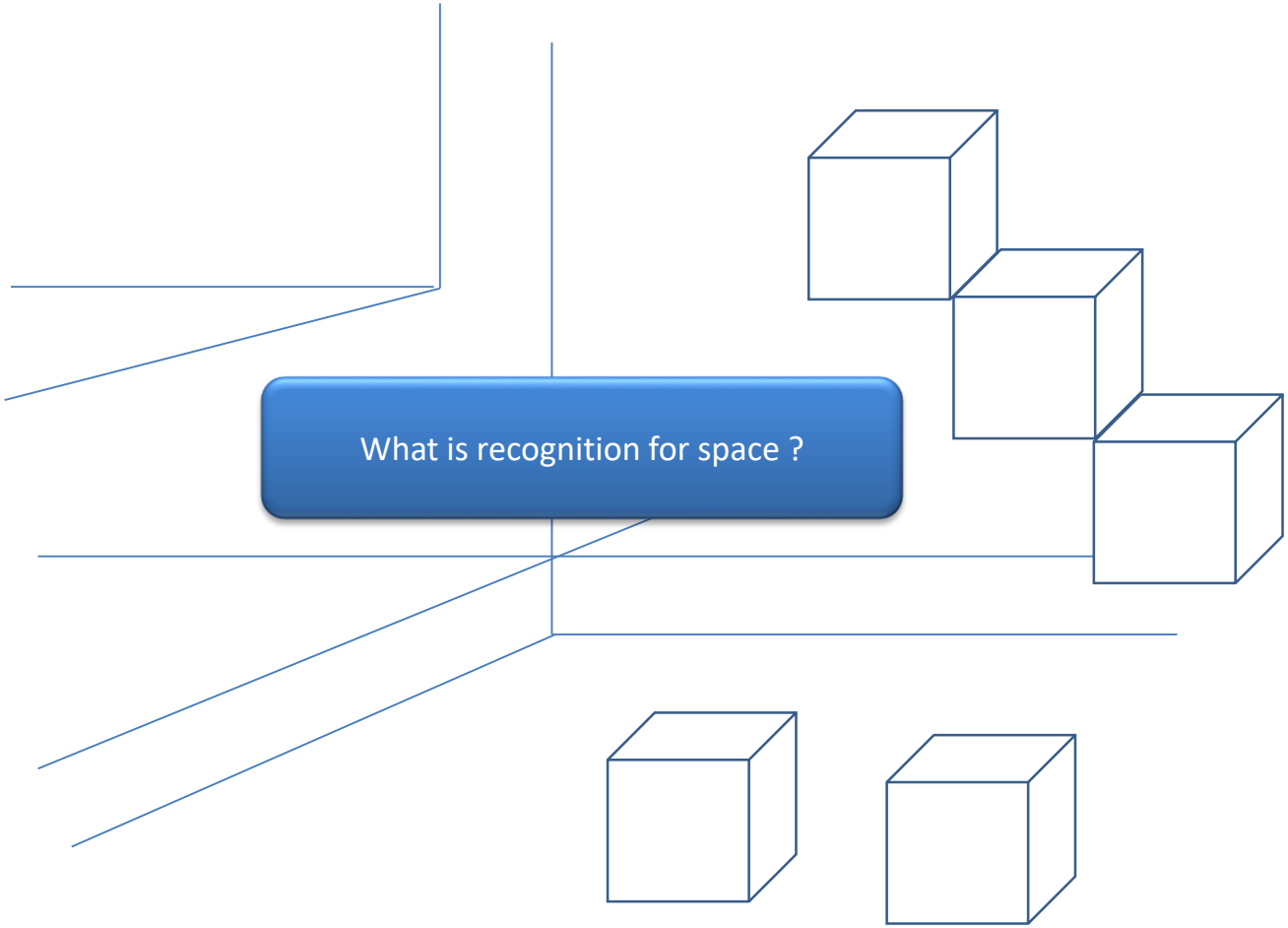
AI must resolve many kinds of problem from small to big ones.

Problem Domain

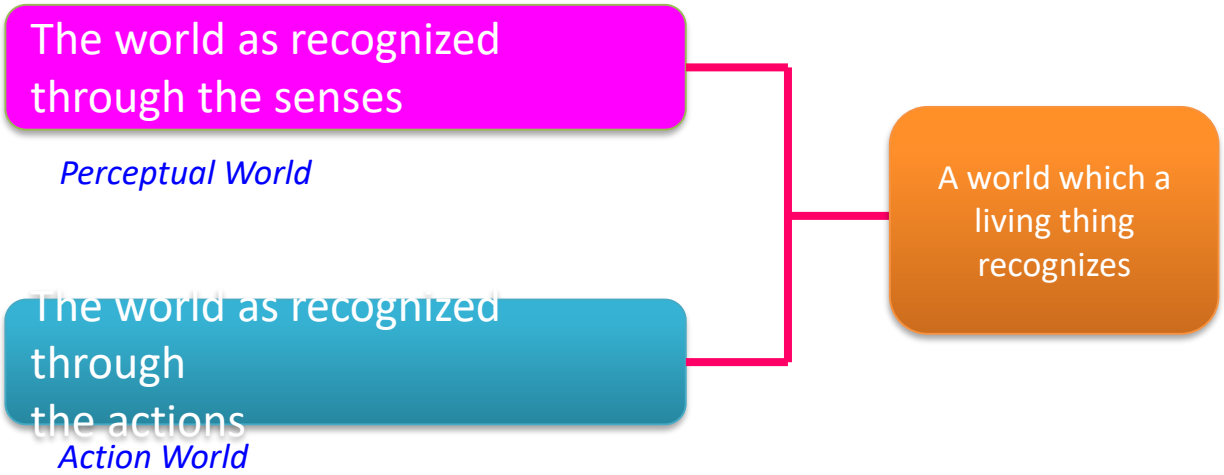




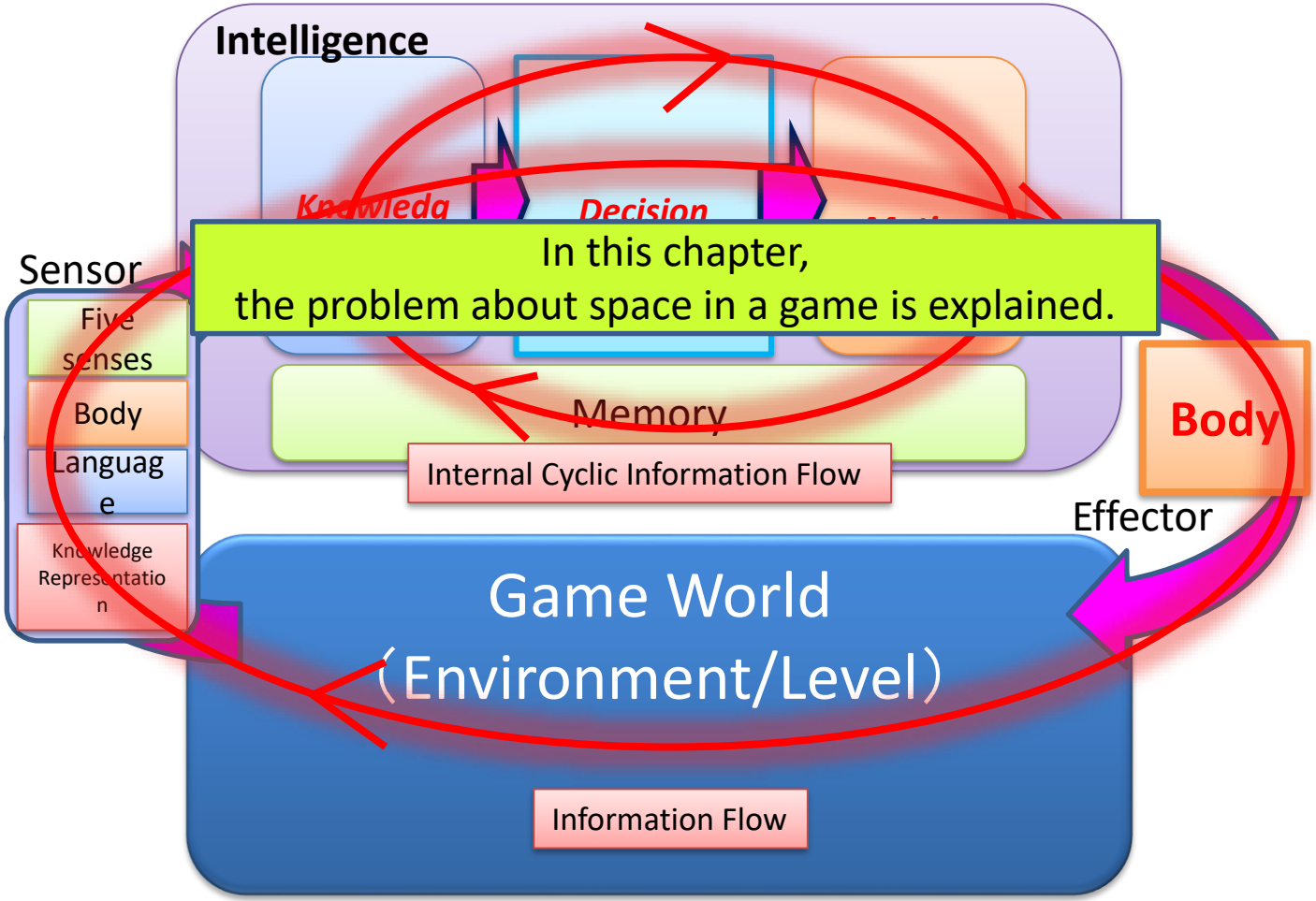


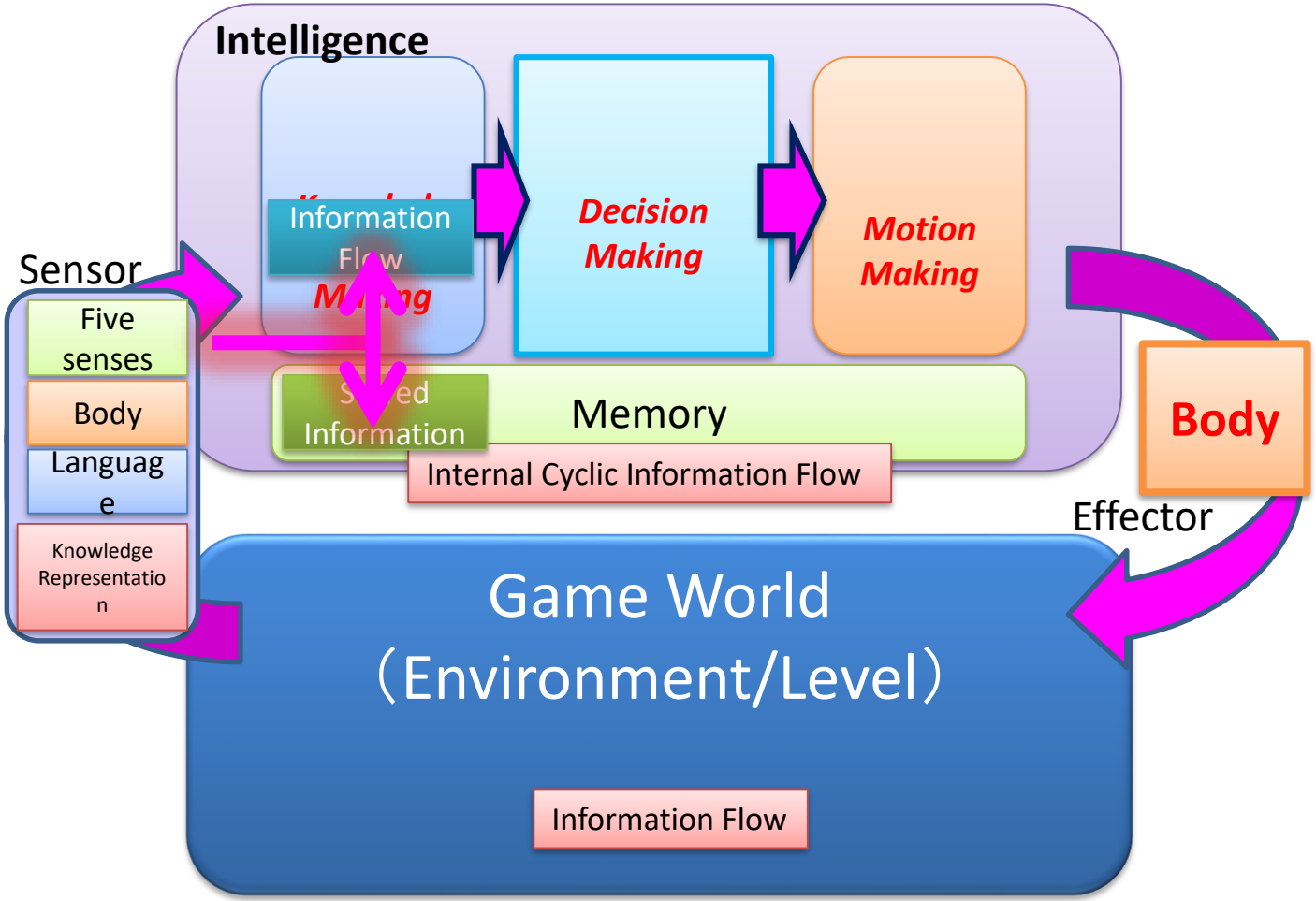


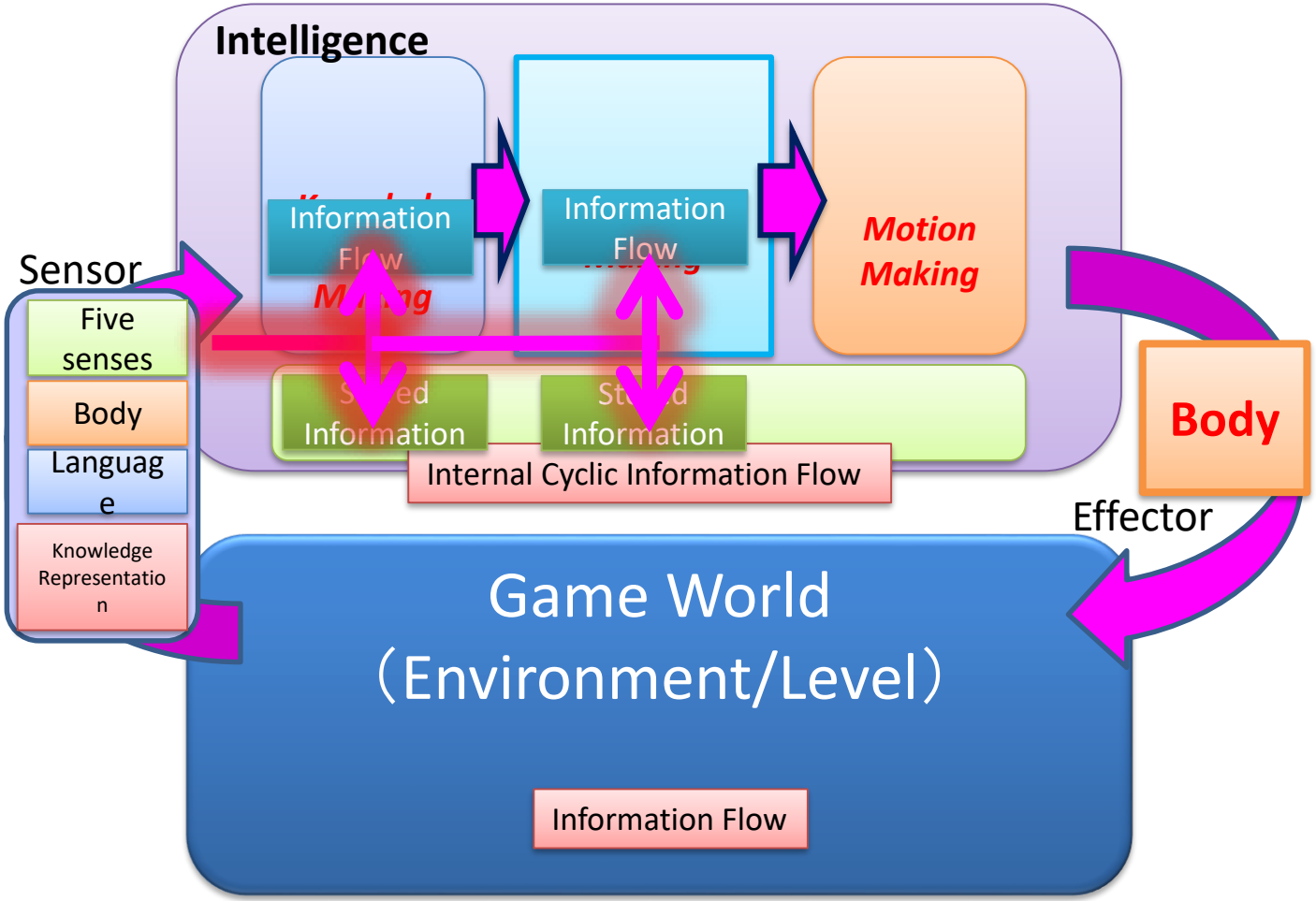
What is environment for a living thing?

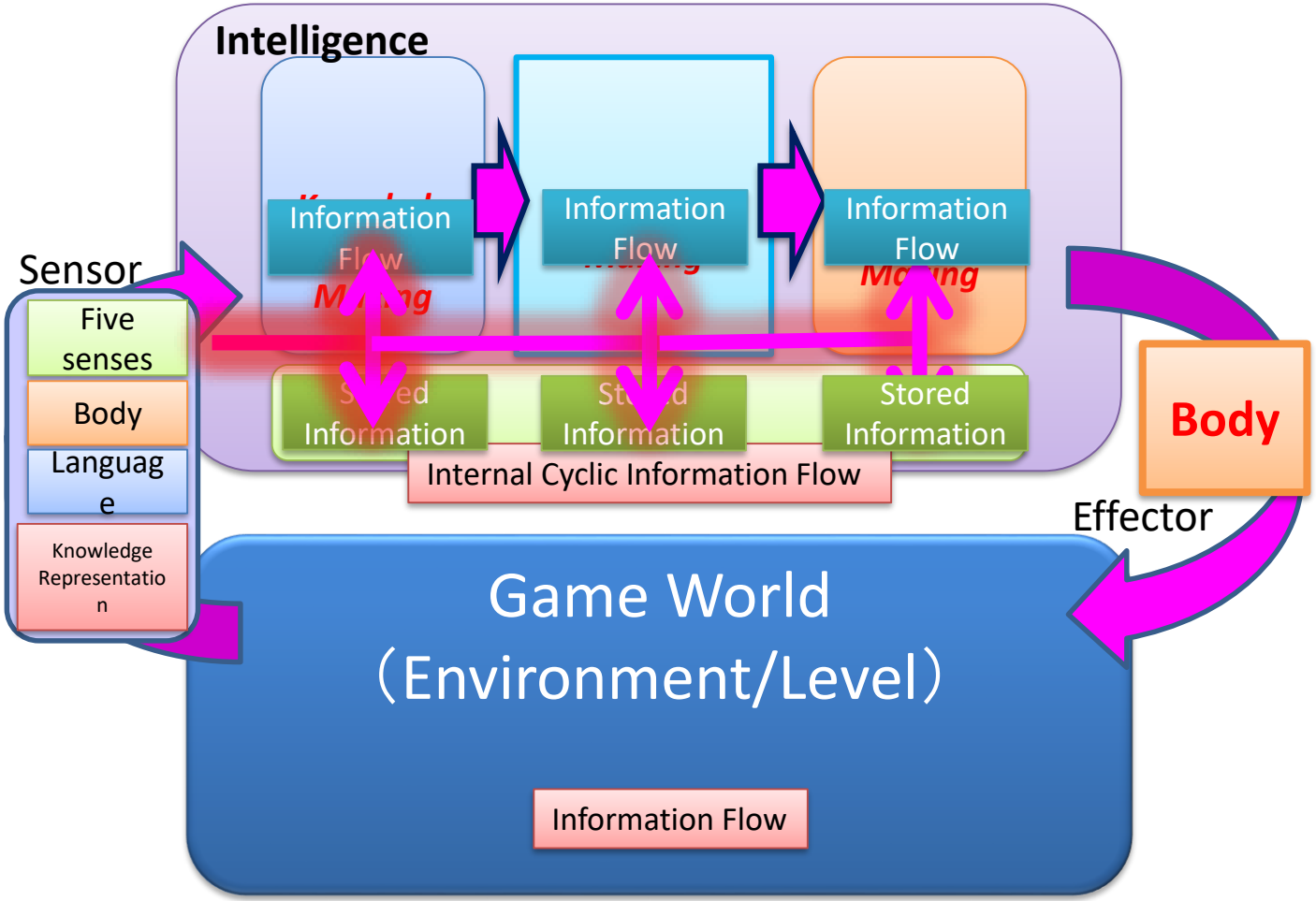


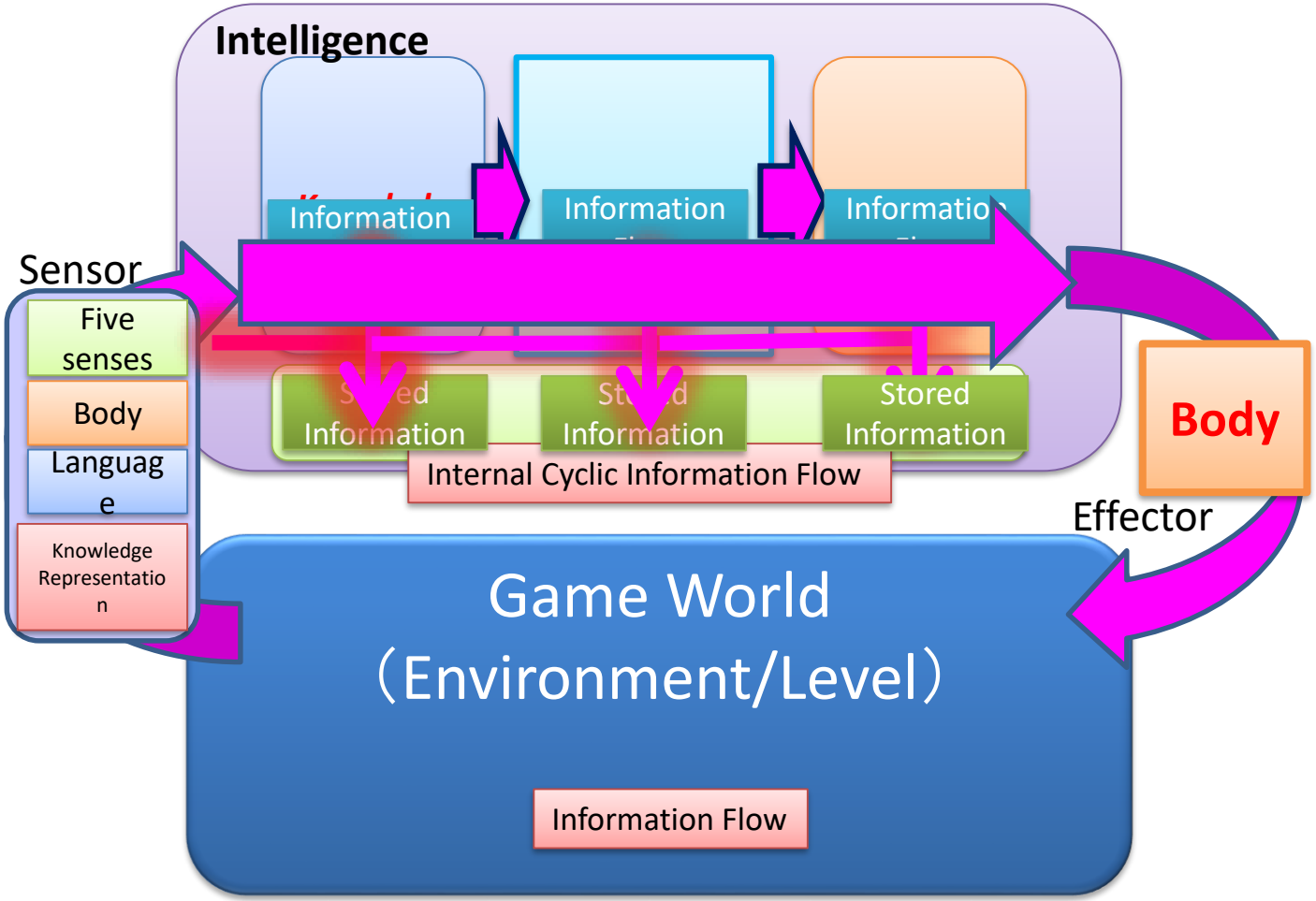
A world which a living thing recognizes consists of two worlds : one is made from inputs via sensors, and the other is made from possibilities of motions.

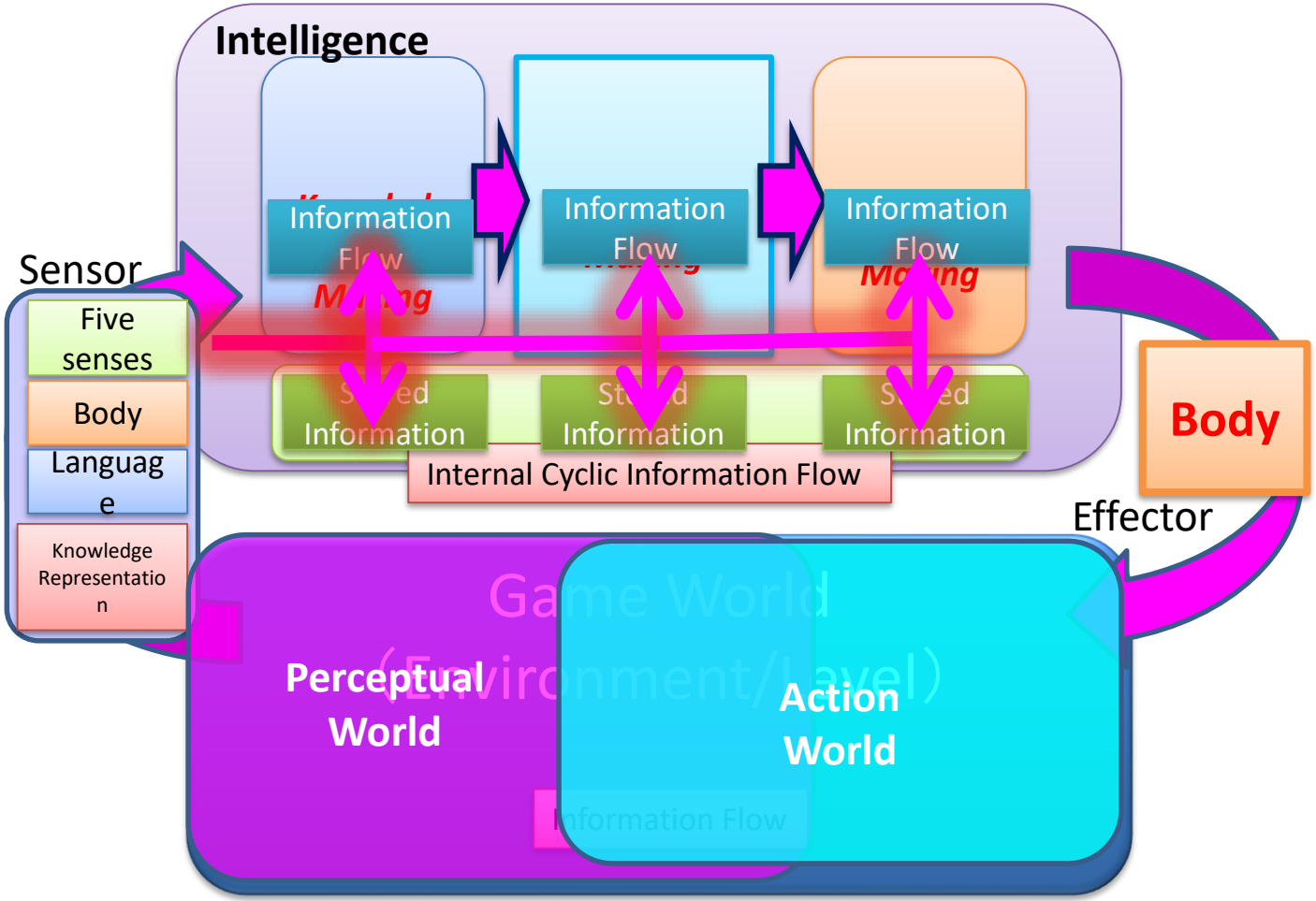


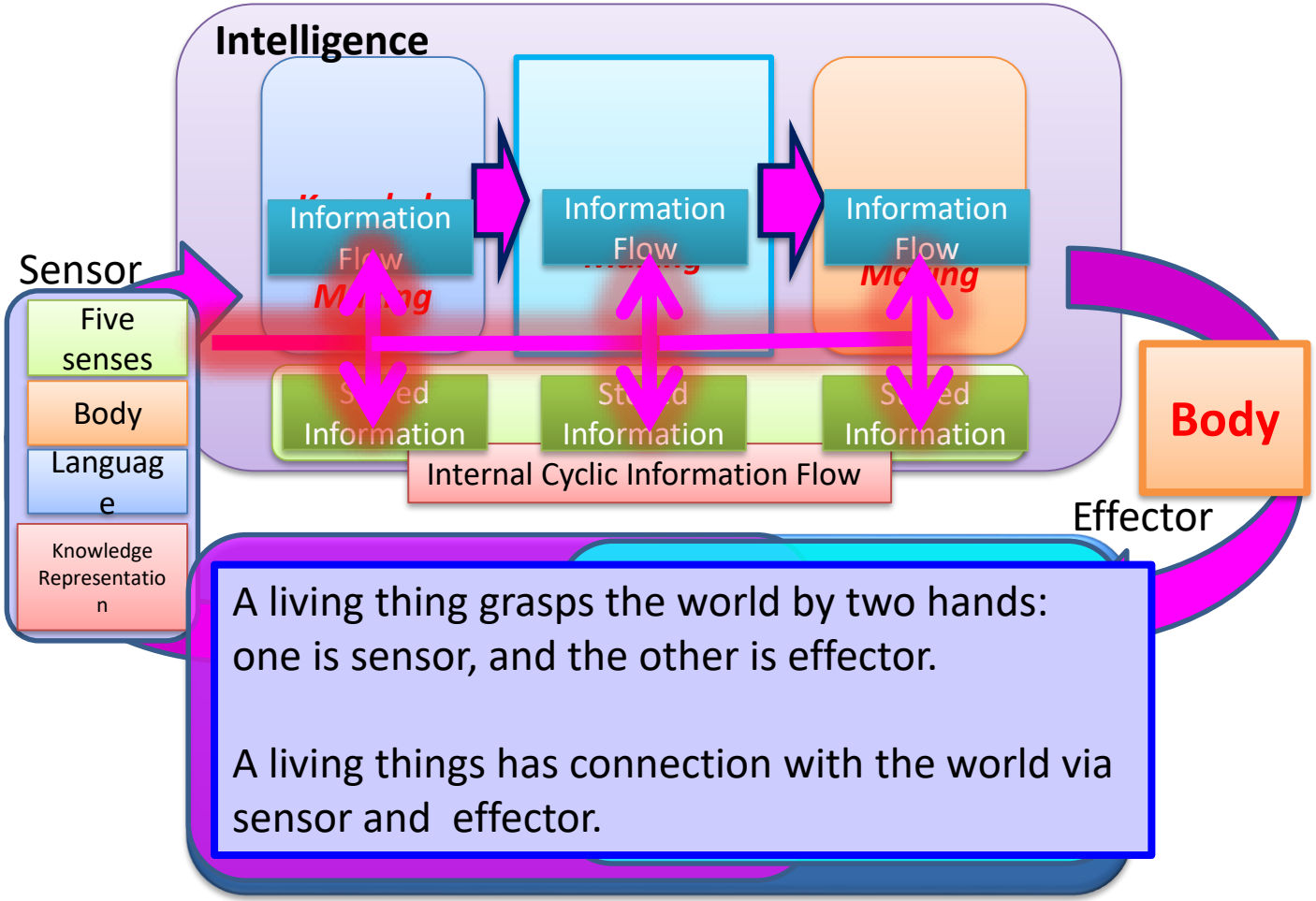


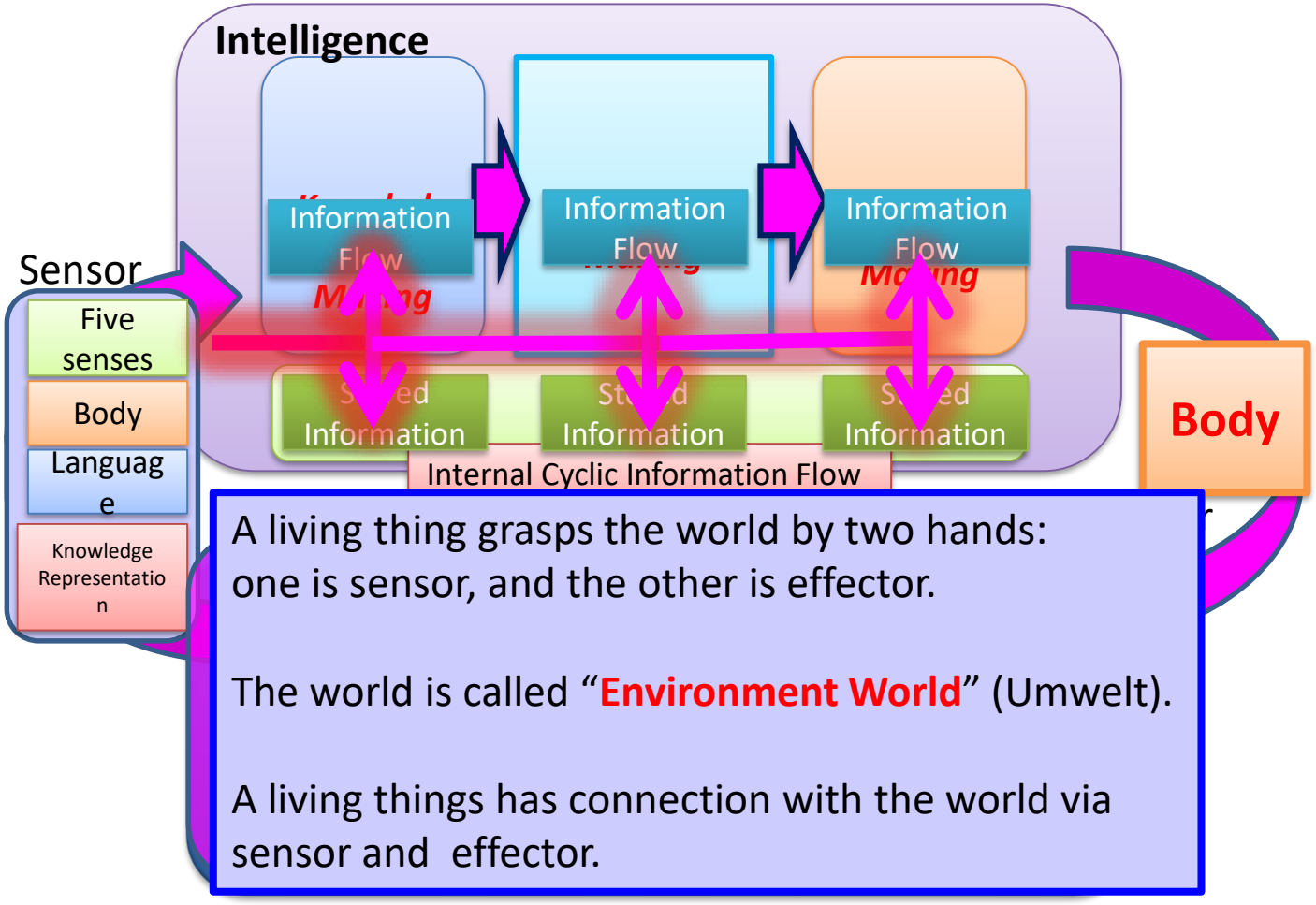




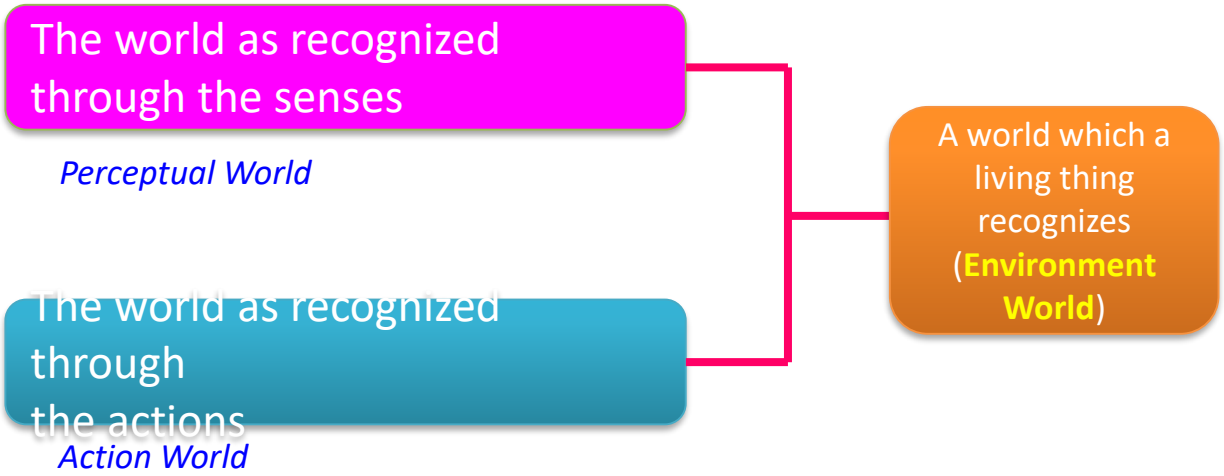






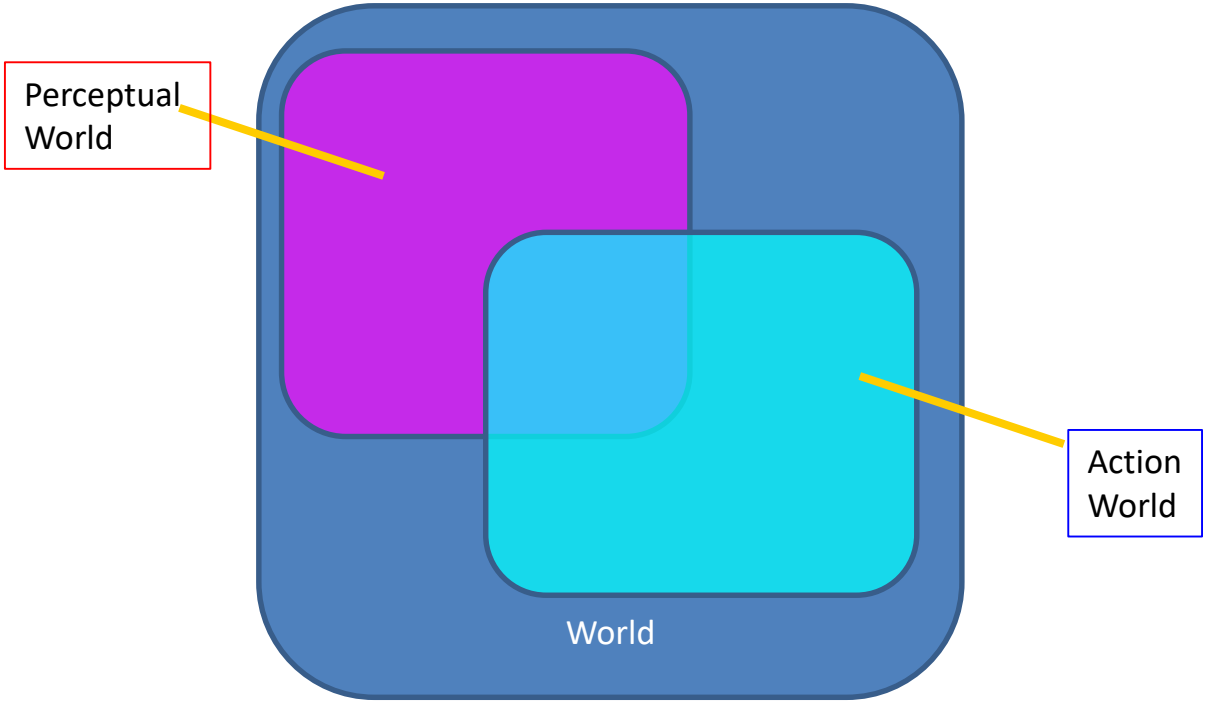


What is environment for a living thing?



An environment world is a subjective world generated by an ecology of a living thing.

Environment World's two faces



Question

What is the difference between an animal's eye and camera eye ?

Comparing of animal and camera eye

	Animal's eye	Camera's eye
Structure	Eyes have connection with body.	Eye is independent.
Who sees ?	Animal itself (Body)	Camera user
What it sees?	Information required for decision-making and recognition and motion (Active)	What is seen（passive）
What it gets	Action and Perceptual World	Pixel
How to see	By moving the body	By moving the camera
When	When the state of the body changes	When a button is pushed
Why	To live	None

Question & Answer

What is difference between
an animal's eye and camera eye ?

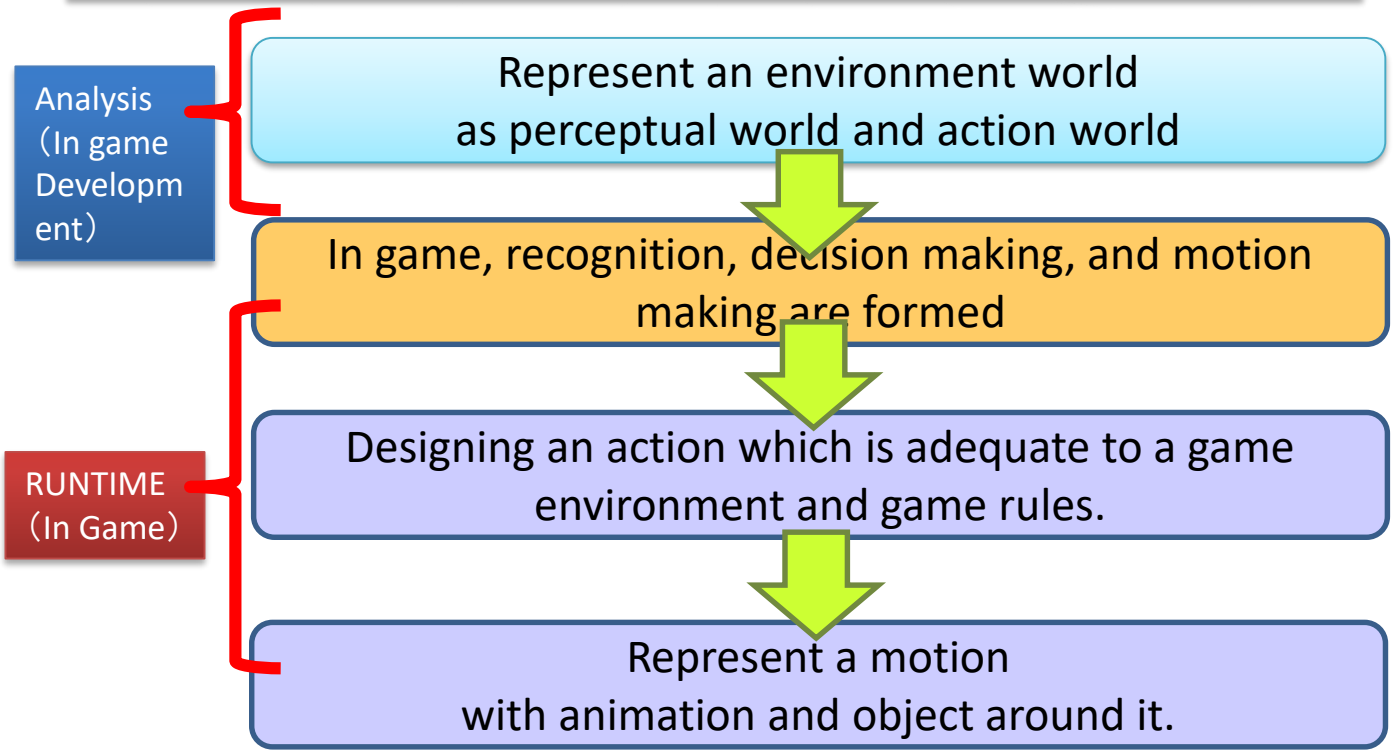
An animal's eyes are connected to its body, and active to get information from the environment.

Camera eyes are a passive device perfectly controlled by a user.

5.0.2

REPRESENTATION OF WHAT AI SEES

Make a motion



Make a motion

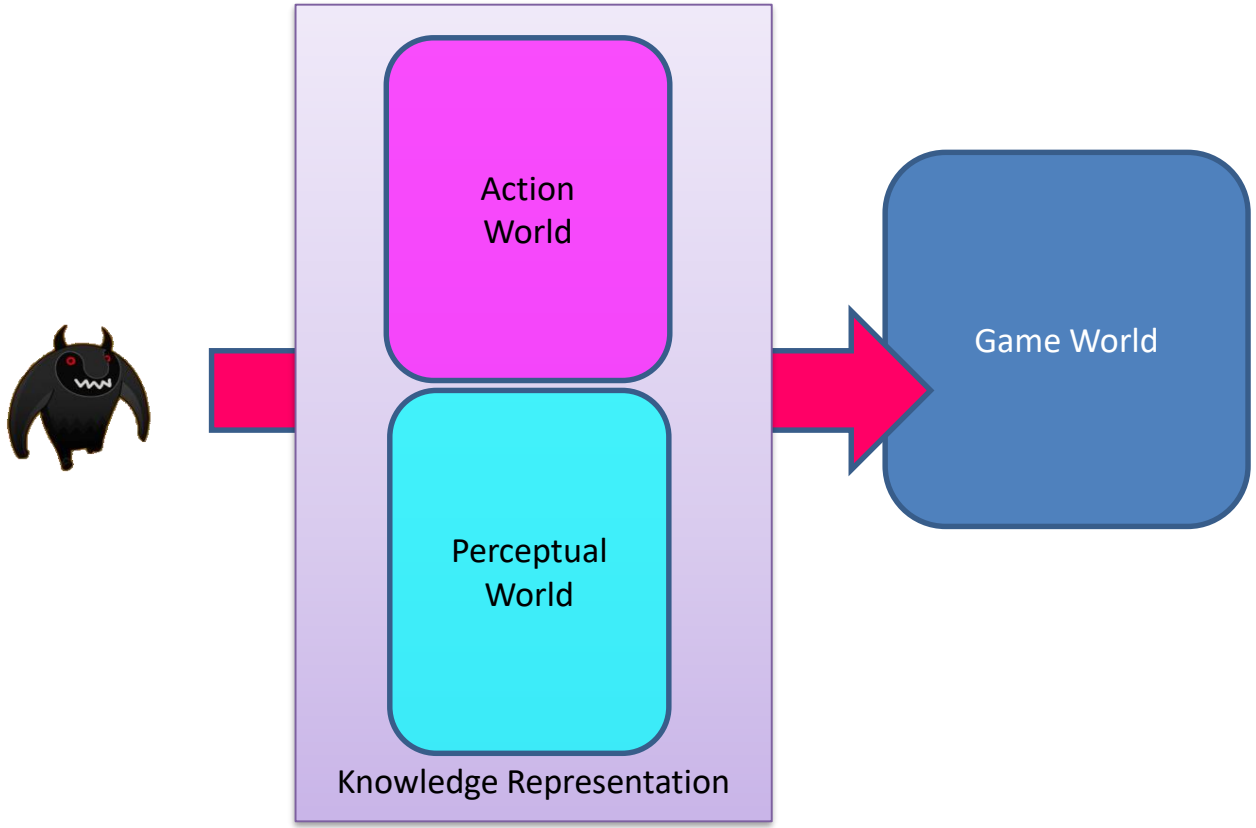
Analysis
（In game
Developm
ent）

Represent an environment world
as perceptual world and action world

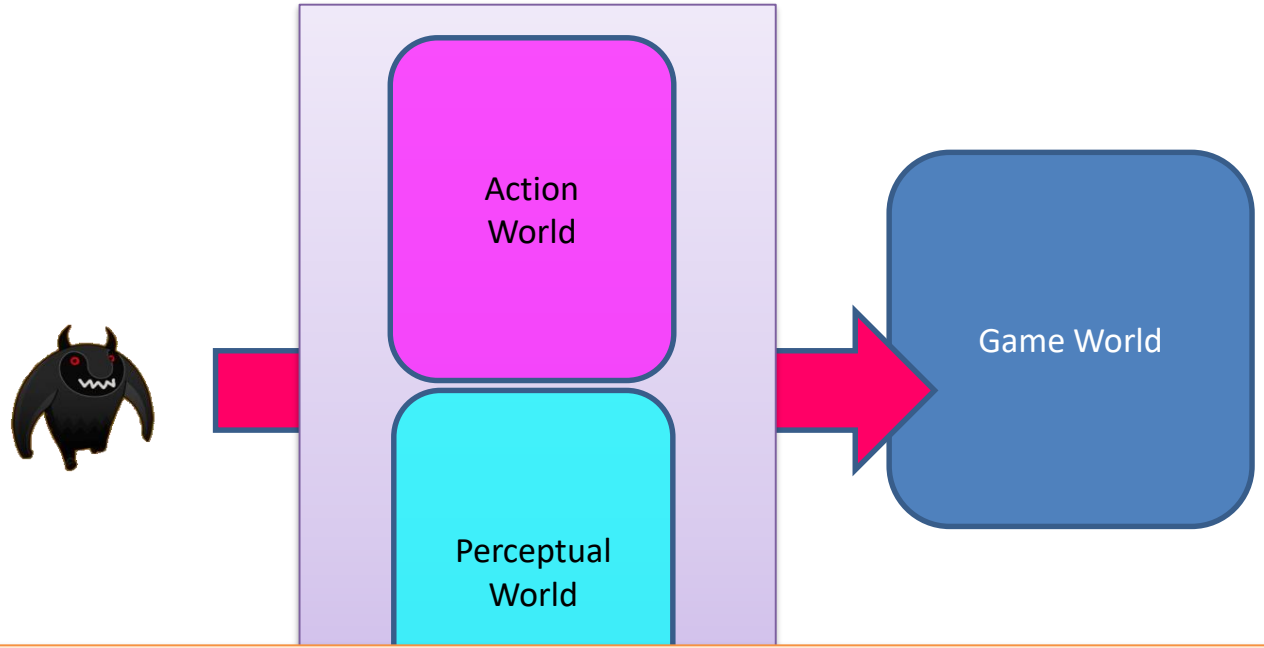
=

In Artificial Intelligence, representation of an environment and object as knowledge is called “**Knowledge Representation** (KR)”.

Knowledge Representation and Action world and Perceptual world



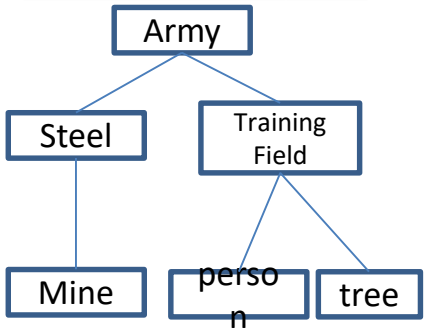
Knowledge Representation and Action world and perceptual world



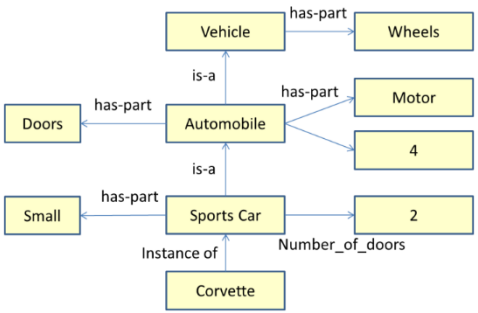
AI understands the game world through knowledge representation. It defines both action world and perceptual world, and subjective world.

Knowledge Representation types Example

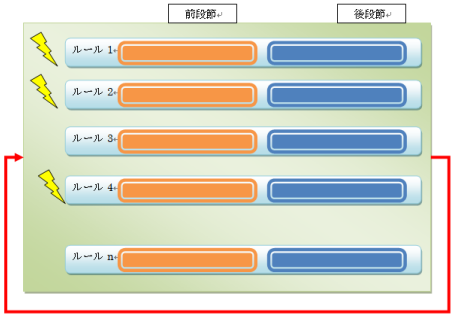
Dependency Graph



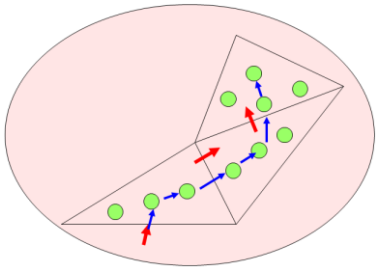
Semantic Net



Rule-based



World Representation



Enemy threat Representation

Target

Perceived data

Location (x,y,z) 0.87

Action shoot 0.40

HP 55 0.82

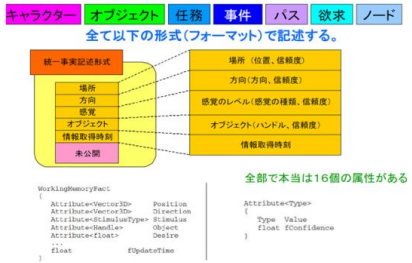
Derived data

Threat 0.8

Target Weight 0.9

“intentions” hurt_me

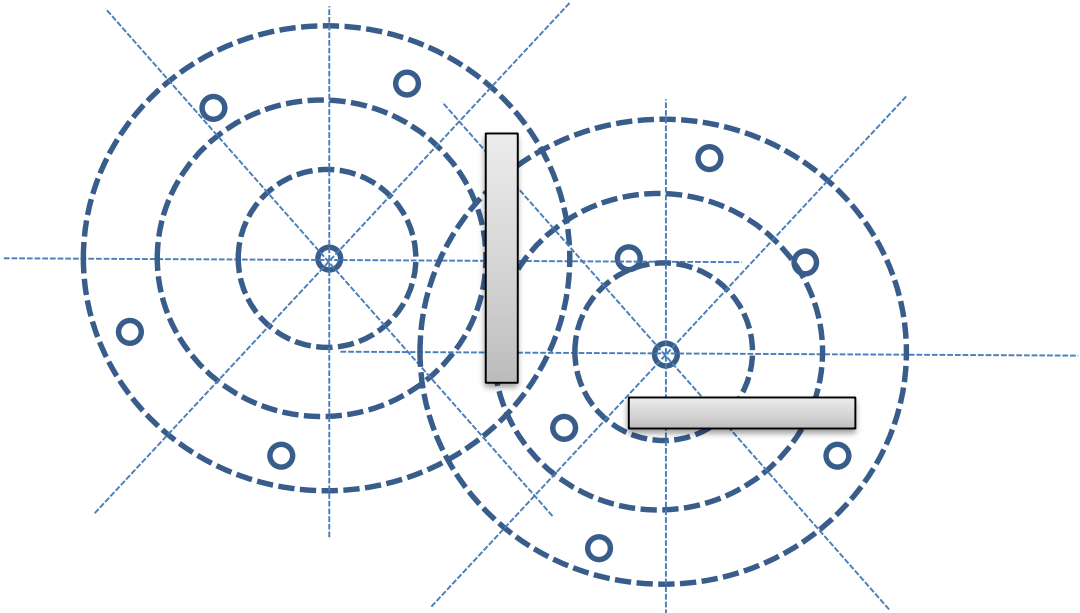
Fact Repsesentation



Griesemer,J, "The Illusion of Intelligence: The Integration of AI and Level Design in Halo", 2002
http://downloads.bungie.net/presentations/gdc02_jaime_griesemer.ppt

World Representation

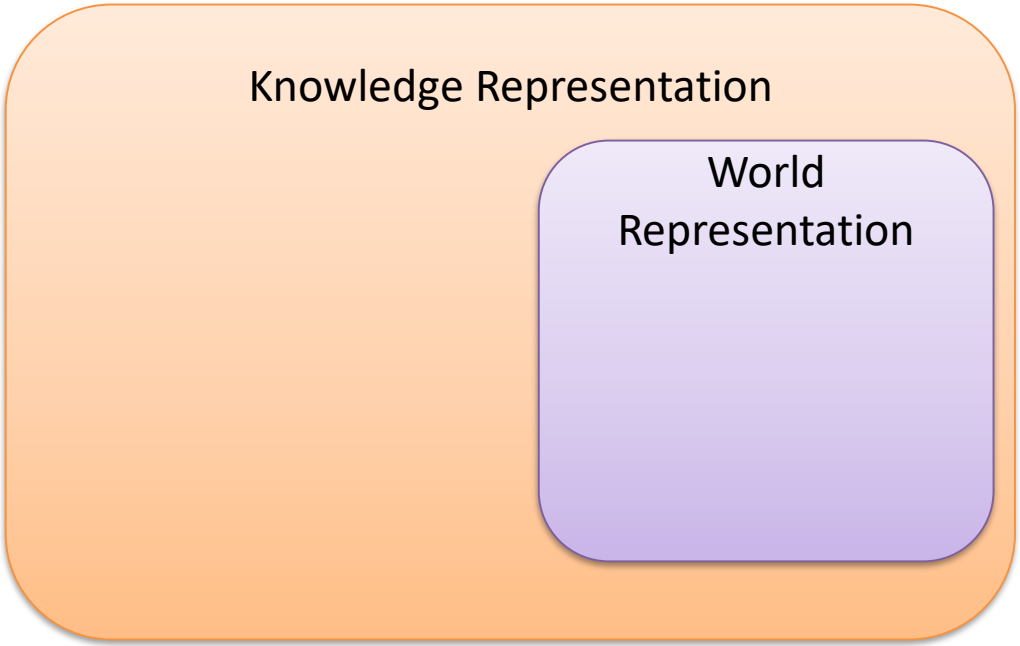
Knowledge Representation for level design
is called **World Representation (WR)**.
WR is based on navigation meshes or waypoints.



（Example） Each waypoint has an 8-direction LOS (Line of Sight) information in Killzone.

Straatman, R., Beij, A., Sterren, W.V.D., "Killzone's AI : Dynamic Procedural Combat Tactics", 2005
http://www.cgf-ai.com/docs/straatman_remco_killzone_ai.pdf

Knowledge Representation and World Representation

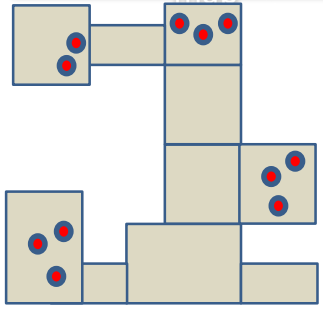


World Representation Example

Damian Isla,"Building a Better Battle: HALO 3 AI Objectives", http://halo.bungie.net/inside/publications.aspx

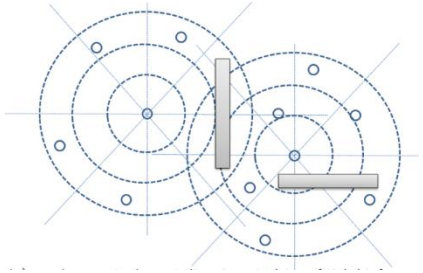
Dude, Where's My Warthog: From Pathfinding to General Spatial Competence, D. Isla, Invited talk, Artificial Intelligence and Interactive Digital Entertainment (AIIDE) 2005
http://naimadgames.com/publications.html

map



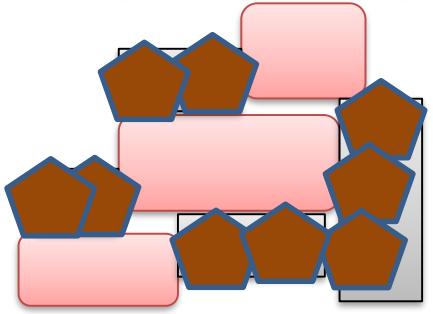
Left 4 Dead

LOS Map



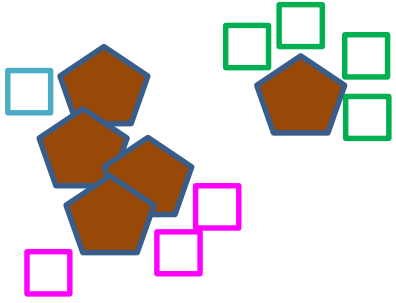
Killzone

Territory Representation



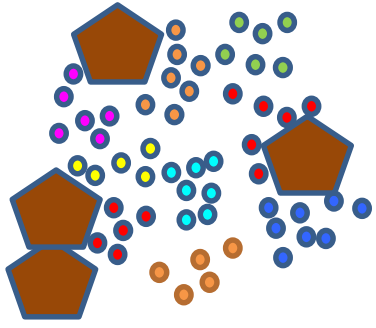
Halo2

Tactical Point System



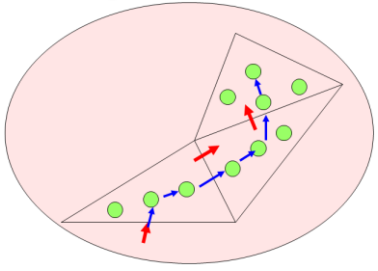
Halo

Waypoint Clustering



Killzone2

NavMesh/Waypoint Hierarchical Representation

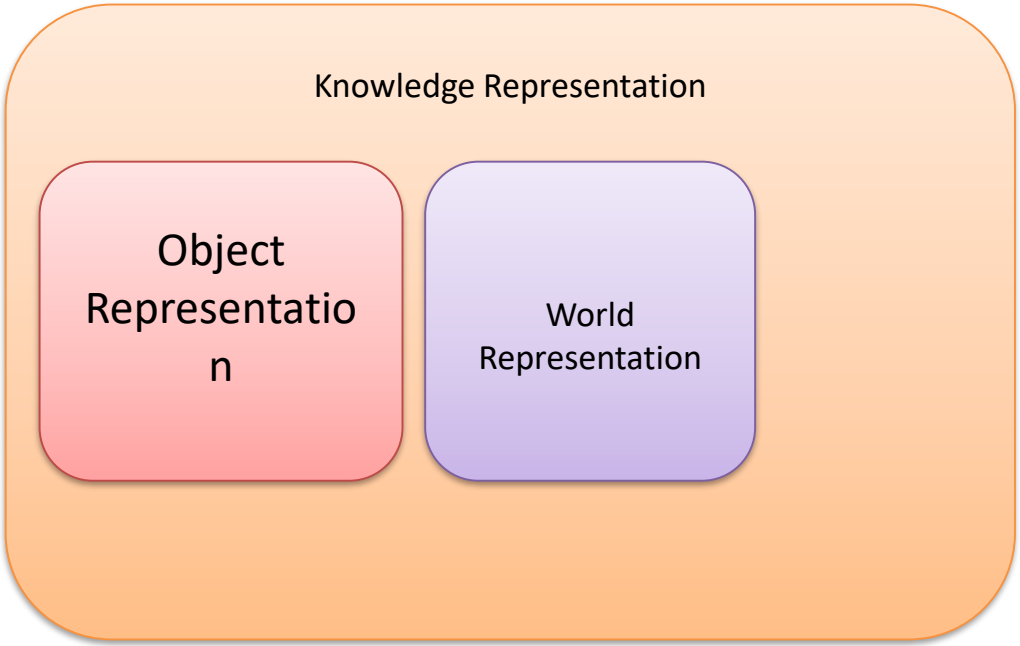


Assassin's Creed

Michael Booth, "The AI Systems of Left 4 Dead," Artificial Intelligence and Interactive Digital Entertainment Conference , http://www.valvesoftware.com/company/publications.html

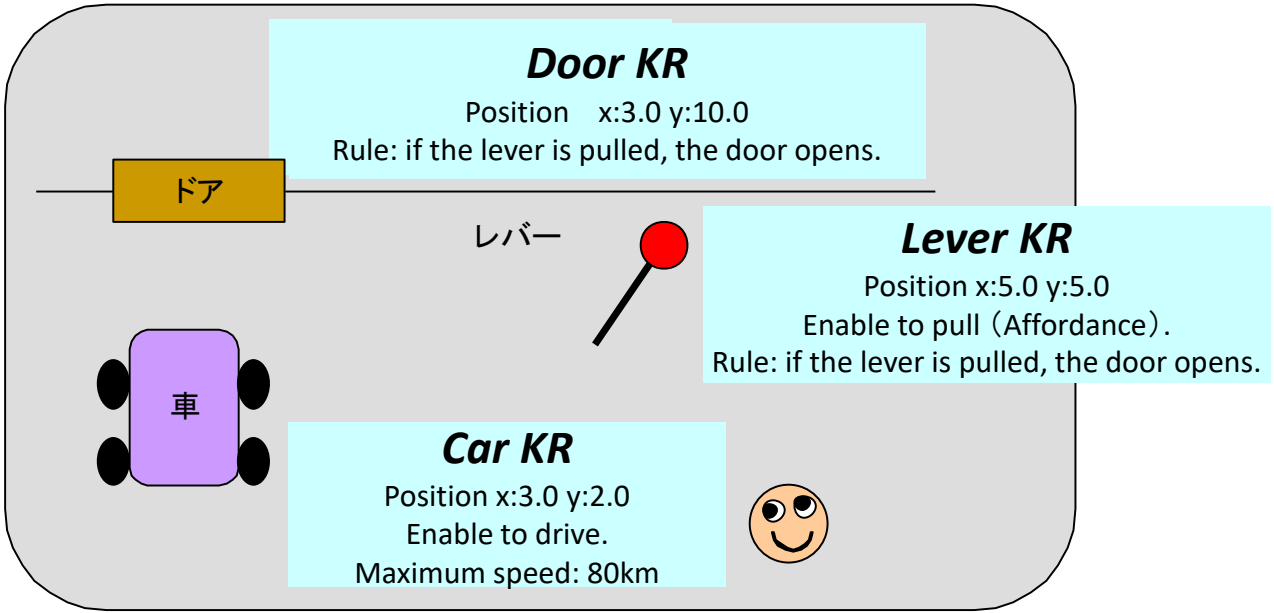
Alex J. Champandard, Remco Straatman, Tim Verweij, "On the AI Strategy for KILLZONE 2's Bots"
http://aigamedev.com/open/coverage/killzone2/

Knowledge Representation・World Representation

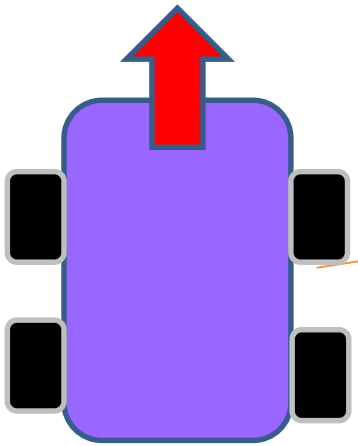


Object Representation

Representation of an object



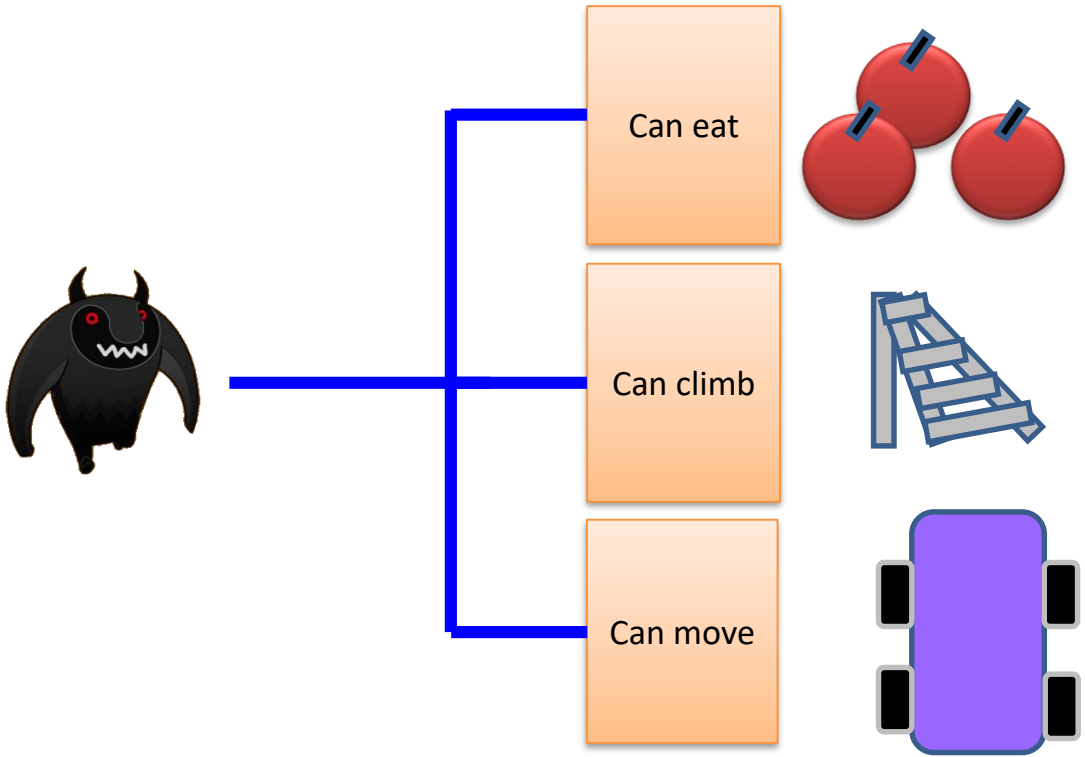
Object Representation



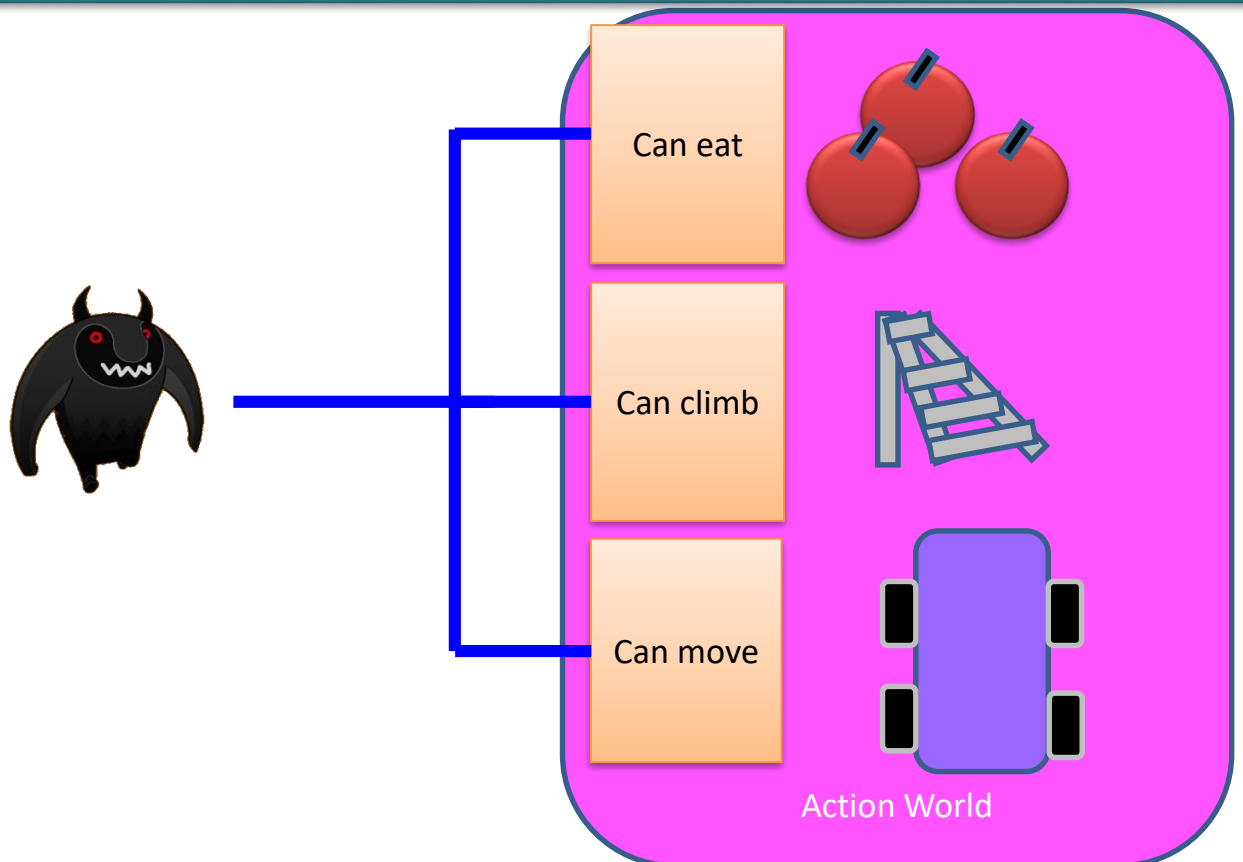
This is a car.
A vector shows the direction
In which the car can move.

Dude, Where's My Warthog: From Pathfinding to General Spatial Competence, D. Isla, Invited talk, Artificial Intelligence and Interactive Digital Entertainment (AIIDE) 2005 http://naimadgames.com/publications.html

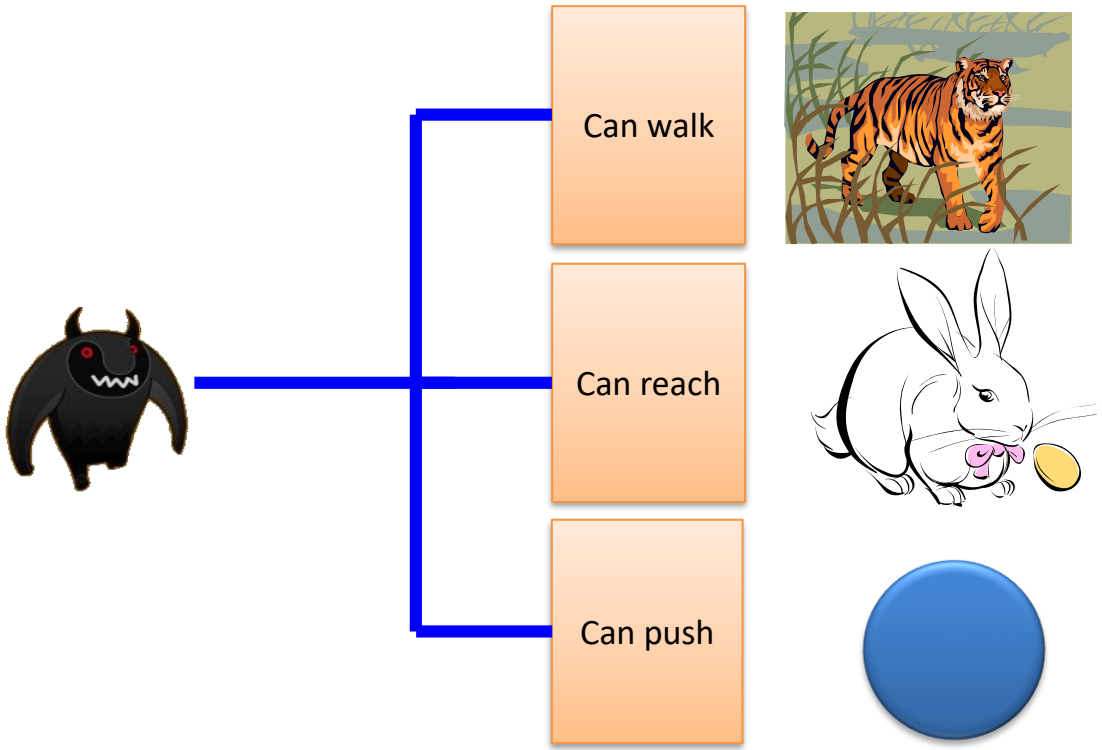
Affordance



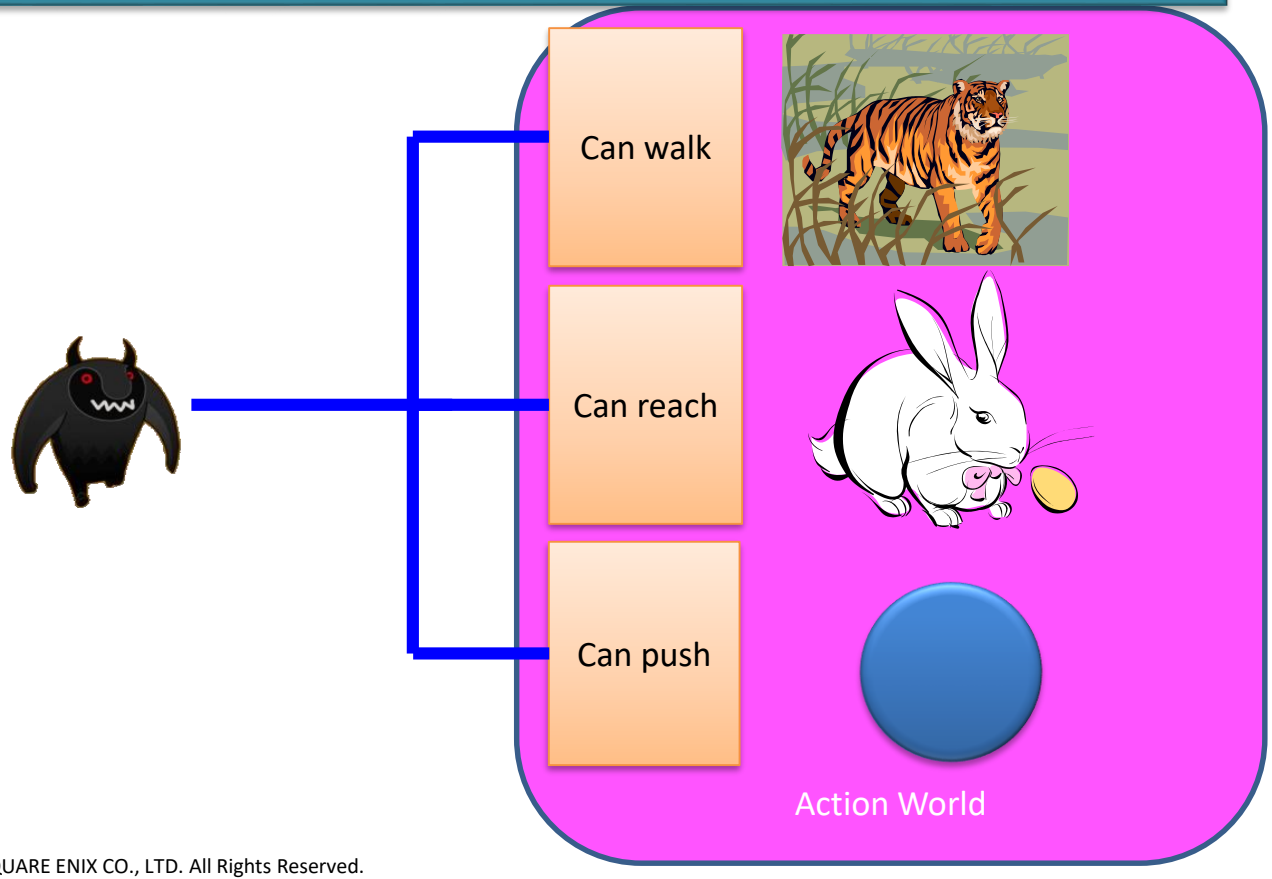
Affordance

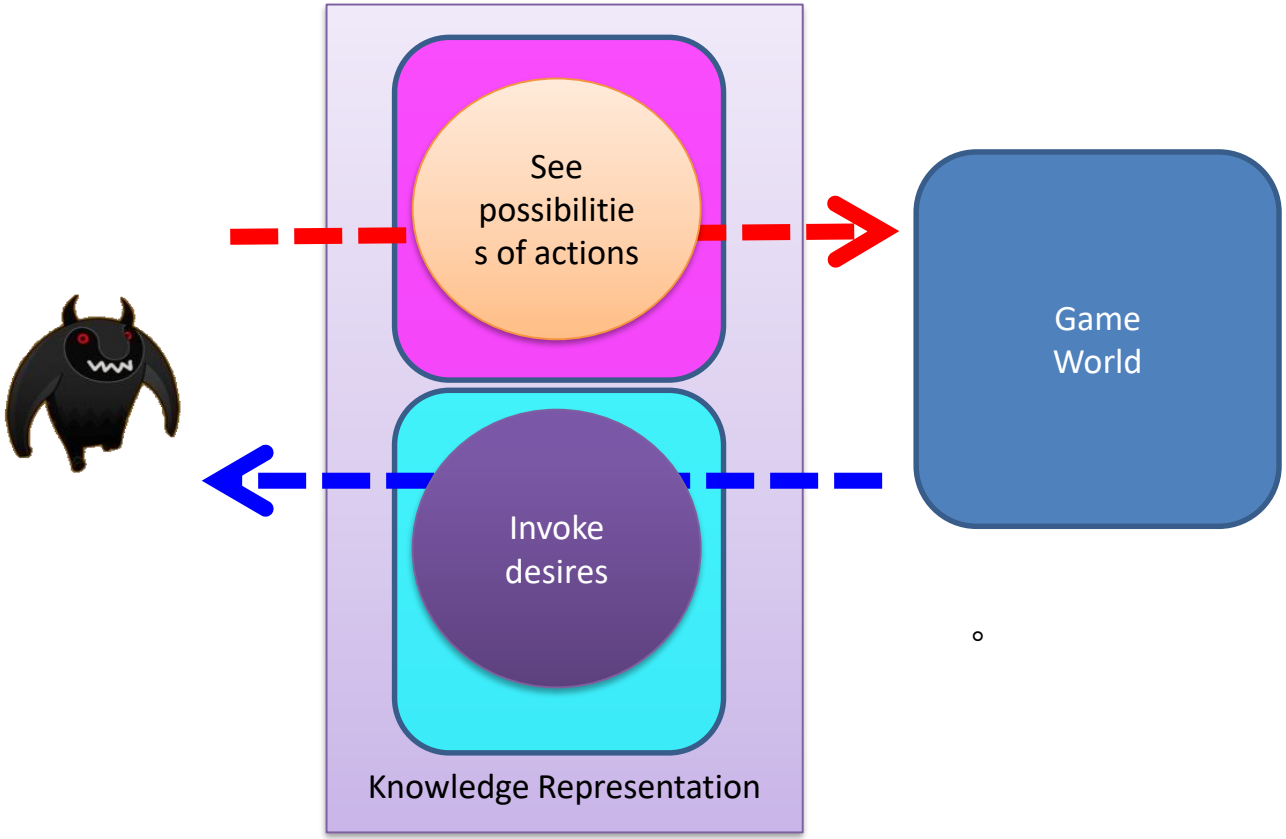


アフォーダンス



アフォーダンス





5.0.3

WALKING

Move a character

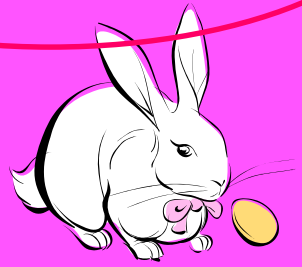
How to realize an action in the game world ?

Now we'll focus on character's walking.

Affordances

Can walk

Can reach



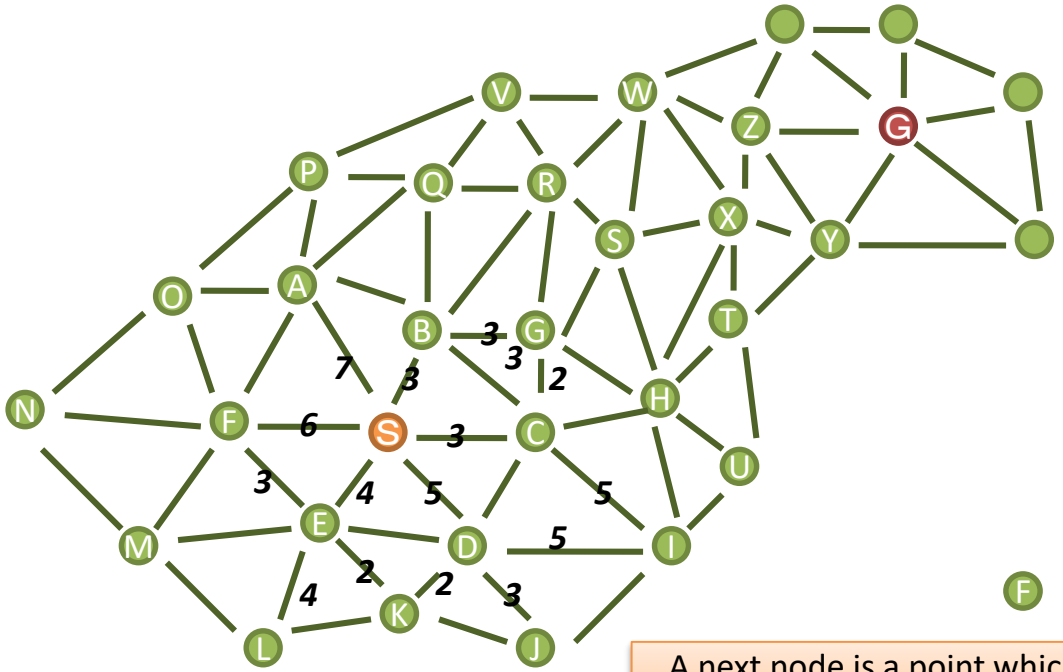
Can push

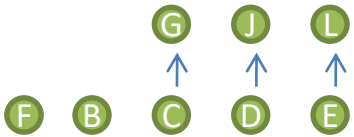
作用空間

Path search on networked Graph

Dijkstra's Algorithm

Evaluation for each node = sum of path from a start point



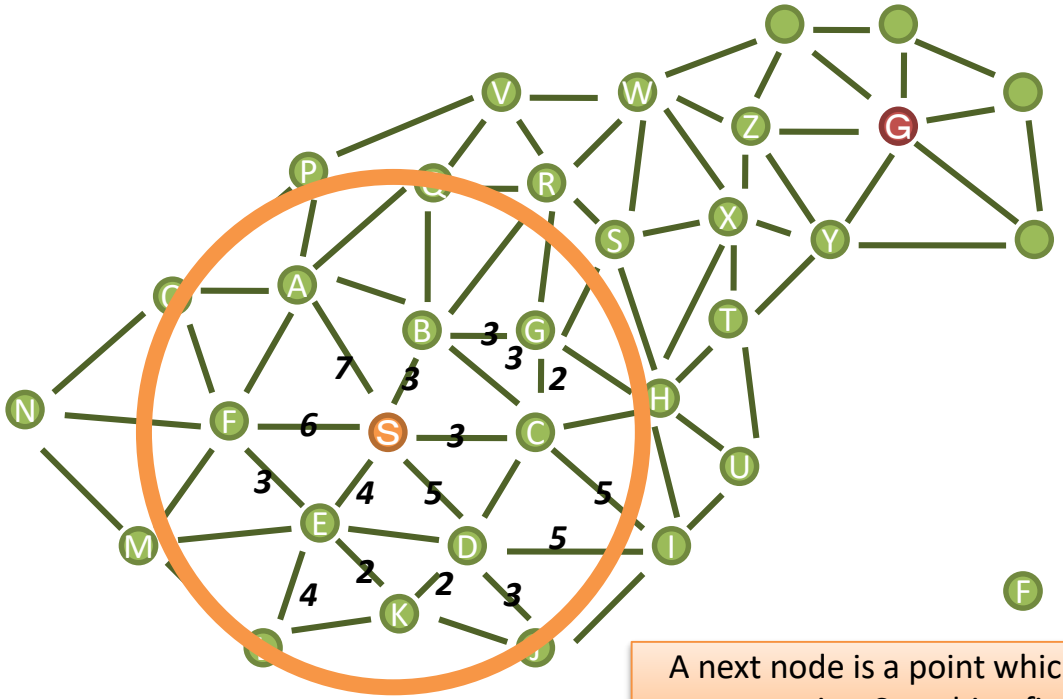


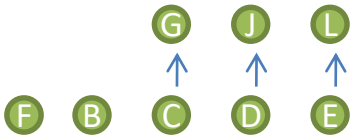
A next node is a point which is shortest from a start point. Searching finishes at the goal.

Path search on networked Graph

Dijkstra's Algorithm

Evaluation for each node = sum of path from a start point





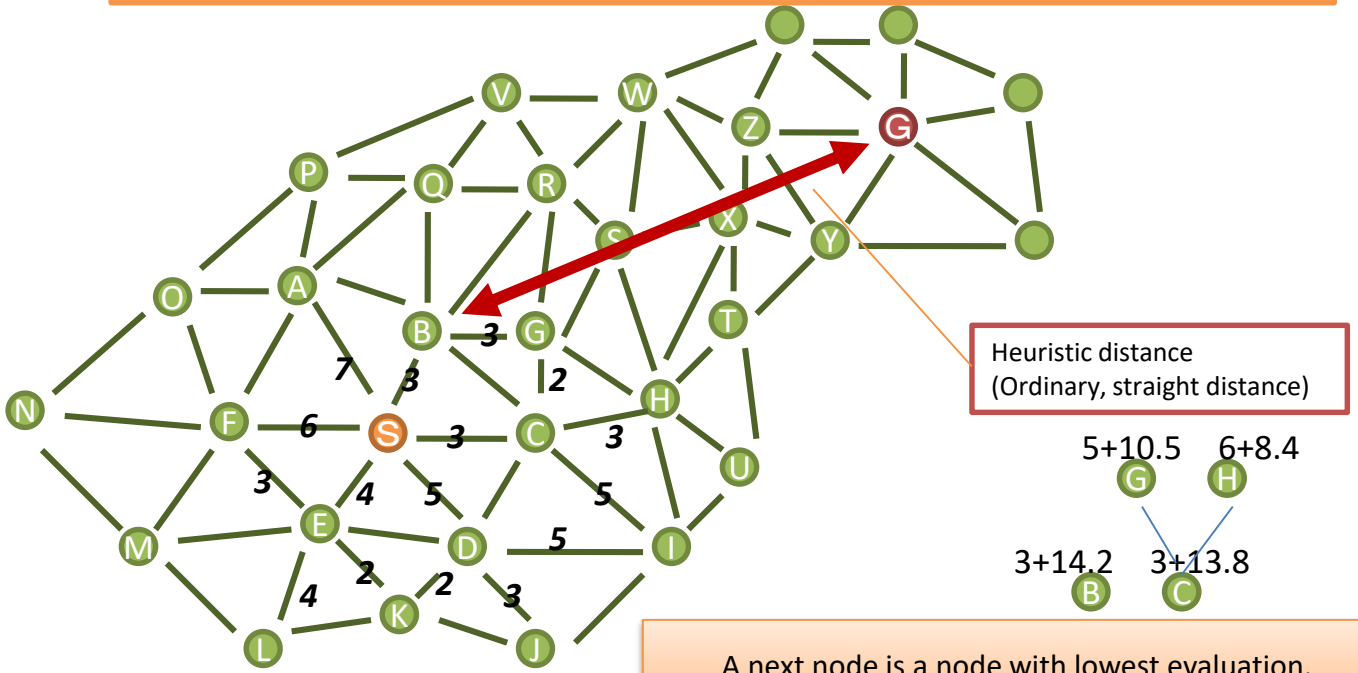
A next node is a point which is shortest from a start point. Searching finishes at the goal.

Path search on networked Graph

A* algorithm

When the position of goal is already known,
path search uses done by using heuristic distance.

Evaluation for each node ＝ sum of path from a start point + Heurisitic distance



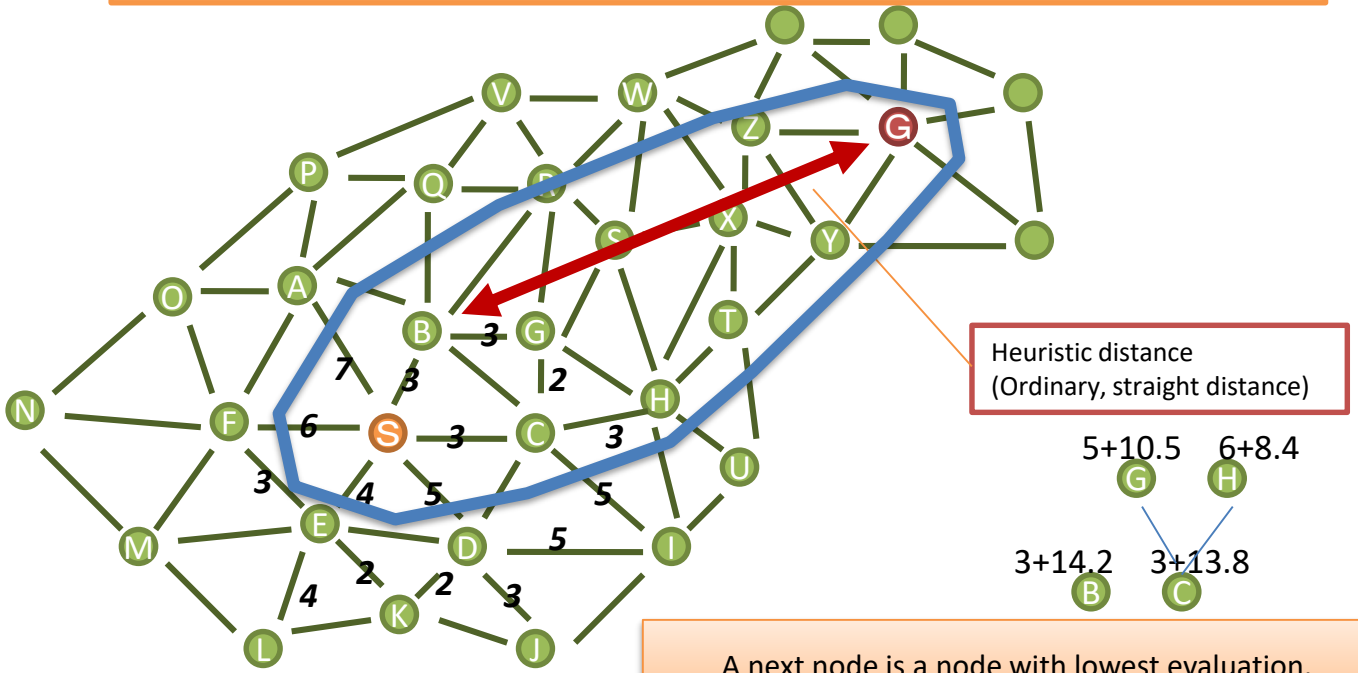
A next node is a node with lowest evaluation.

Path search on networked Graph

A* algorithm

When the position of goal is already known,
path search uses done by using heuristic distance.

Evaluation for each node ＝ sum of path from a start point + Herusitic distance



Heuristic distance
(Ordinary, straight distance)

5+10.5 6+8.4

G H

3+14.2 3+13.8

B C

A next node is a node with lowest evaluation.

Counter Strike (2000) : Nav Mesh

The Official Counter-Strike Bot
http://aigamedev.com/insider/presentation/official-counter-strike-bot/

Dragon Age : Way Point

Dragon Age pathfinding program put to the test
https://www.youtube.com/watch?v=l7YQ5_Nbifo

5.0.4

SMART TERRAIN

Smart Terrain

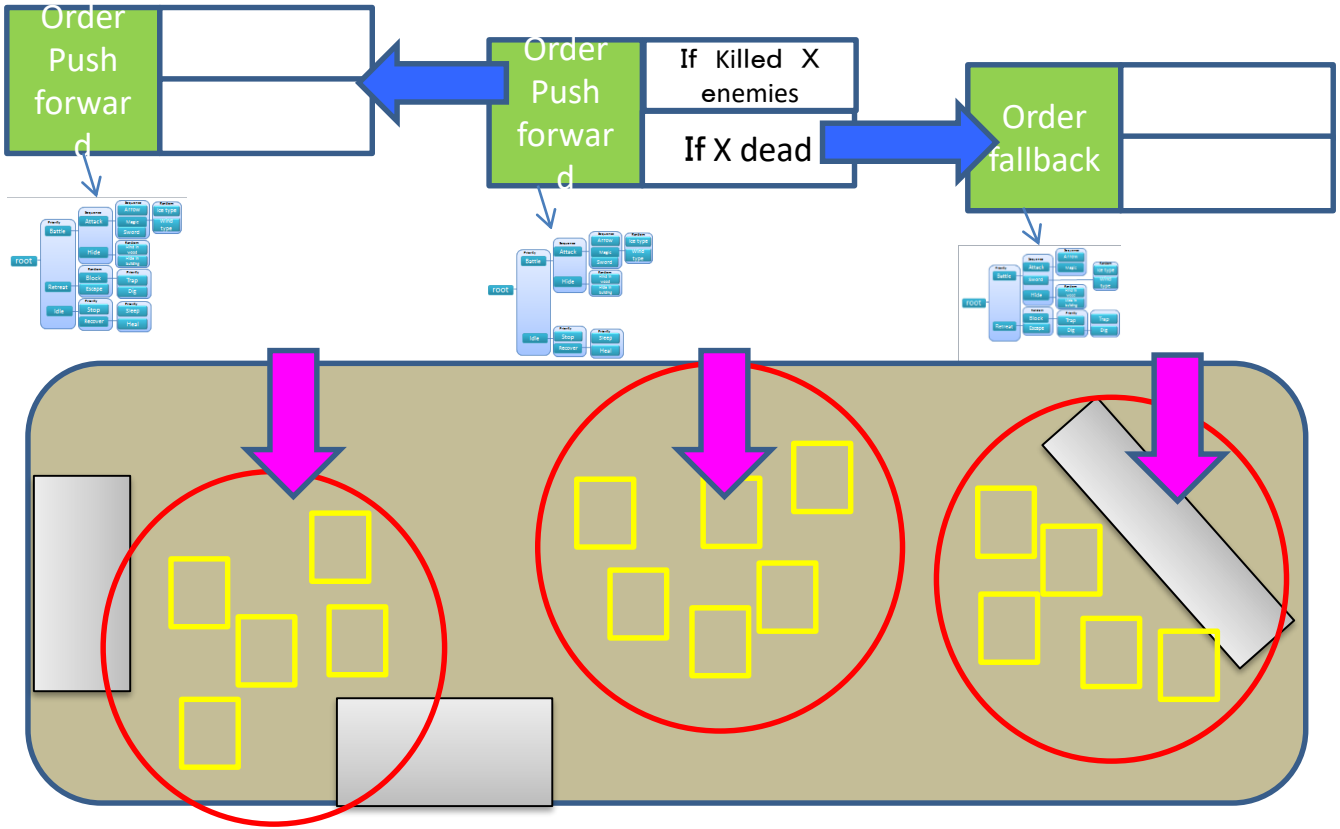
- Some points attached to an object or a terrain which help a character make an action with the object.
- The point has a logic, an animation to use the object
- It suggests the action when a character closes with it.

http://www.gdcvault.com/play/1020831/Bringing-BioShock-Infinite-s-Elizabeth

3.6.

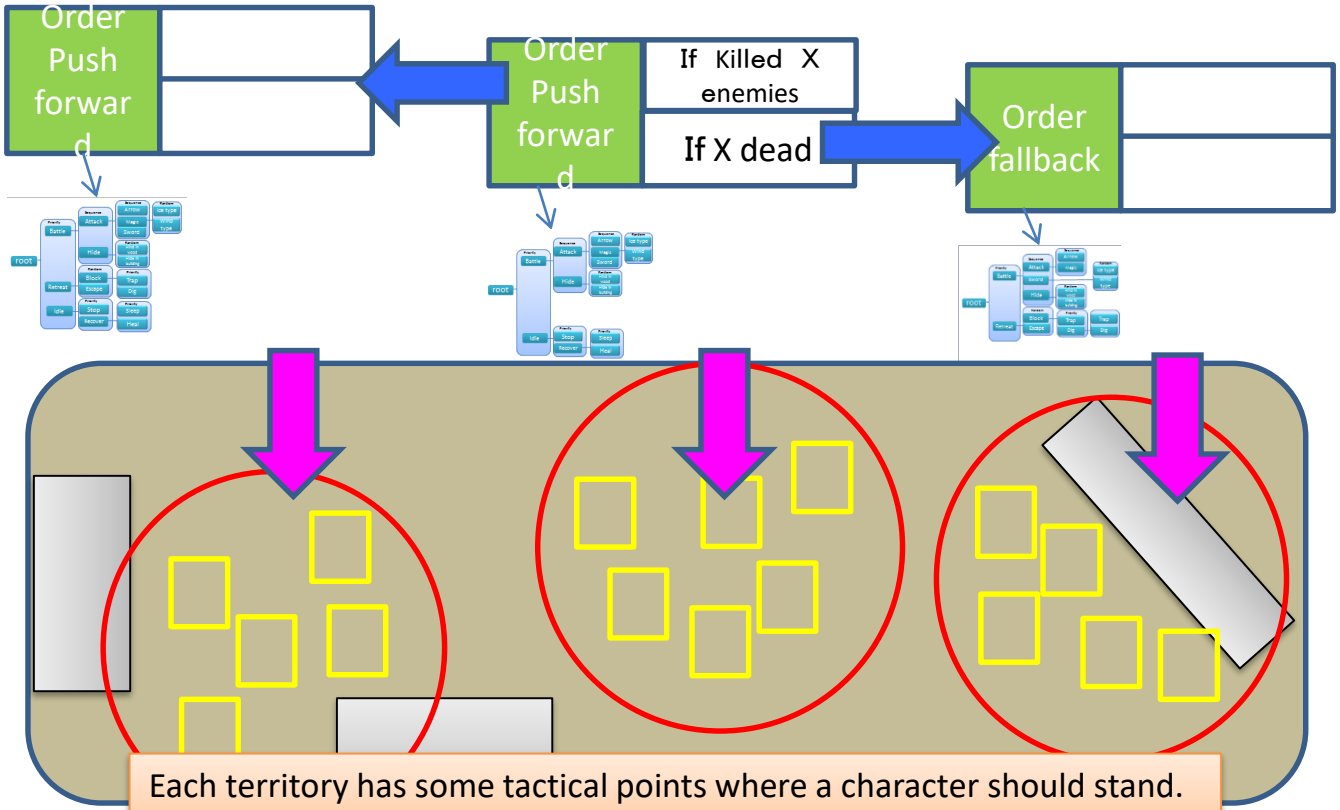
DECISION MAKING AND WORLD REPRESENTATION

Halo2: Orders & Styles



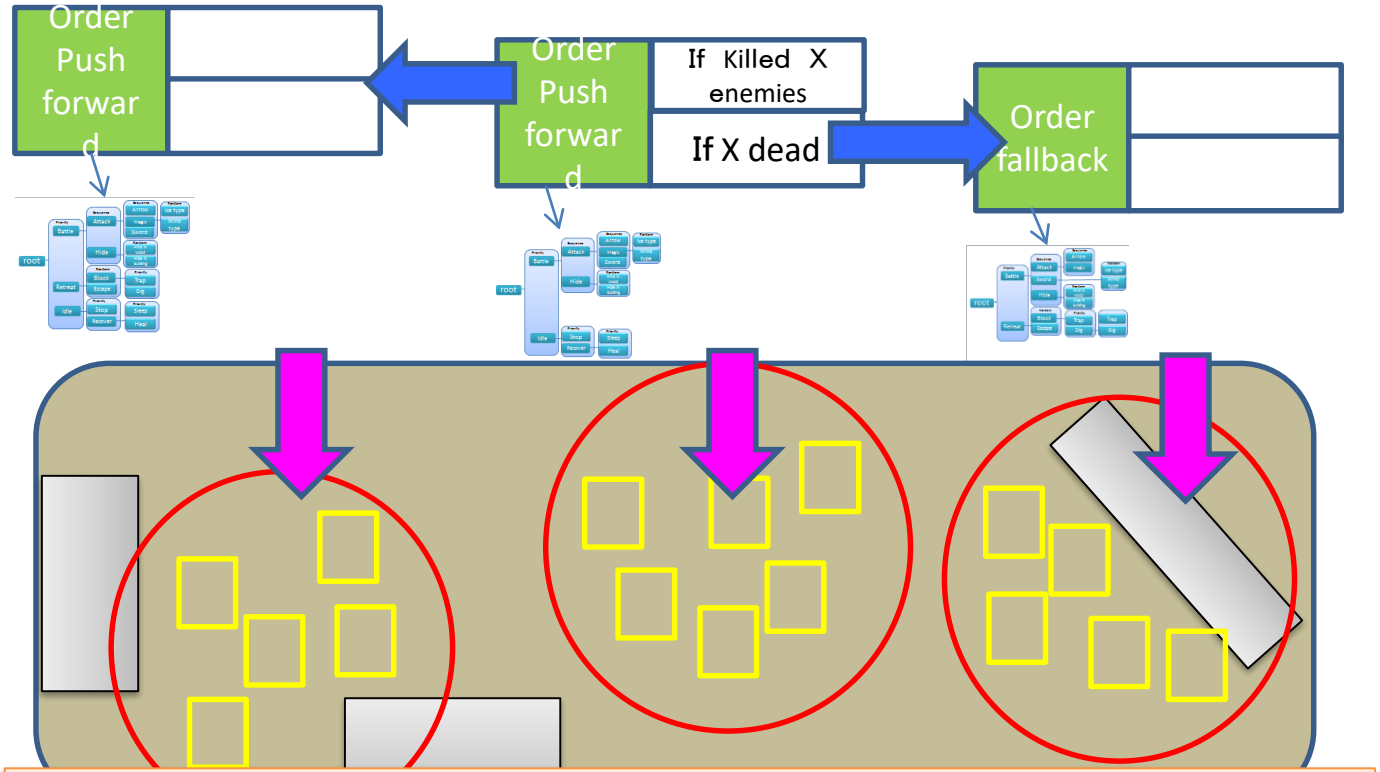
Handling Complexity in the Halo 2 AI, D. Isla, GDC 2005
http://naimadgames.com/publications.html

Halo2: Orders & Styles



Handling Complexity in the Halo 2 AI, D. Isla, GDC 2005
http://naimadgames.com/publications.html

Halo2: Orders & Styles



Each territory has a different behavior tree which is used by the character who enters in it.

Handling Complexity in the Halo 2 AI, D. Isla, GDC 2005
http://naimadgames.com/publications.html

Summary

- Making a character's subjective world means making a meaningful world.
- A subjective world consists of Action World and Perceptual World.
- The two worlds consist of Knowledge Representation, World Representation, and Object Representation.
- A subjective world enables characters to take an action by themselves.

Digital Game AI

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Chapter 5

NAVIGATION AI

Chapter 5.1

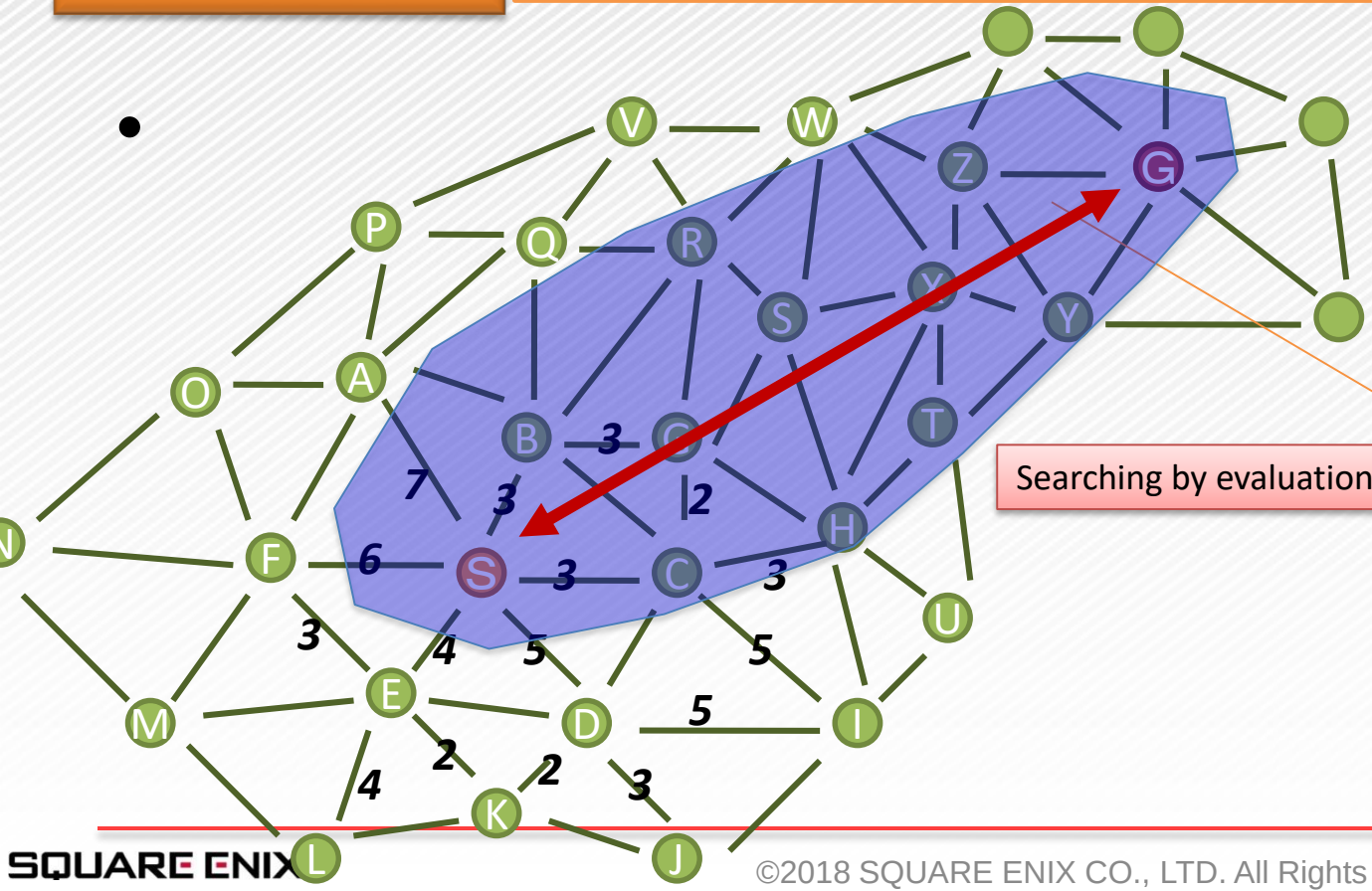
PATHFINDING SYSTEM

SQUARE ENIX

Graph Search on networked Graph

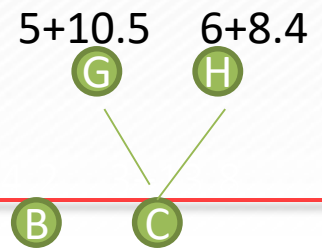
A* Algorithm

Evaluation distance ＝distance form start ＋ Heuristic distance

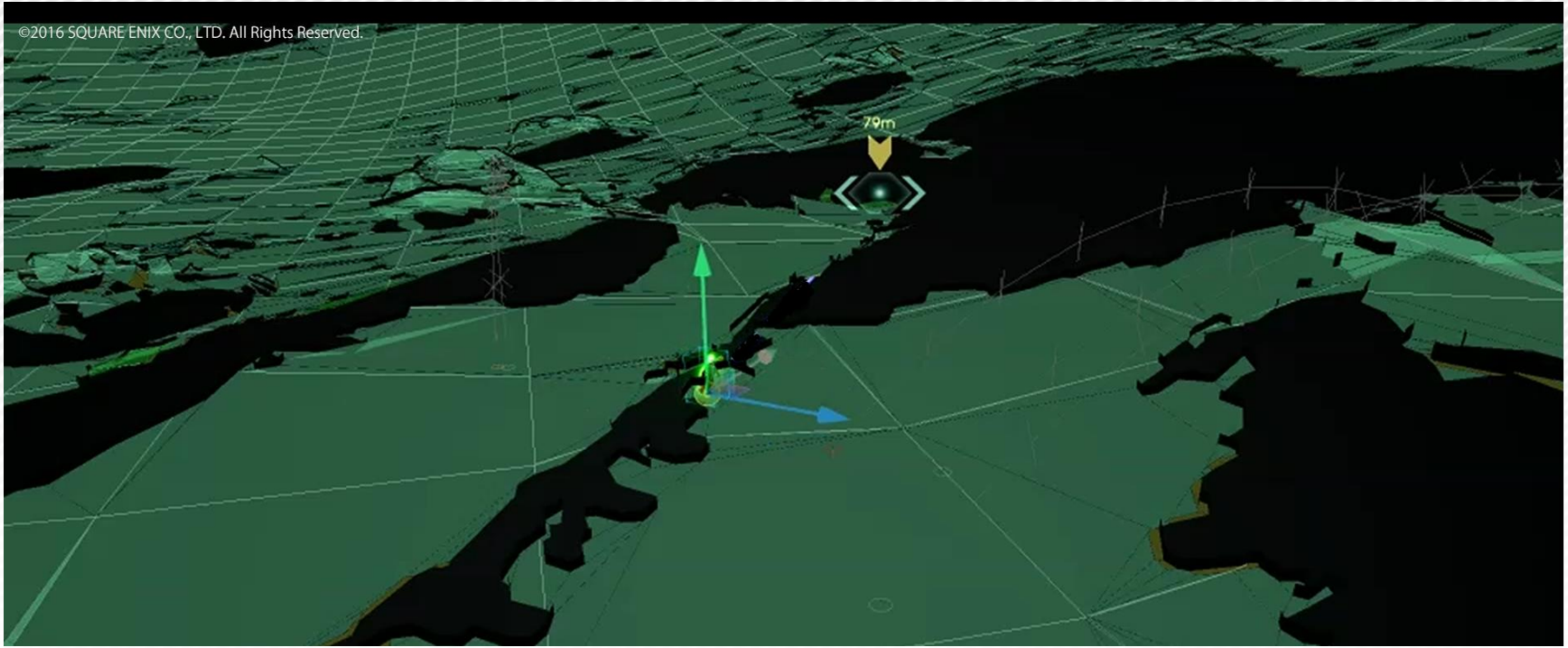


Heuristic
(Euclid distance)

Searching by evaluation distance



FFXV Navigation Mesh



Navigation QA

- Nightly build of all maps
- Navigation mesh for each character size
- Overview on the development site
- Viewing the difference

FFXV Navigation mesh

Digital Game AI

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Chapter 5.2

POINT QUERY SYSTEM

SQUARE ENIX

History of Tactical Point Search

- Tactical Position Picking
  Killzone (2005, Guerrilla) in Program
- TPS (Tactical Point System)
  CRYENGINE (2010, CRYTEK) Tool & Runtime System
- EQS(Environment Query System)
  UNREAL ENGINE 4（2014, Epic games）Tool & Runtime System
- PQS (Point Query System)
  FINAL FANTASY XV (2016, SQUARE ENIX)

Point Query System

A system to find a best positon

- for a character’s ability
- in a terrain
- in real-time

Point Query System principle

Point distribution（Generation）
distributing point around the objective（例）grid、circle

Filtering
Removing points not adjust for a purpose by a conditon (1)

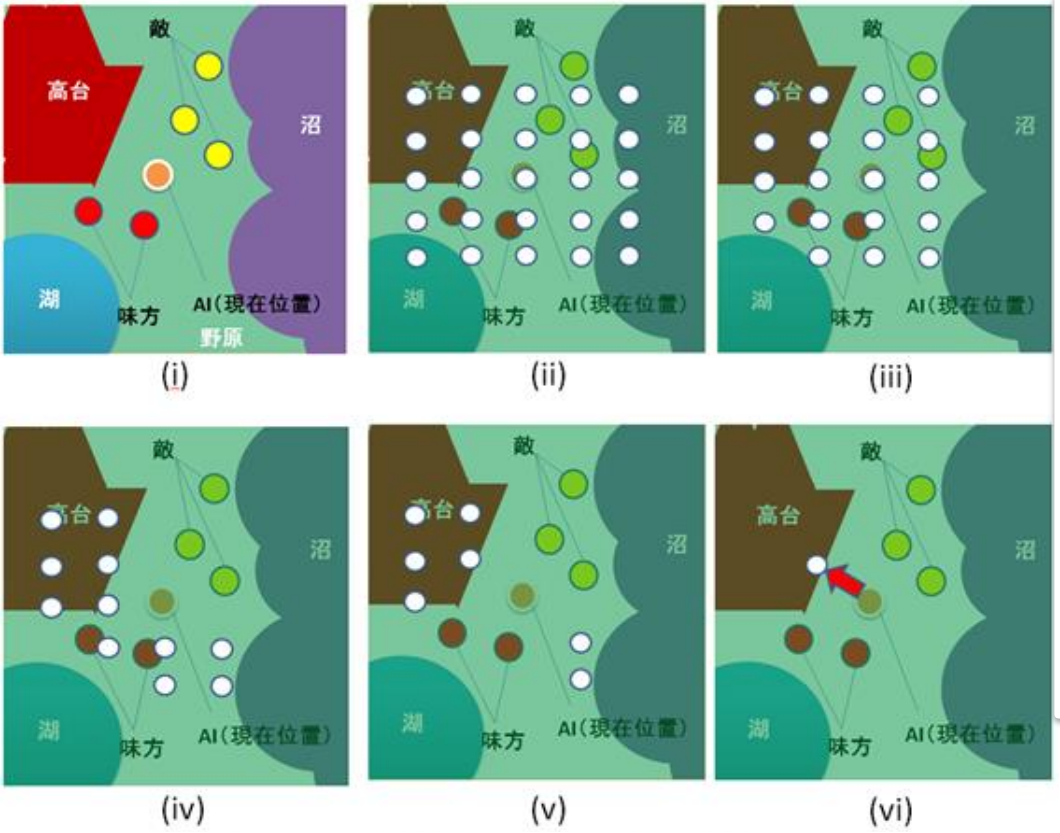
Filtering
Removing points not adjust for a purpose by a conditon (2)

.
.

Filtering
Removing points not adjust for a purpose by a conditon (N)

Evaluation
Evaluation for remained points and pick up one points with best score

PQS (Point Query System)



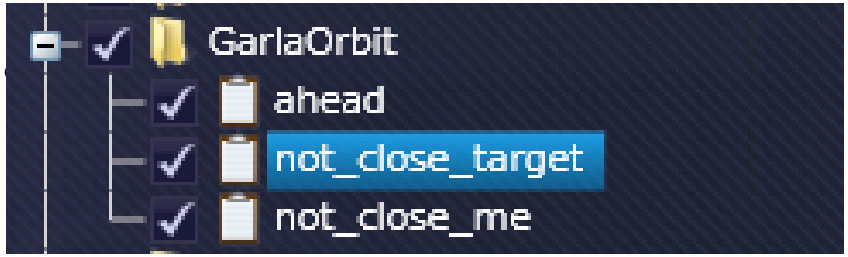
A bowman finds the best point

(i) Game situation
(ii) Generating points around it

(iii) Filtering points with bad terrain
(iv) Filtering points where it's arrow can not reach
(v) Filtering points around buddies

(vi) Picking up one point with highest terrain

PQS Tool



Combination of filtering

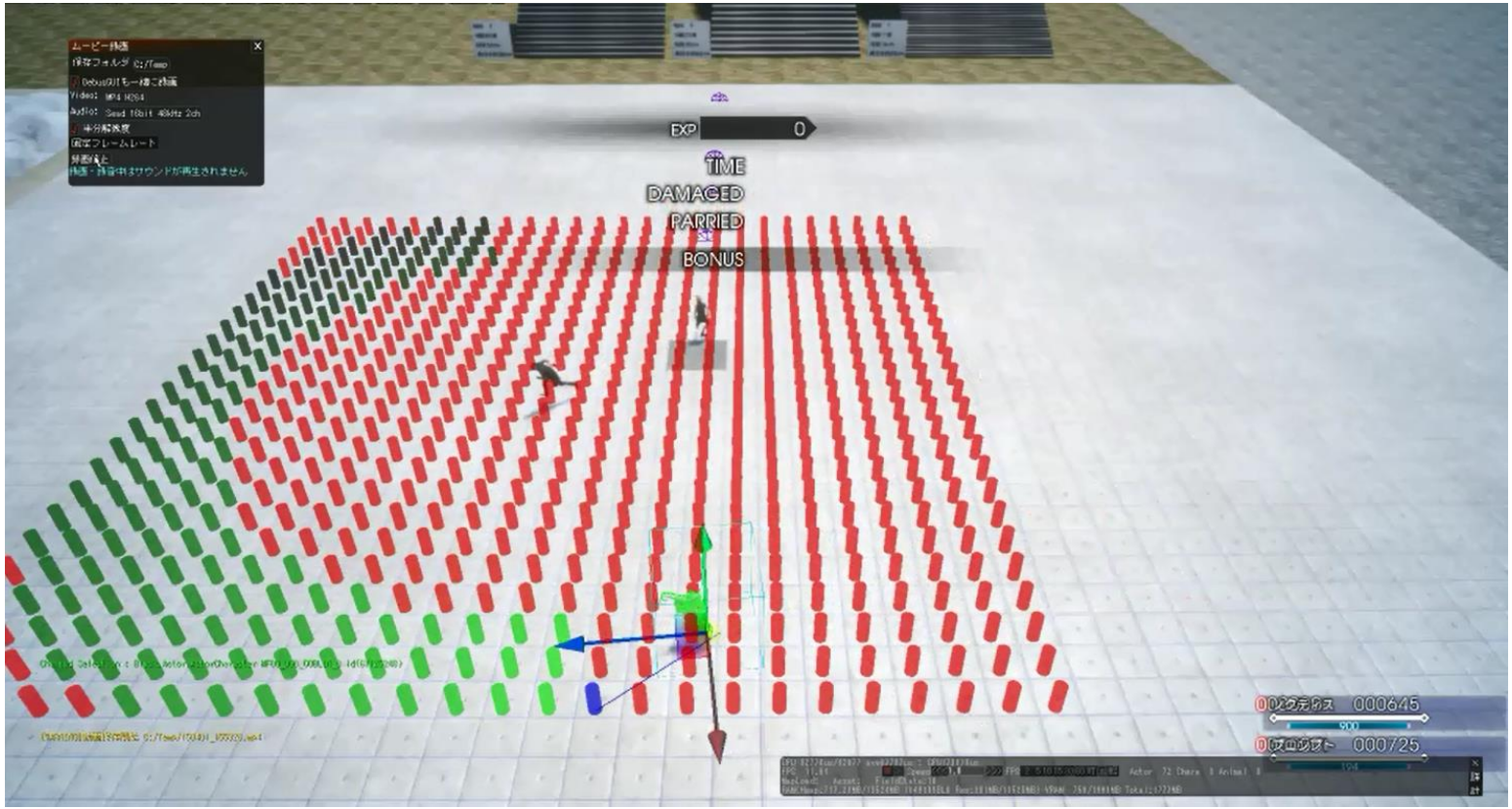
(Example)

Angle filtering = 30°

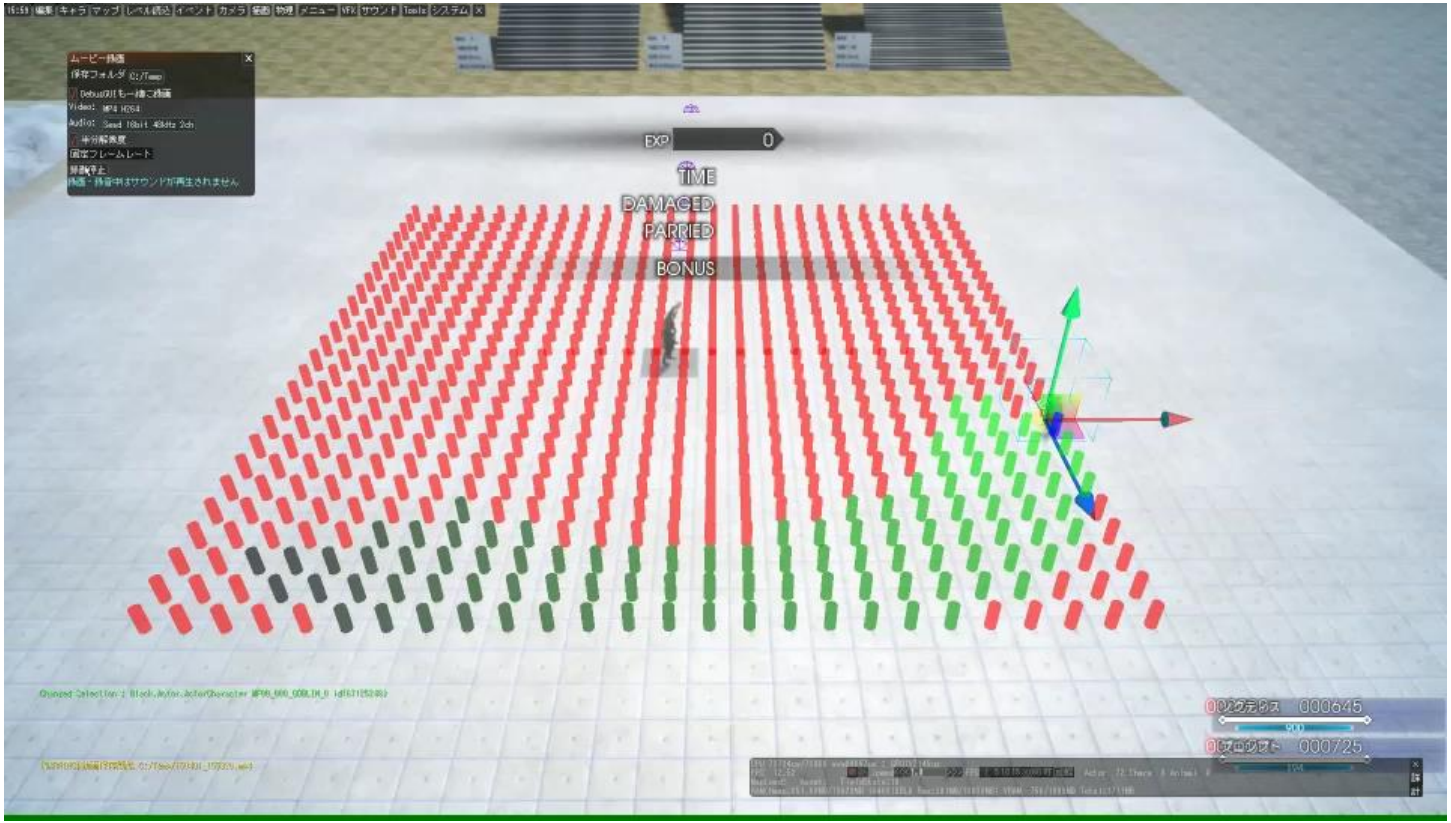
Distance filtering = 10m

⇒ character goes around a player

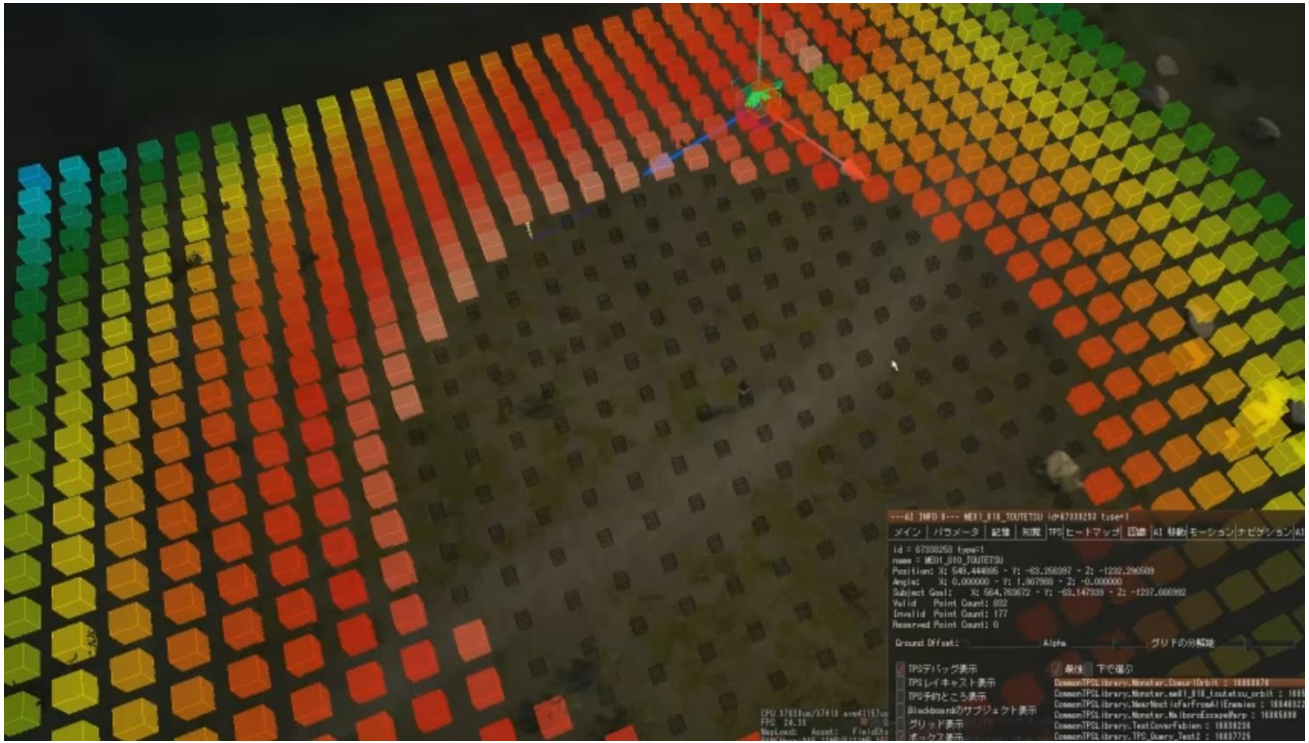
PQS and Movement



PQS and Movement



PQS and Movement



PQS and Movement (movie)

PQS

Character

PQS Query

Best Position

PQS

Usage of PQS

Finding

- An attack position of a monster
- An attack position of a buddy
- A position in conversation of a buddy
- A spawning point of crowd

Statistics of PQS Query

SID_5755243f9b36a728a8e501c8
SID_5755232dec64381d7898d95b
SID_5755229b9b36a728a8dec575
SID_57551dfdf606f2297435e50b
SID_57551a8fec64381d788501d0
SID_575519539b36a728a8d767be
SID_5755186071d7922100543b7f
SID_575517daf606f2297435de76
SID_575515646d21381690a37947
SID_575513116d21381690a072b4
SID_57551022f606f229743575a9
SID_57550bfa9b36a728a8cb45bf
SID_57550b5271d79221004f529e
SID_575508dcec64381d78772325
SID_57550890f606f22974350100
SID_575507e5f606f2297434a201
SID_5755071af606f2297433e092
SID_57550625f606f22974337981
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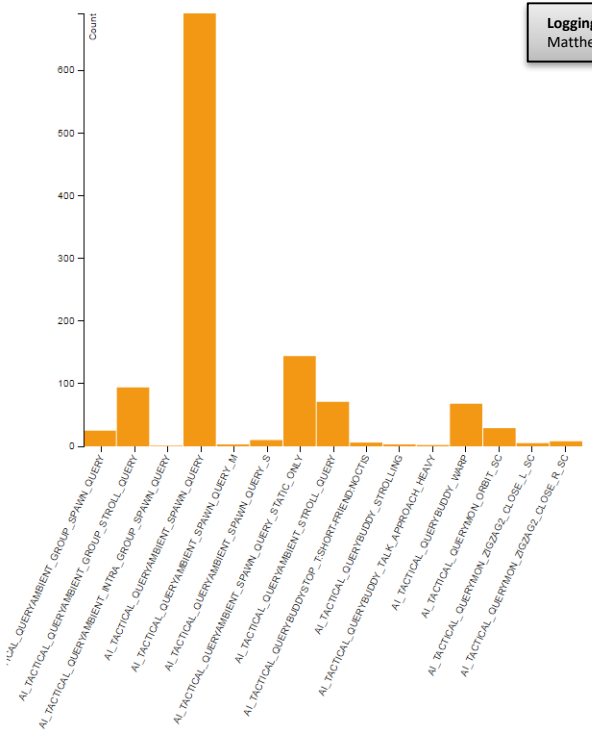
SID_5754fd89ec64381d7861789c



Logging Visualization in FINAL FANTASY XV
Matthew W. Johnson, Fabien Gravot, Shintaro Minamino, Ingimar Gudmundsson, Hendrik Skubch, and Miyake Youichiro

Query's variation

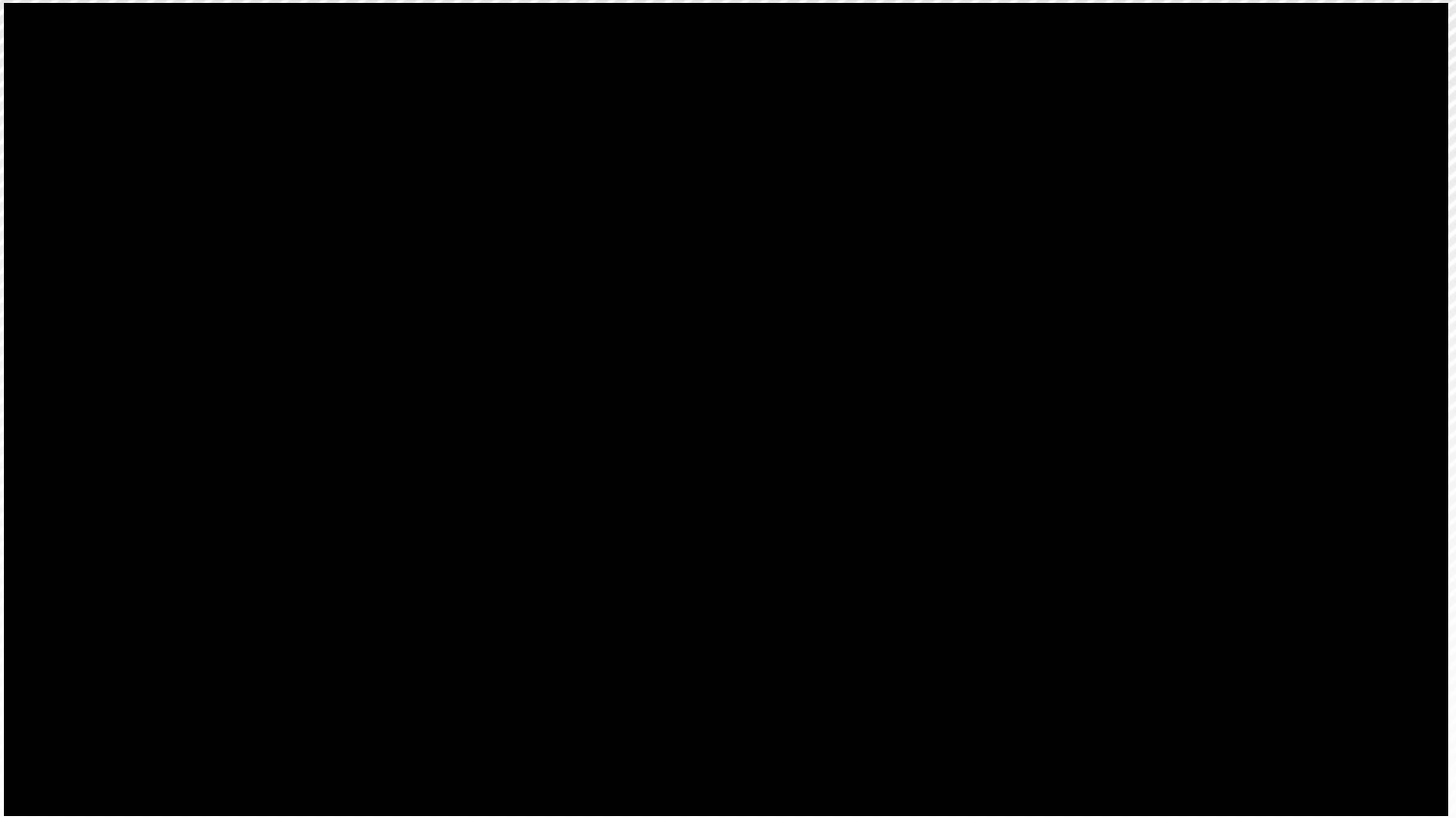
PQS（point querying system）Statistics in a town

Chapter 5.2 an example PQS applied

FACE TO FACE CONVERSATION SYSTEM

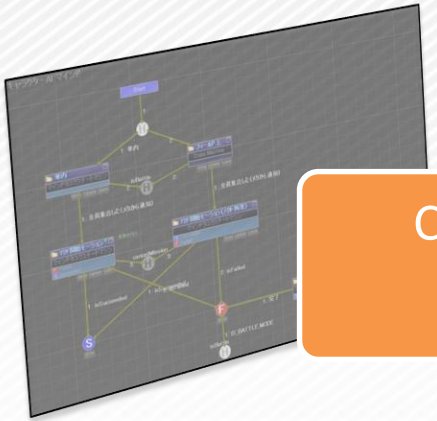
Face to Face Conversation System

Face to Face Conversation System



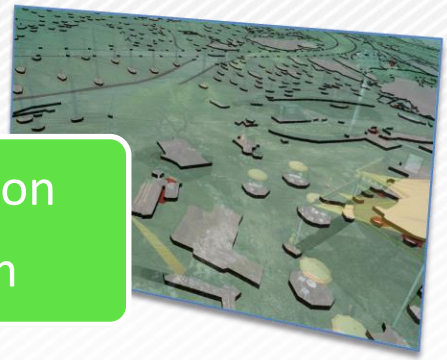
Face-to-Face = F2F

Meta AI

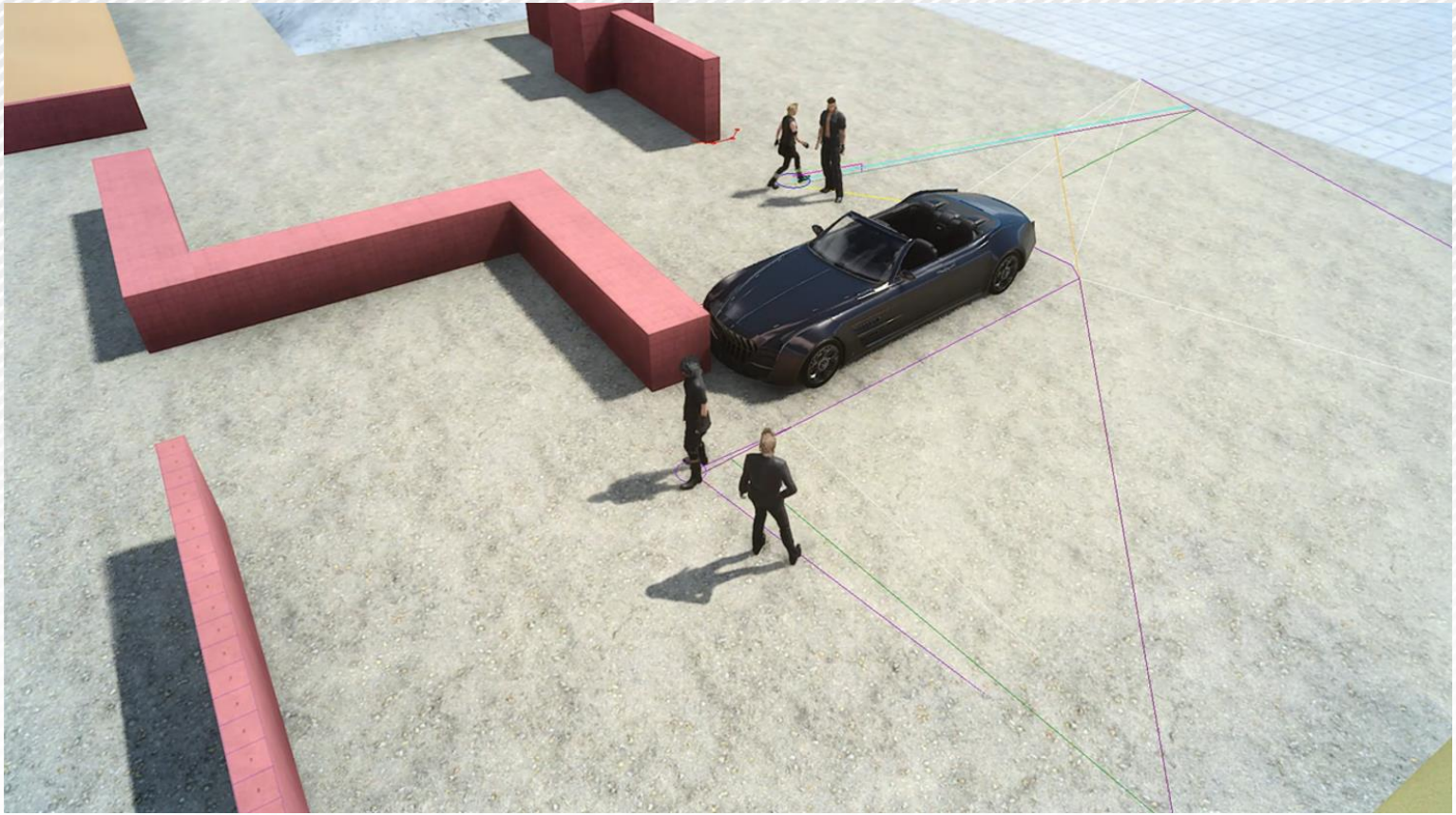


Character AI

Navigation System



Face-to-Face = F2F



Face-to-Face = F2F (movie)

Digital Game AI

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Chapter 5.3

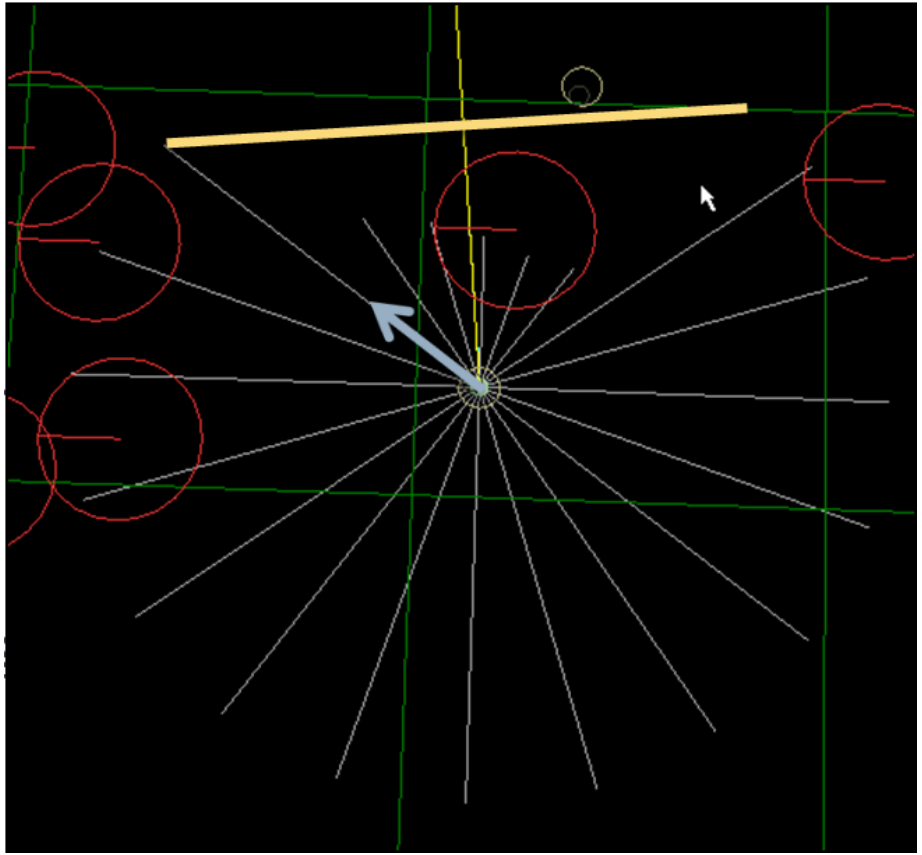
STEERING SYSTEM

SQUARE ENIX

Huma-like Avoidance

A distance from a character without collision is calculated to all direction.

And one direction nearest to the following path is selected.

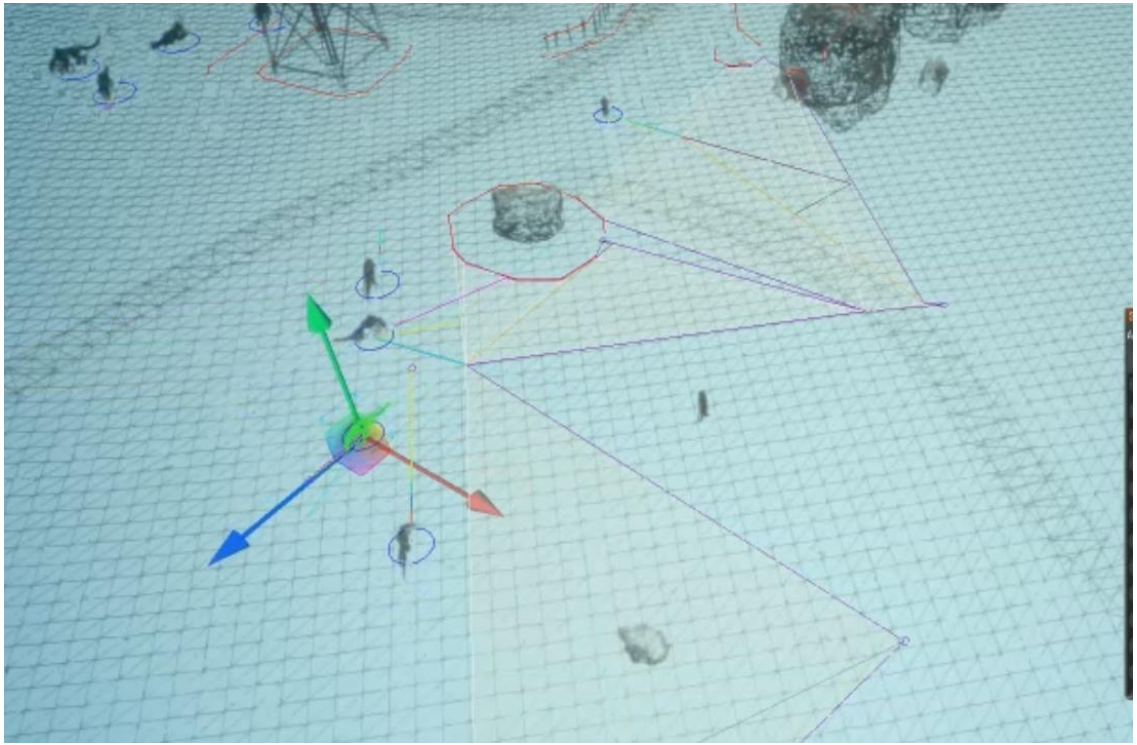


[Guzzi 13a] J. Guzzi, A. Giusti, L. Gambardella, and G. A. Di Caro：Human-friendly robot navigation in dynamic environments. In Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), pages 423430, Karlsruhe, Germany, May 610, 2013.

[Guzzi 13b] J. Guzzi, A. Giusti, L. Gambardella, and G. A. Di Caro：Local reactive robot navigation: a comparison between reciprocal velocity obstacle variants and human-like behavior. In Proceedings of the IEEE International Conference on Intelligent Robots and Systems (IROS), pages 26222629, Tokyo, Japan, November, 37, 2013.

Steering

- Auto-avoidance in movement



Steering (movie)

- Auto-avoidance in movement

Digital Game AI

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Chapter 6

MOTION ANALYSIS

Attack Motion Analysis

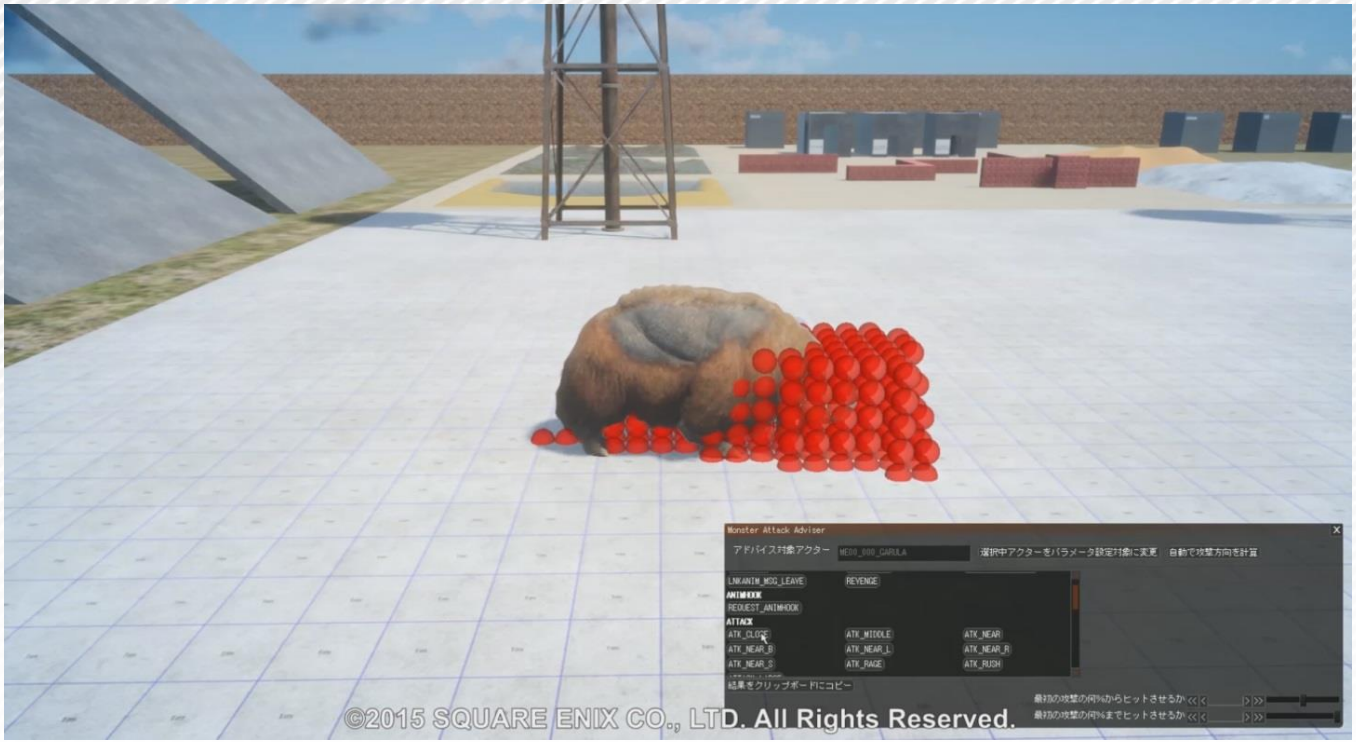
Attack motion analysis system automatically finds the maximum distance and angle for attack by a simulation of animation and attack.

AI graph uses the distance and angle motion found.

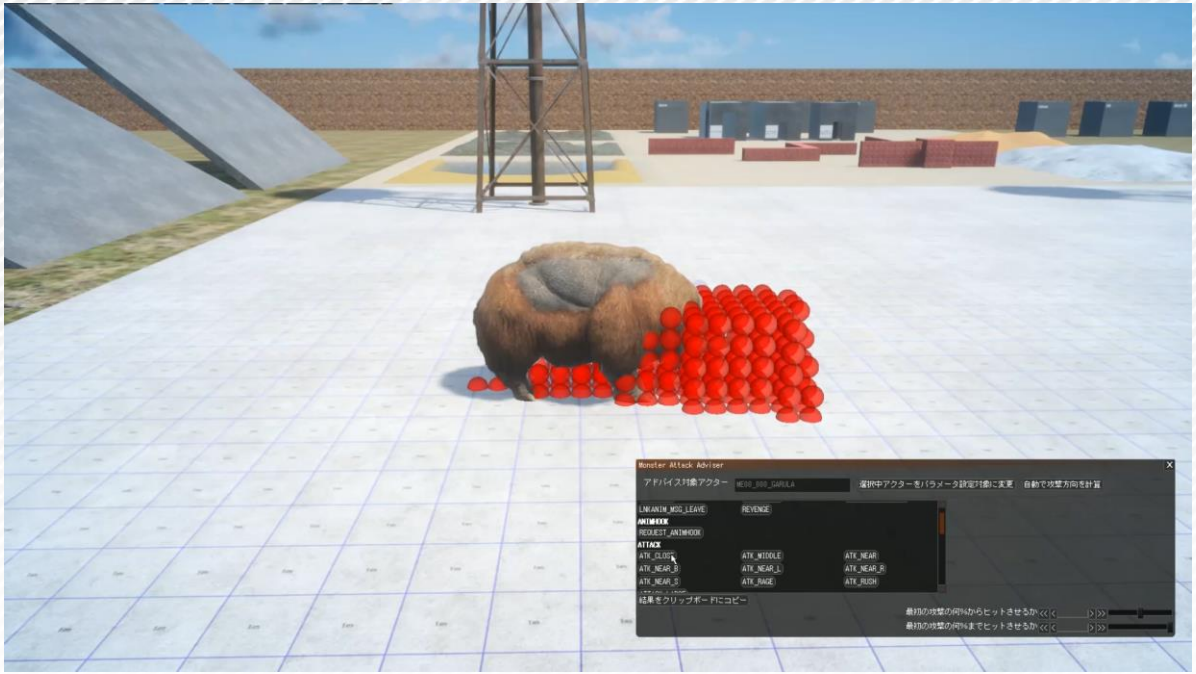
This semi-automatic system can reduce the workload of a game designer by half.

Attack Motion Analysis (movie)

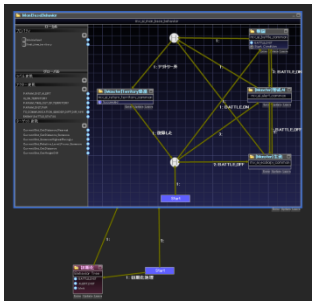
Attack Motion Analysis

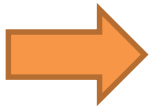


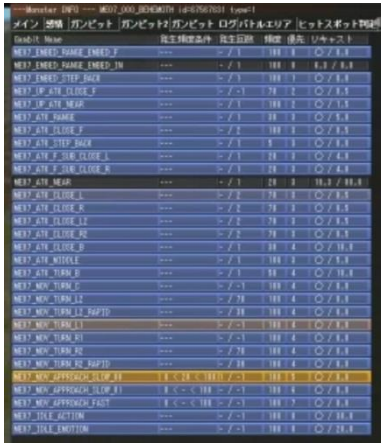
Attack Motion Analysis (movie)

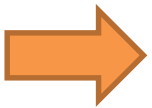


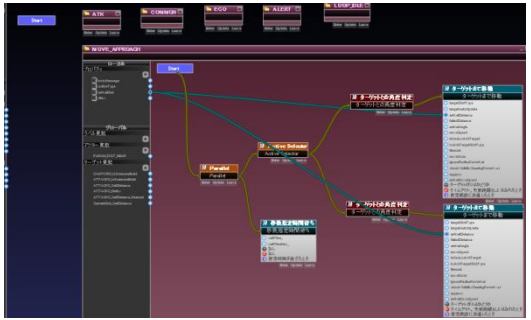
Rule-based AI System









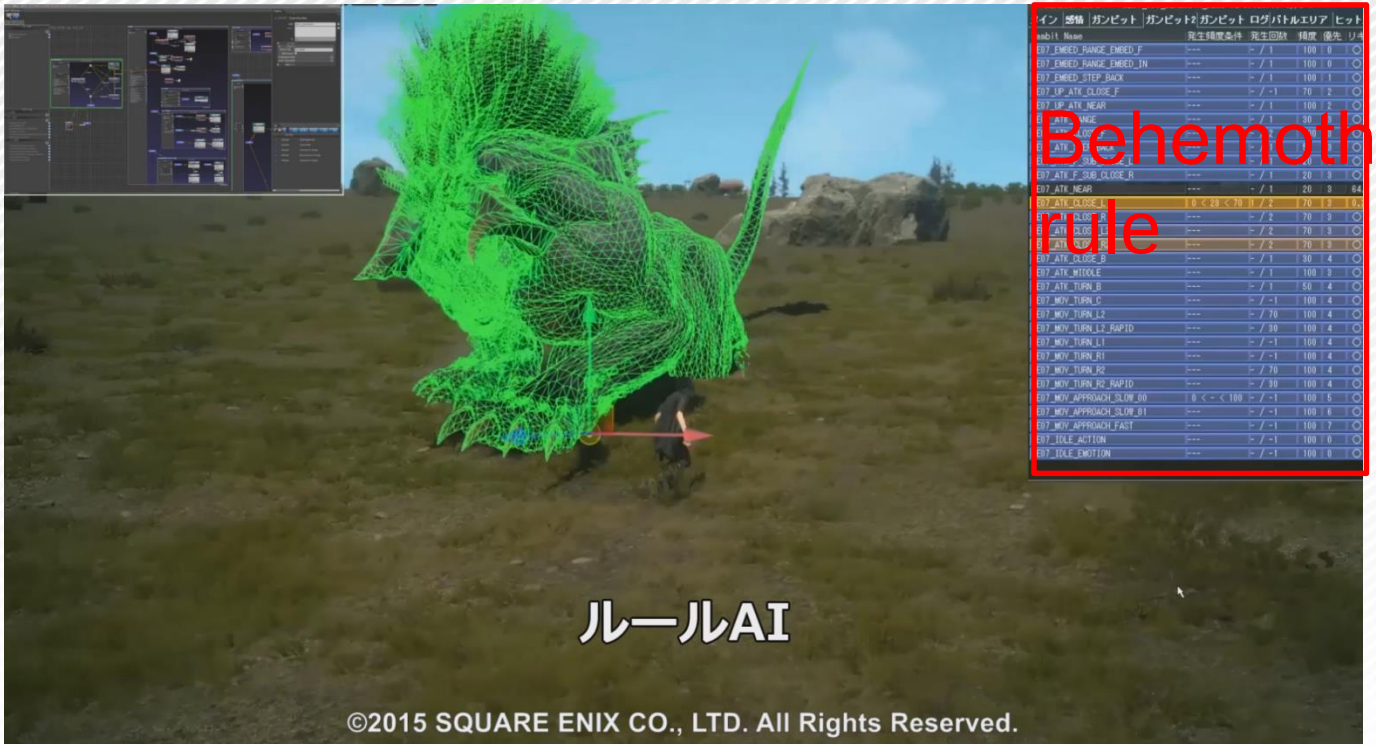


AI Graph
Basic logic execution

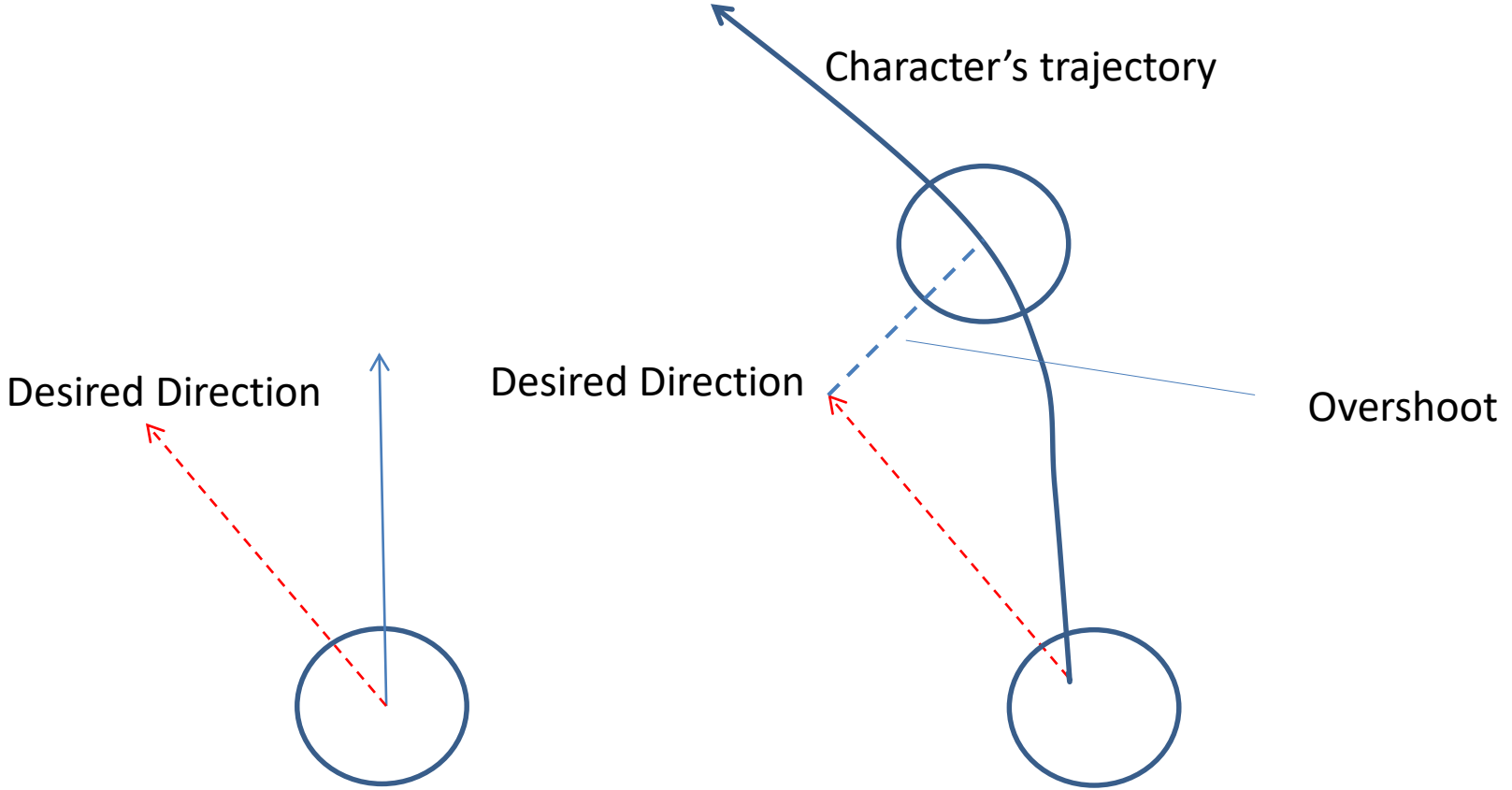
Rule execution

AI Graph
Behavior template execution

Rule-based AI System



Simulation of character's curving



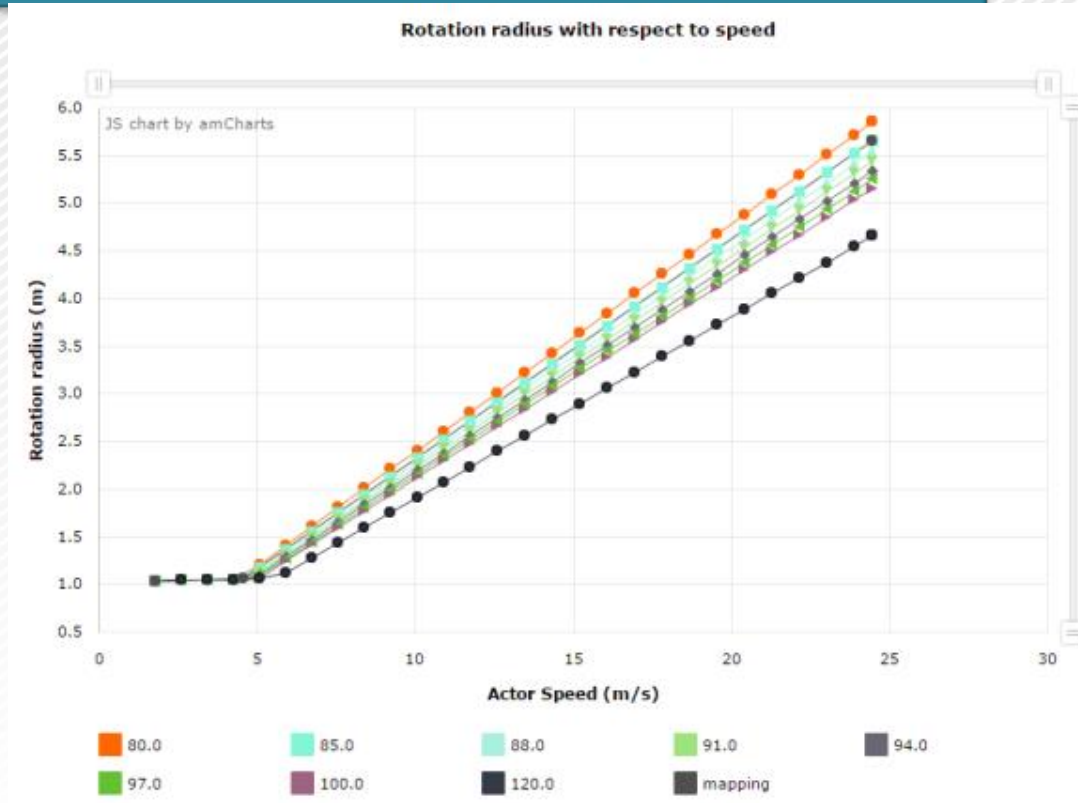
Curving Motion Analysis (movie)

Curving Motion Analysis (movie)

Movement Motion Analysis

Charts auto-generation of character's turning performance and stopping performance by using the automatic move motion analysis system

Further, "automatic motion" overlapped by image find errors in the animation data and correct them.



Movement Motion Analysis

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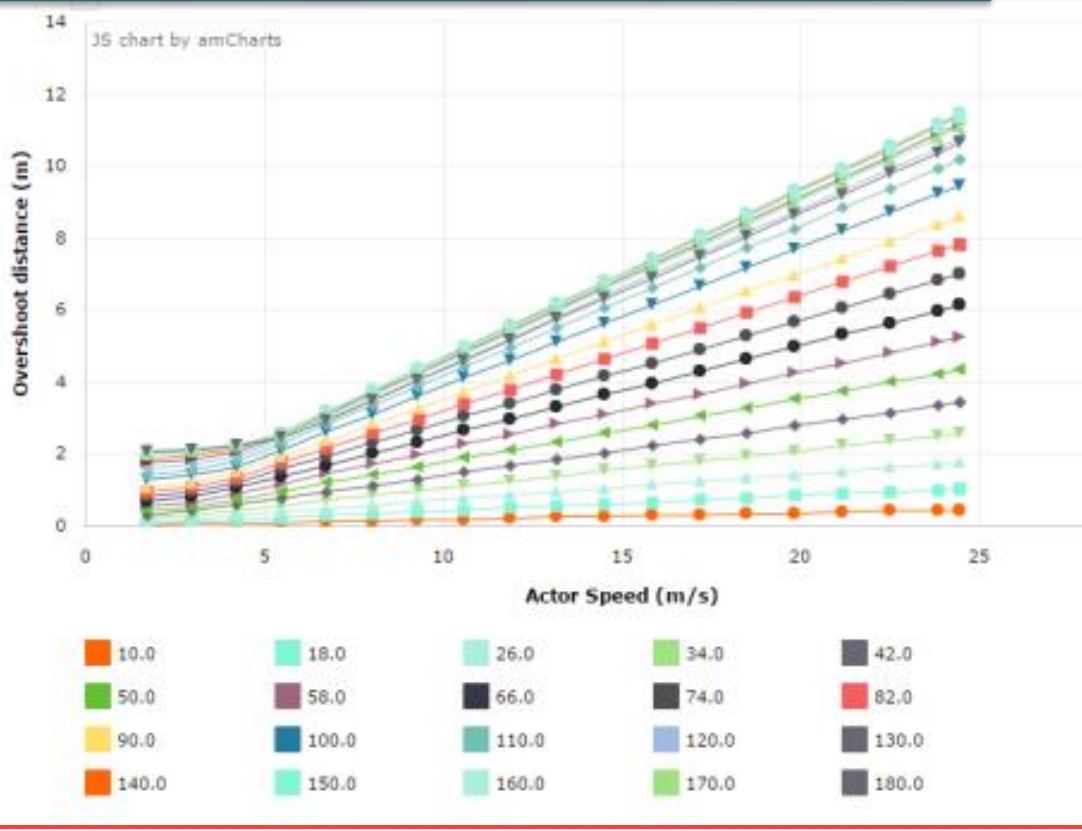

Movement Motion Analysis

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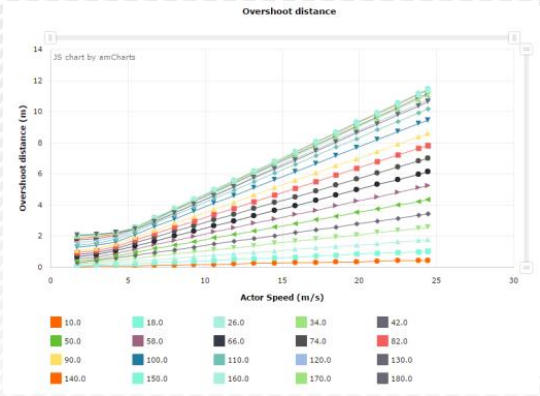

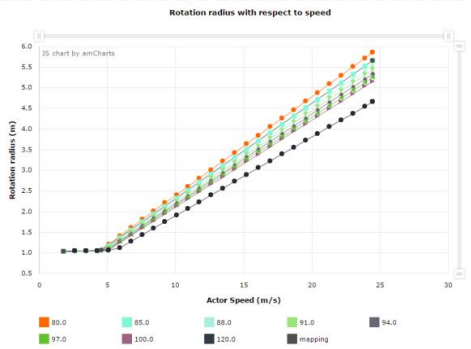

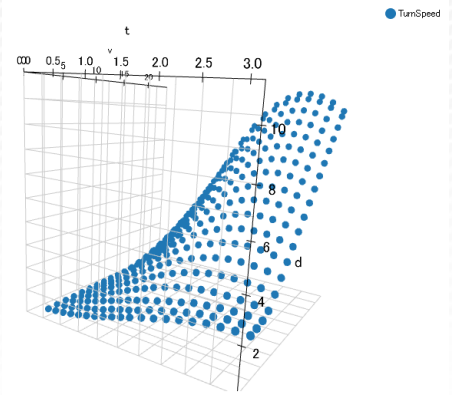

Digital Game AI

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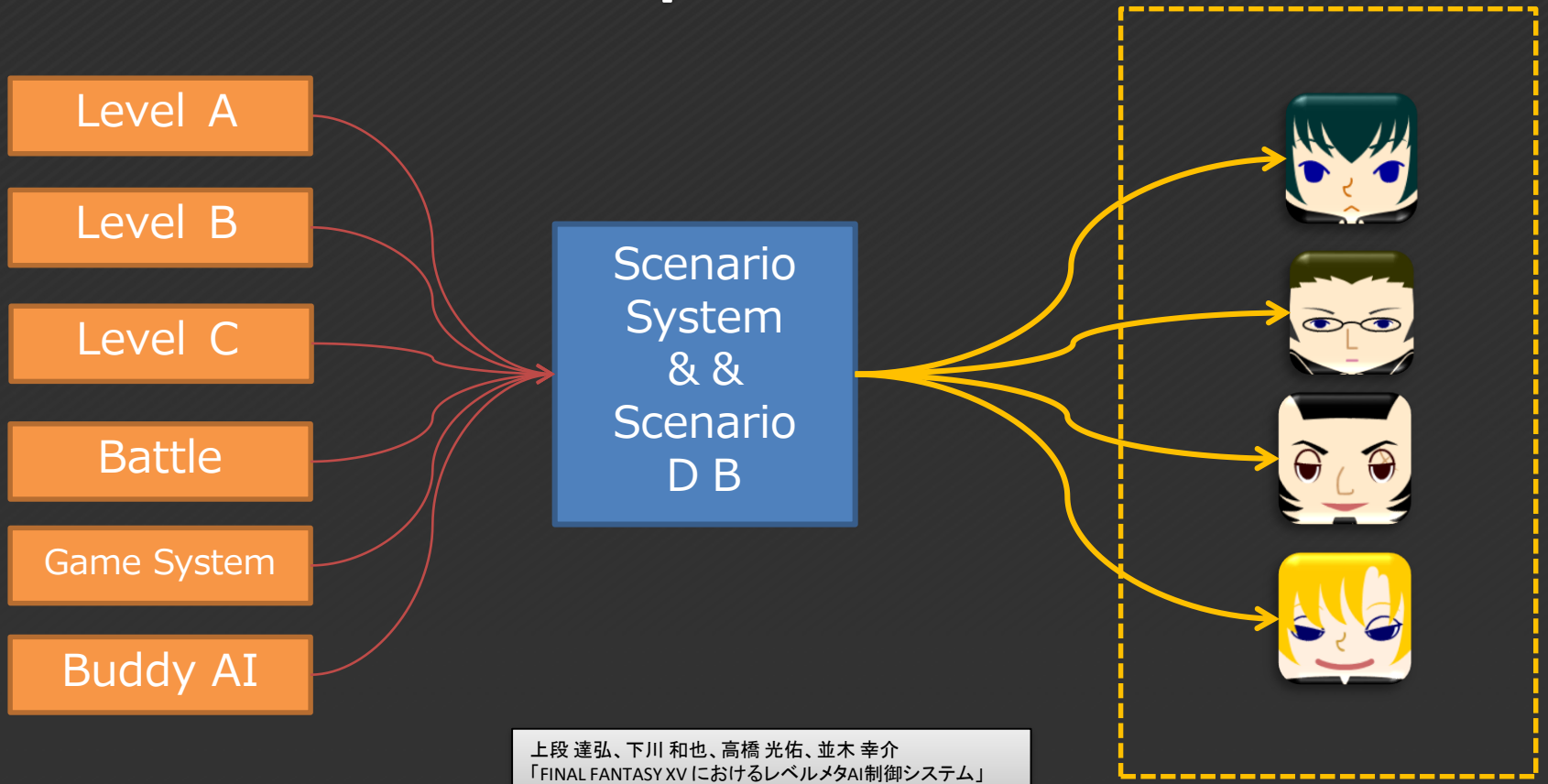
Chapter 7

CHARACTER CONVERSATION

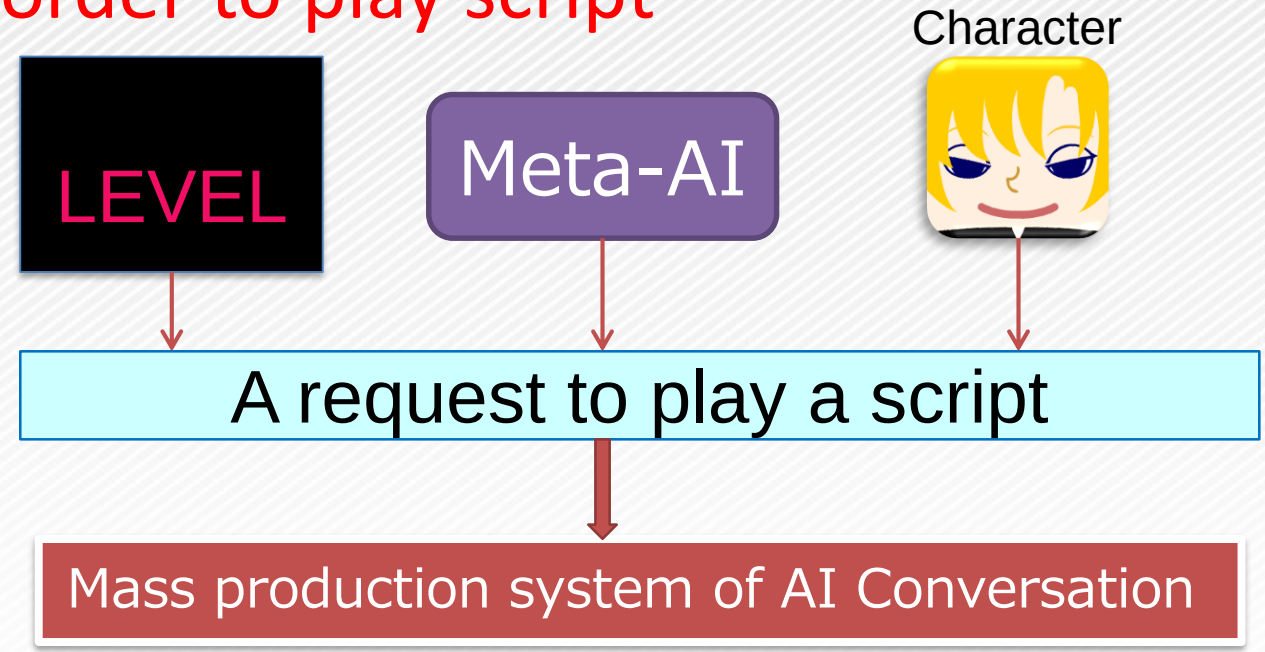
Conversation request



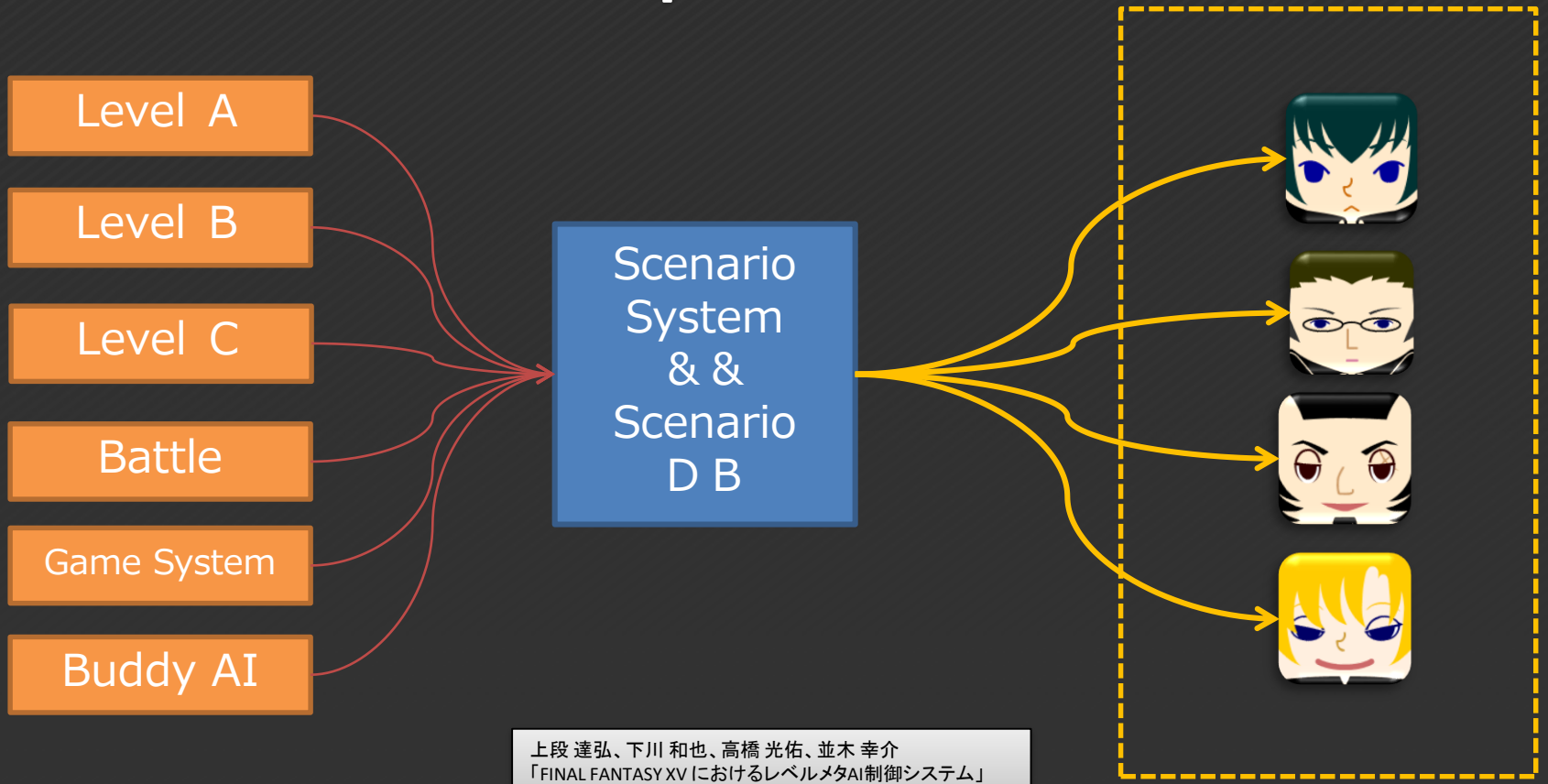
上段 達弘、下川 和也、高橋 光佑、並木 幸介
「FINAL FANTASY XV におけるレベルメタAI制御システム」
https://cedil.cesa.or.jp/cedil_sessions/view/1544

Character Conversations

An order to play script



Conversation request



上段 達弘、下川 和也、高橋 光佑、並木 幸介
「FINAL FANTASY XV におけるレベルメタAI制御システム」
https://cedil.cesa.or.jp/cedil_sessions/view/1544

Character Conversation

- Condition to play a script
  - Interval time from previous play
  - Character
  - Time zone (morning, night, afternoon)
  - Area (city, dungeon, car)
  - Weather, Temperature
  - Story progress
  - Battle condition (hard, easy)
  - Body condition

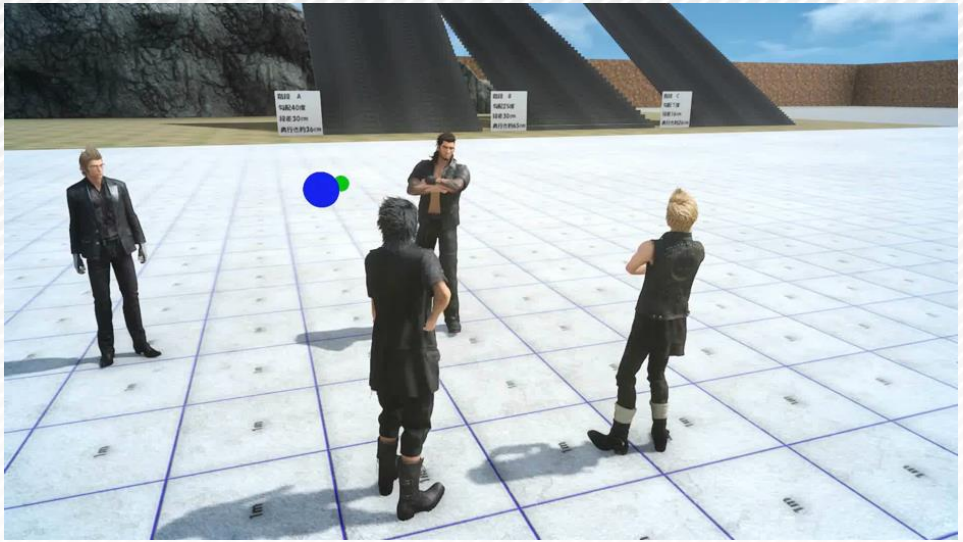
Group No	Script No	Time	Place	…
Group A	ScriptA-1	Morning	City	…
	ScriptA-2	Morning	Car	…
	ScriptA-3	Night	Any	…
Group B	ScriptB-1	Noon	Outdoor	…
	…	…	…	…

Character Conversation

Representing a character's attention

To move its body and motion to a speaker

To change a motion even in running

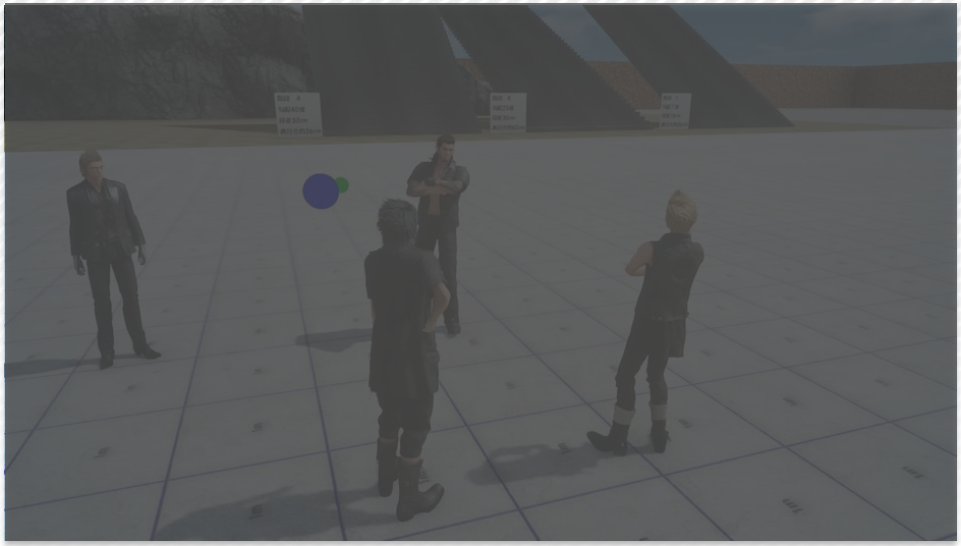


Character Conversation

Character Conversation

A buddy character predict a player's goal, runs
in front of a player and has a relaxed conversation.

To change a motion even in running



Character Conversation

Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button ▶

CHAPTER 8. CROWD AI

4.1

REPUTATION SYSTEM IN GUNSLINGER (SURREAL SOFTWARE)

Greg It, Kristin King, "A Dynamic Reputation System Based on Event Knowledge", 8.6, AI Game Programming Wisdom

Reputation System

Greg It, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

Master Event List
1. Bandit Killed Farmer
2. Player Aided Lawmen
3. Player Killed Bandit
4. Player TradedWith Townsperson
5. […]

NPC Memory

Memory Element
1
2
3
5

Bandit

Group	Reputation
Farmers	Neural
Lawmen	Hate
Bandits	Like
Player	Hate
Townspeople	Neural

The Bandit sees a Player killed the friend Bandit and helps a Lawmen, so dislikes the Player

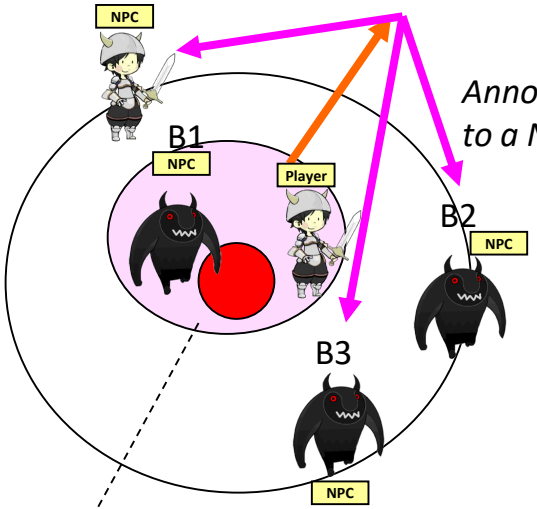
Greg It, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

Reputation System

Event Announcer

Register Event

Master Event List	Reference Count
1. Bandit Killed Farmer	4
2. Player Aided Lawmen	1
3. Player Killed Bandit	3
4.	
5.	



Announces "3"
to a NPC within a radius .

Referenced by
3 NPC

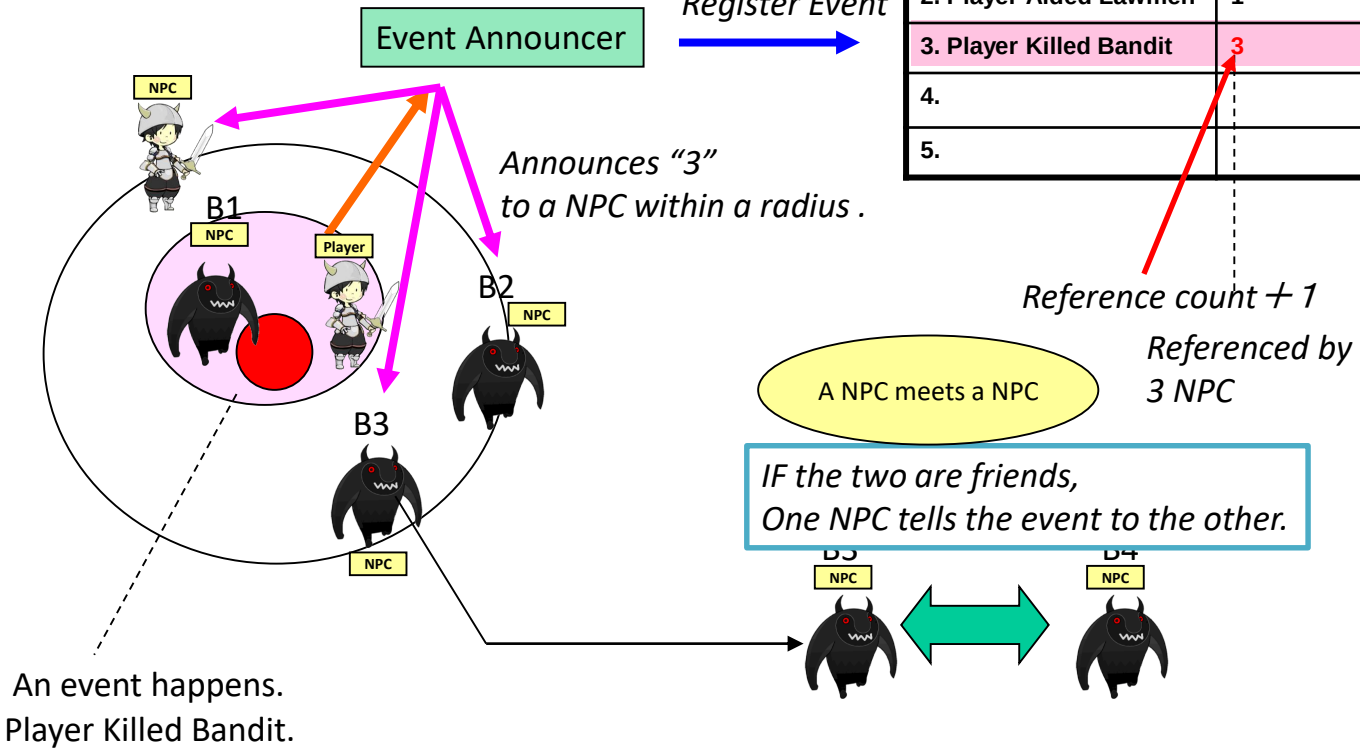
An event happens.
Player Killed Bandit.

Greg It, Kristin King, "A Dynamic Reputation System Based on Event Knowledge", 8.6, AI Game Programming Wisdom

Reputation System

Master Event List	Reference Count
1. Bandit Killed Farmer	4
2. Player Aided Lawmen	1
3. Player Killed Bandit	3
4.	
5.	

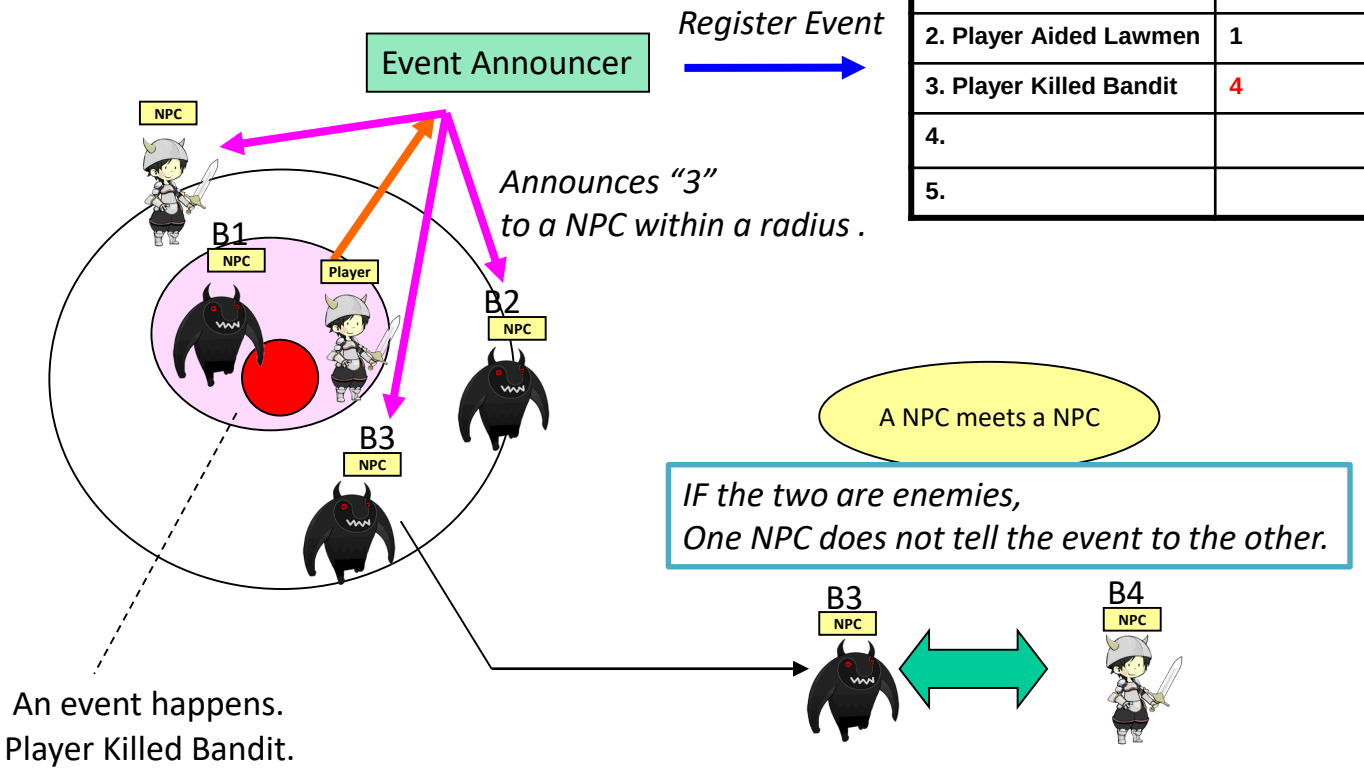
Register Event



Greg It, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

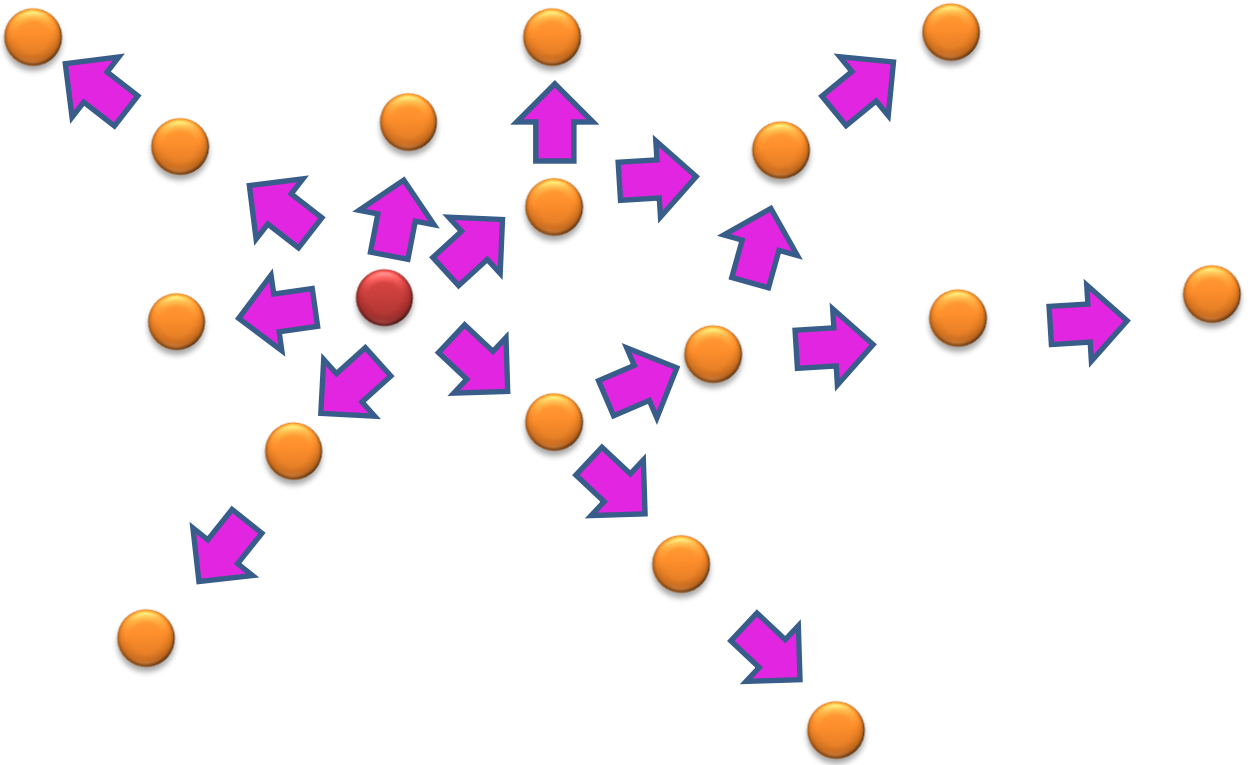
Reputation System

Master Event List	Reference Count
1. Bandit Killed Farmer	4
2. Player Aided Lawmen	1
3. Player Killed Bandit	4
4.	
5.	



Greg lt, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

Reputation System



Reputation System（Event form）

Greg It, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

Master Event List	参照回数
1. Bandit Killed Farmer	4
2. Player Aided Lawmen	1
3. Player Killed Bandit	11
4.	
5.	

Subject Group	Player
Verb	DidViolenceTo
Object Group	Bandit
Object Individual	Joe
Magnitude	75(Killed)
Where	50,20,128(In front of saloon)
When	High noon
Template	KilledBanditTemplate
ReferenceCount	Known by 11 NPCs
Reputation Effects	Bandits hate player more Lawmen like player more Farmers like player more

Reputation System（Information Exhange）

NPC Memory

Memory Element	Confidence	Time Stamp
1	43	0:13:43
3	76	1:4:53
7	63	1:7:45
11	12	1:24:54
12	52	2:6:55

NPC Memory

Memory Element	Confidence	TimeStamp
2	43	0:15:13
4	87	0:46:3
7	12	2:17:56
15	53	2:14:45
71	84	3:56:15

NPC

Memory Matching

NPC

If there are memories for the same event, one memory is over-written by the other with a higher confidence,
If there are memories for the same object, one memory is over-written by the other newer memory.

Event to overwrite → In Master Event List, Reference Count ＋1
Event to be deleted → Master Event List -1
(If a reference count becomes zero, it is deleted from Master Event List)

Greg lt, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

Reputation System
（Information Complementation System）

When NPC A meets Joe, Joe is already dead.

Joe was Killed by unknown group

NPC saw Joe was shot by a Lawmen.

Joe was shot by lawmen group

Reconstruct a new information
From incomplete information.

Joe was killed by lawmen group

It may be wrong, but human is like that….

Greg It, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

References

(1) Greg lt, Kristin King, “A Dynamic Reputation System Based on Event Knowledge”, 8.6, AI Game Programming Wisdom

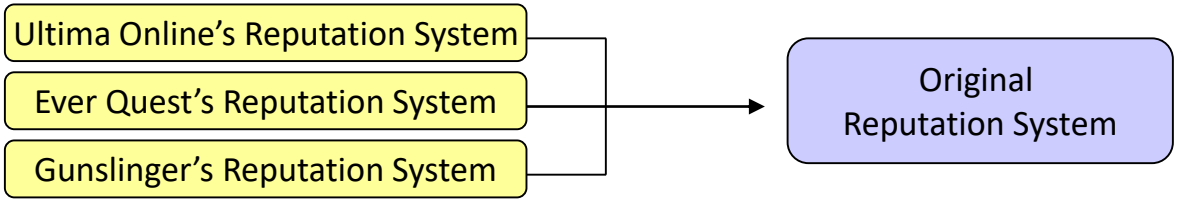
(2) Richard Rouse III,"Postmortem: The Game Design of Surreal's The Suffering", Gamasutra, http://www.gamasutra.com/view/feature/2110/postmortem_the_game_design_of_.php

(3) "Gunslinger: First Impressions",IGN, http://ps2.ign.com/articles/134/134549p1.html

(4) Gunslinger [PS2 - Cancelled]

http://www.unseen64.net/2009/09/15/gunslinger-ps2-cancelled/

Never Winter Night's Reputation System



Never Winter Night's Reputation System

Friend parameter = How good the subject thinks the object .

Subject \ Object	Monster	Bandit	Guard	People
Monster	100	0	0	0
Bandit	50	50	0	0
Guard	0	0	100	100
People	0	0	100	80

How Friend parameter changes to the enemy action.

Witness	Nobody	Attack to the friend species	NPC who is friend with the object	Neutrality	NPC who is neutral to the object	Attack to the enemy species	An enemy
Attack	-2	-12	-6	-4	-2	-2	0
Kill	-5	-45	-25	-15	-5	-5	0
Steal	-1	-5	-3	-2	0	-1	0

Influence to friend parameter changes to who saw the event

Mark Brokington, "Building a reputation system: Hatred, Forgivveness, and Surrender in Never Winter Nights", 6.5, Massive Multiplayer Game Development

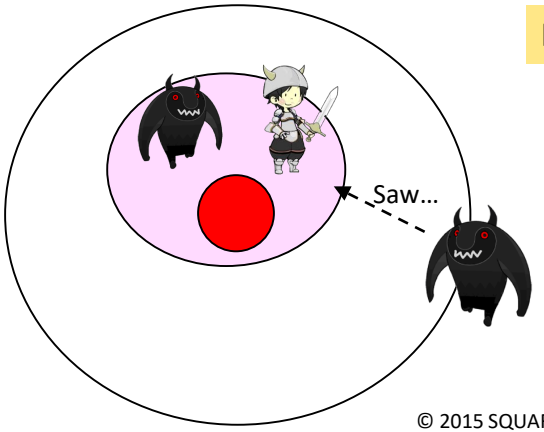
Never Winter Night's Reputation System

How Friend parameter changes to the enemy action.

Witness	Nobody	Attack to the friend species	NPC who is friend with the object	Neutrality	NPC who is neutral to the object	Attack to the enemy species	An enemy
Attack	-2	-12	-6	-4	-2	-2	0
Kill	-5	-45	-25	-15	-5	-5	0
Steal	-1	-5	-3	-2	0	-1	0

Friend parameter reduces based on the kind of enemy the NPC killed

Friend parameter reduces from the witness



Mark Brokington, "Building a reputation system: Hatred, Forgiveness, and Surrender in Never Winter Nights", 6.5, Massive Multiplayer Game Development

Never Winter Night's Reputation System

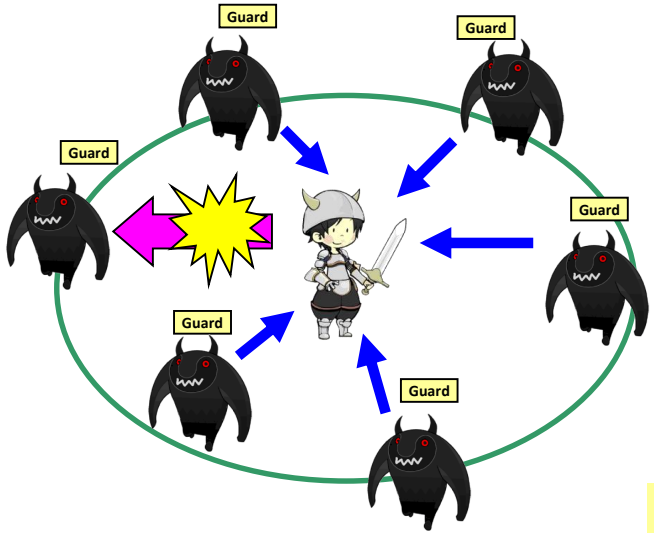
Friend parameter = How good the subject thinks the object is .

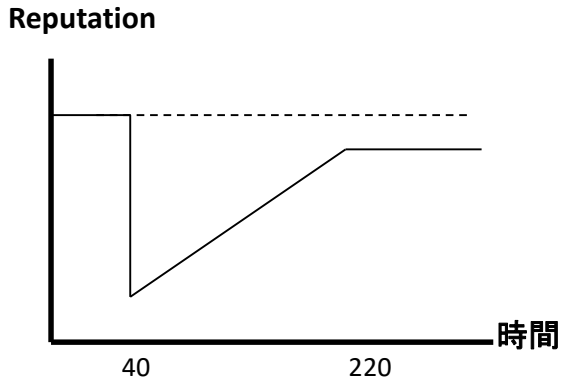
Subject \ Object	PC	Monster	Bandit	Guard	People
Monster	0	100	0	0	0
Bandit	0	50	50	0	0
Guard	95	0	0	100	100
People	75	0	0	100	80

Mark Brokington, "Building a reputation system: Hatred, Forgivveness, and Surrender in Never Winter Nights", 6.5, Massive Multiplayer Game Development

Personal Reputation

Guard remembers the character who attacked it.





Guard changes the reputation to the PC who attacked it

To prevent all from attacking the PC,
PC's reputation becomes recovered automatically.

Mark Brokington, "Building a reputation system: Hatred, Forgivveness, and Surrender in Never Winter Nights", 6.5, Massive Multiplayer Game Development

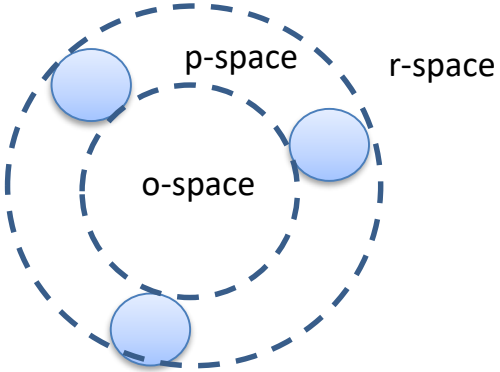
Reference

Mark Brokington, “Building a reputation system: Hatred, Forgivveness, and Surrender in Never Winter Nights”, 6.5, Massive Multiplayer Game Development

4.2

DISTRIBUTION AND ALLOCATION OF NPC

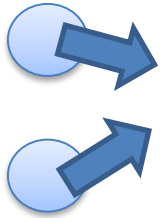
F-formation (Kendon, 1984)



- Standing position of a group

Paul Marshall,Yvonne Rogers,Nadia Pantidi
Using F-formations to analyse spatial patterns of interaction in physical environments
http://mcs.open.ac.uk/pervasive/pdfs/MarshallCSCW2011.pdf

F-formation Pattern



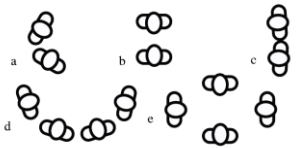
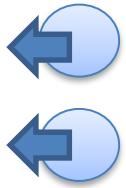
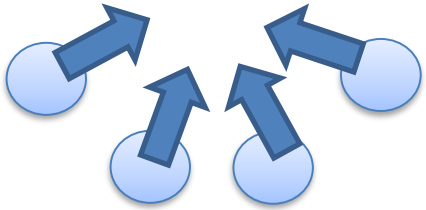
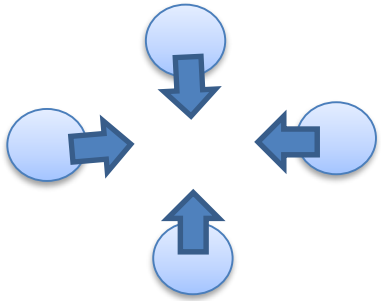


Figure 2: some different F-formation configurations.
a. L-arrangement; b. face-to-face; c. side-by-side; d. semi-circular; e. rectangular







Paul Marshall,Yvonne Rogers,Nadia Pantidi
Using F-formations to analyse spatial patterns of interaction in physical environments
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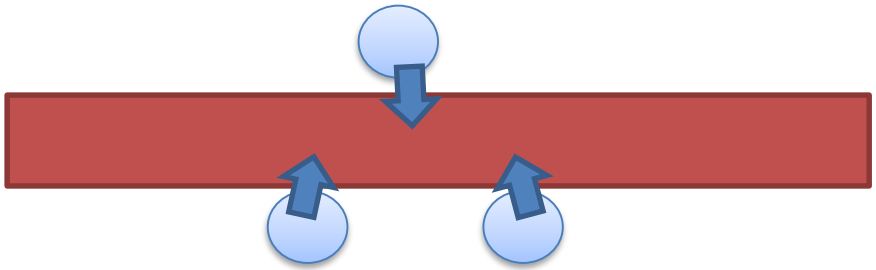
F-formation Pattern



Paul Marshall,Yvonne Rogers,Nadia Pantidi
Using F-formations to analyse spatial patterns of interaction in physical environments
http://mcs.open.ac.uk/pervasive/pdfs/MarshallCSCW2011.pdf

Territory and Influence

- Territory …distance between two people

- behavioral influence

  Region where a behavior has influence

  - Social place
  - Social situation

Social Dynamics

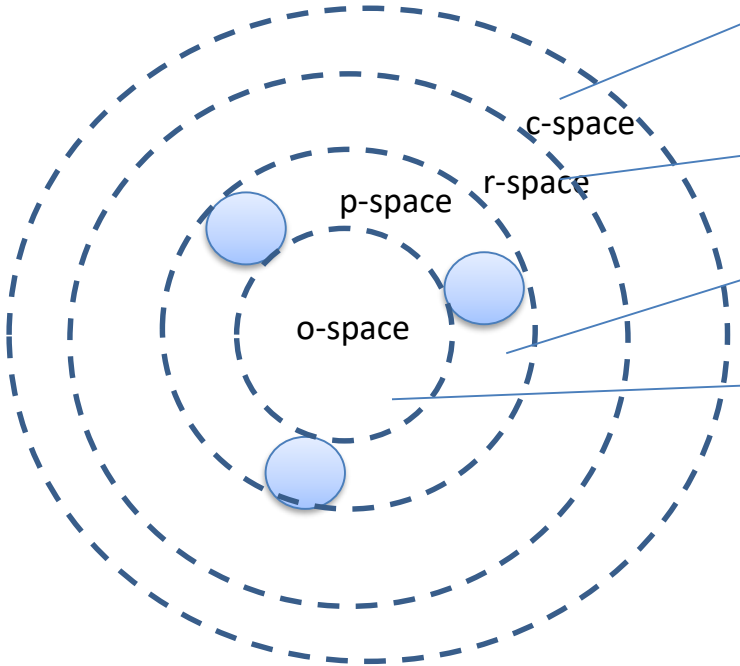
Social Dynamics

= Social Behavior influence

at Social place

makes Social Situation

F-formation



A person who enters the circle, someone sees the person.

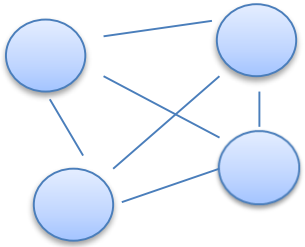
A person who enters the circle, someone sees that person carefully.

Rings of the attendees for conversation.

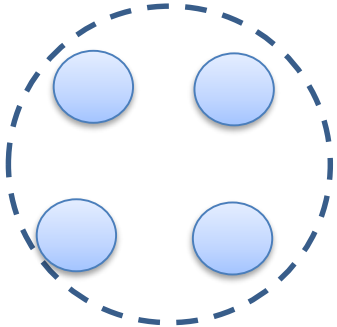
Common space (do not enter!)

Cladio Pedica - Spontaneous Avatar Behaviour for Social Territoriality Reykjavik University.
http://www.ru.is/faculty/hannes/students/MSThesisClaudioPedica.pdf

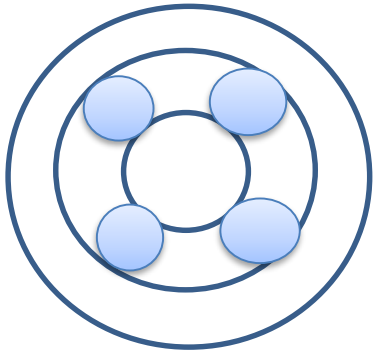
F-formation



The distance social behavior has enough effectiveness



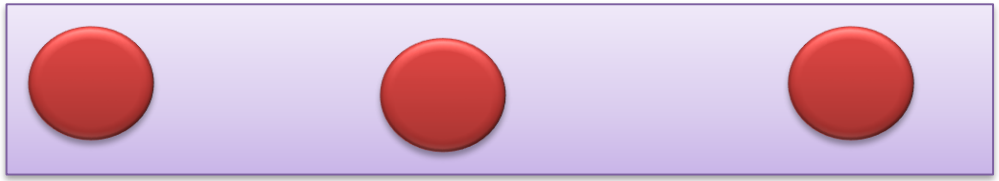
A distance of conversation



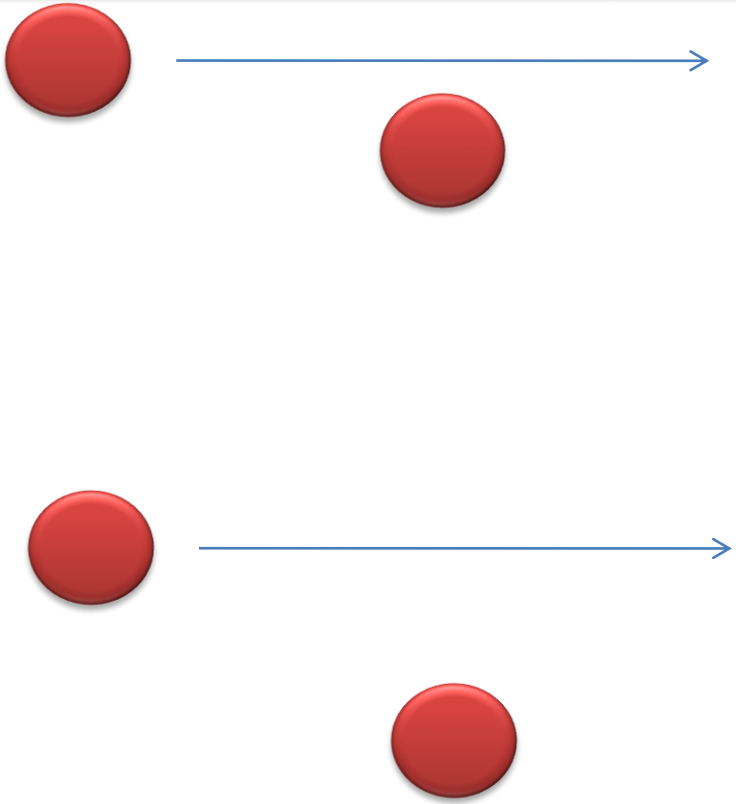
Territory four people forms

Cladio Pedica - Spontaneous Avatar Behaviour for Social Territoriality Reykjavik University.
http://www.ru.is/faculty/hannes/students/MSThesisClaudioPedica.pdf

Unnatural/Natural

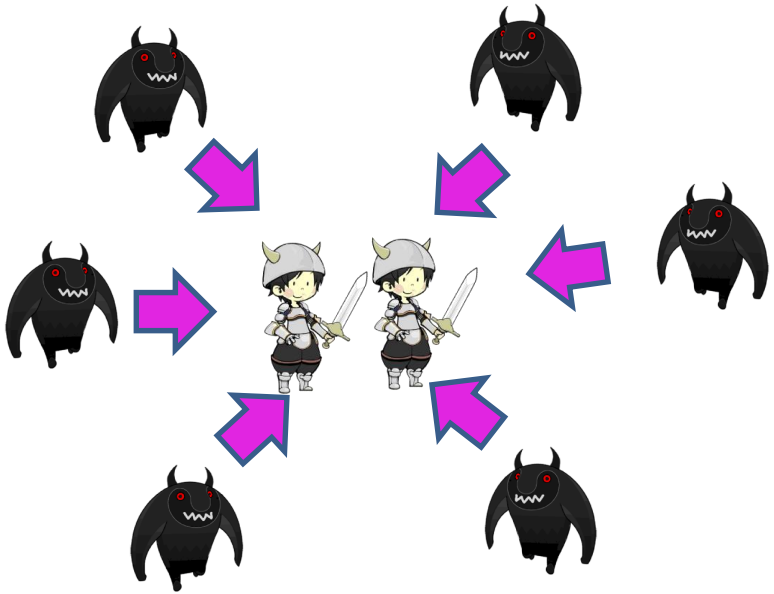


Unnatural/Natural



Targeting System

What is targeting problem ?



Which enemy NPC should attack ?
If all NPCs attacks the same enemy, it seems very foolish.

Belgian AI
Grid capacity, Attack Capacity

12

Attack Weight = 4

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Grid Capacity = Number of monsters that can enter the region

Each monster has an attack weight,

Attack Capacity = maximum sum of the monsters' attack weight.

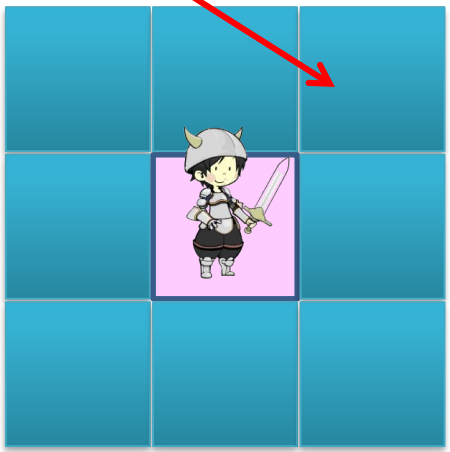
Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12

Assign

Request



Attack　Weight = 4

A monster requests to a stage Manager.
The stage manager assigns possession of the nearest slot

After the monster attacks a player,
It returns the possession soon.

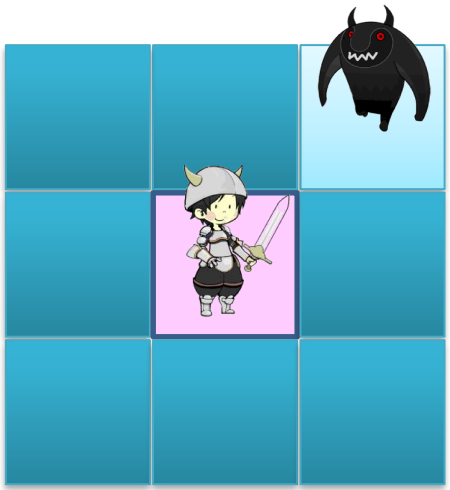
12

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12



Attack　Weight = 4

8

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
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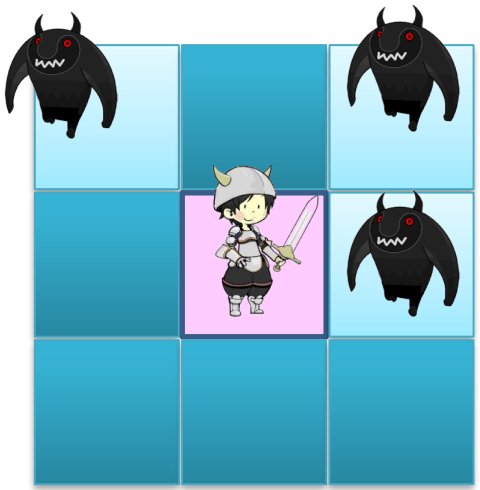
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12



Attack　Weight = 4

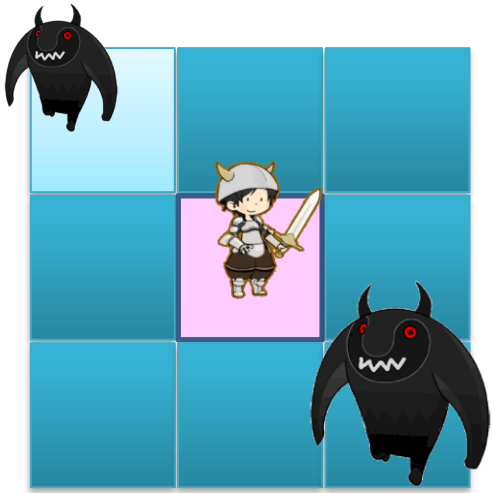
O

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12



Attack　Weight = 4

Attack　Weight = 6

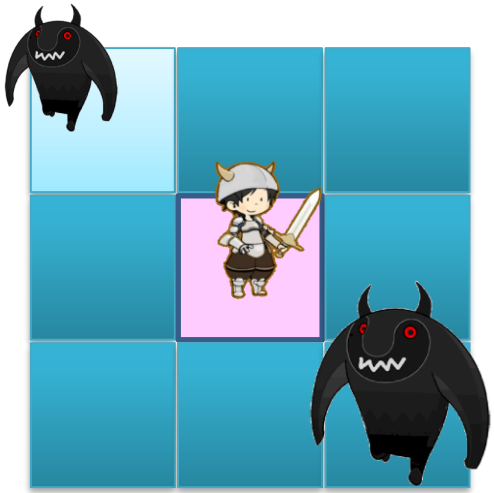
2

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12



Attack　Weight = 4

Attack　Weight = 6

2

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
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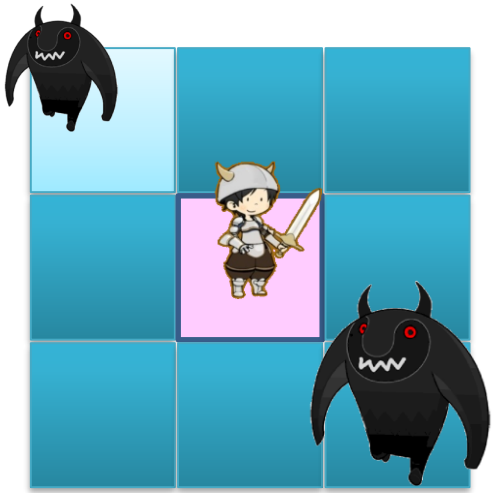
Belgian AI（Example）

Stage Manager

Grid Capacity = 5
Attack Capacity = 12



Attack　Weight = 4

Attack　Weight = 6
（Normal Attack）

Attack　Weight = 10
（Special Attack）

2

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
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Belgian AI（Example）

Stage Manager

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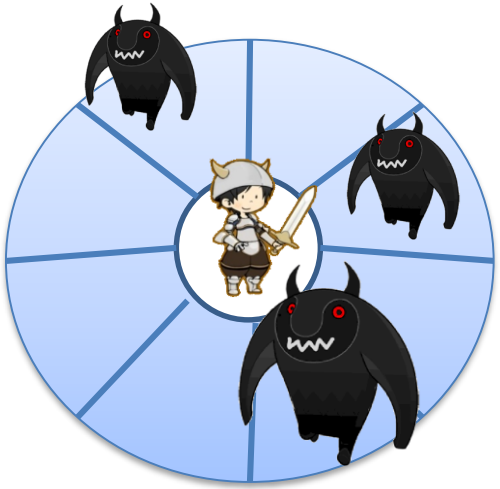

A monster requests to a stage Manager.
The stage manager assigns possession of the nearest slot

After the monster attacks a player,
It returns the possession soon.

Belgian AI（Example）

Stage Manager

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
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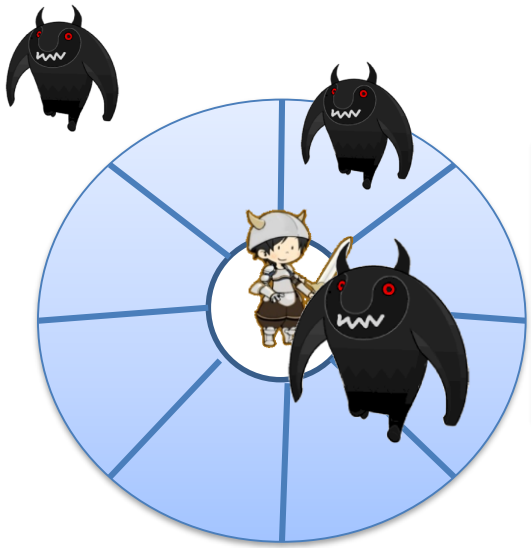

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Belgian AI（Example）

Stage Manager

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Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
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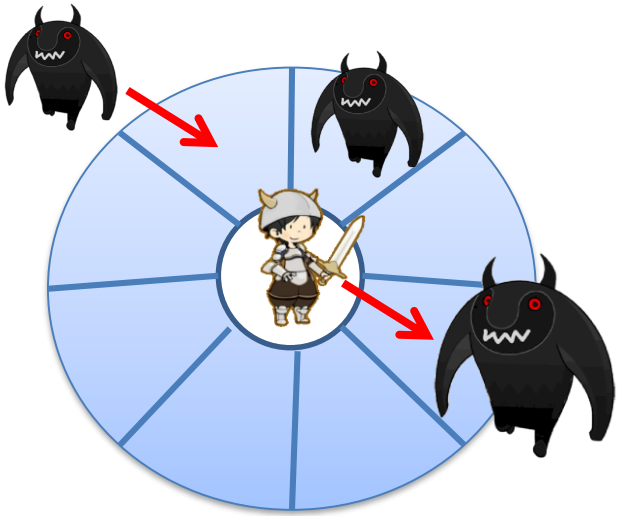
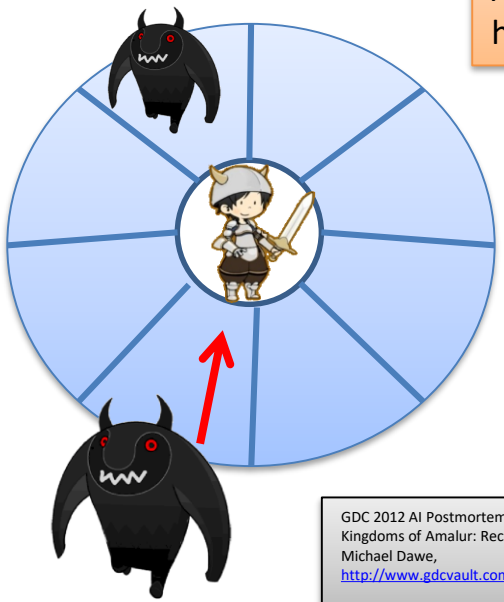


Belgian AI（Example）

Stage Manager

The monster does not remember the slot.

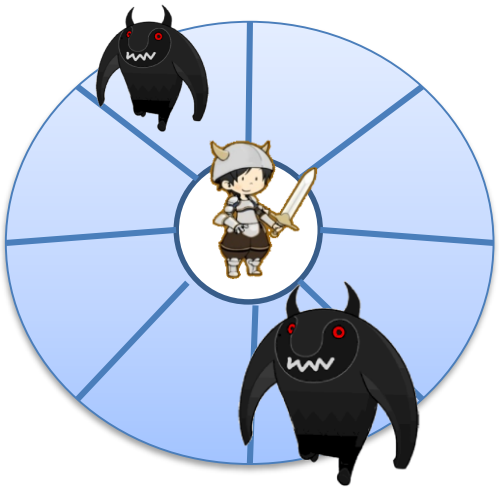
Always the Stage Manager has all control.



GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

Belgian AI（Example）

Stage Manager



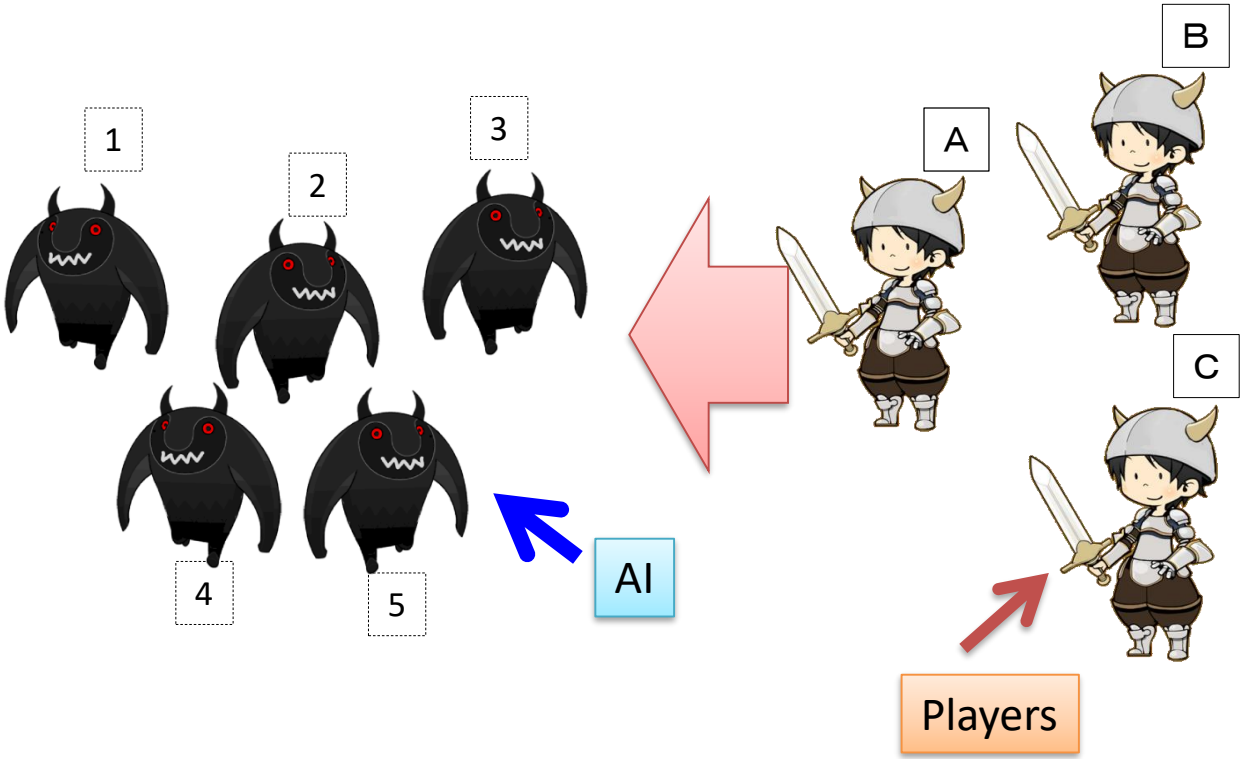
A monster who begins to attack can lock itself to a given assignment.

GDC 2012 AI Postmortems:
Kingdoms of Amalur: Reckoning, Darkness II and Skulls of the Shogun
Michael Dawe,
http://www.gdcvault.com/play/1015380/AI-Postmortems-Kingdoms-of-Amalur

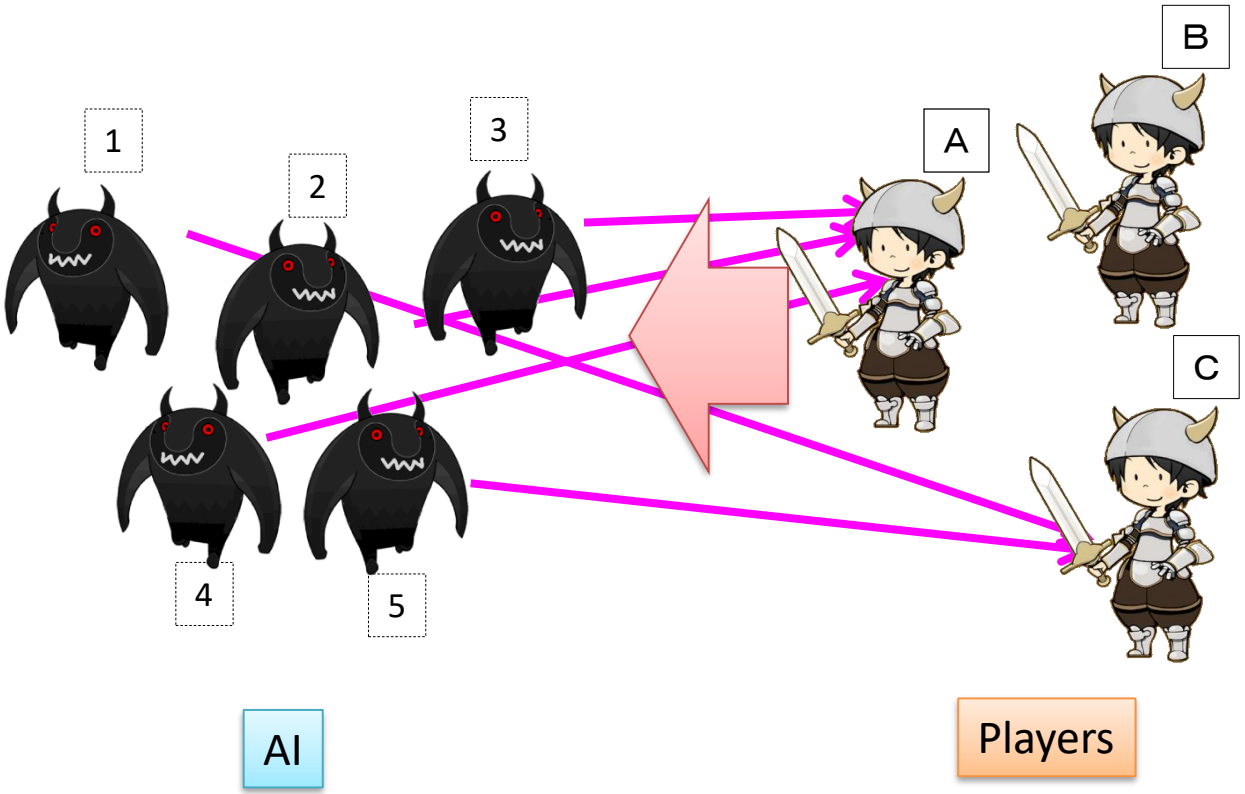
4.3

TARGETING WITH BLACKBOARD

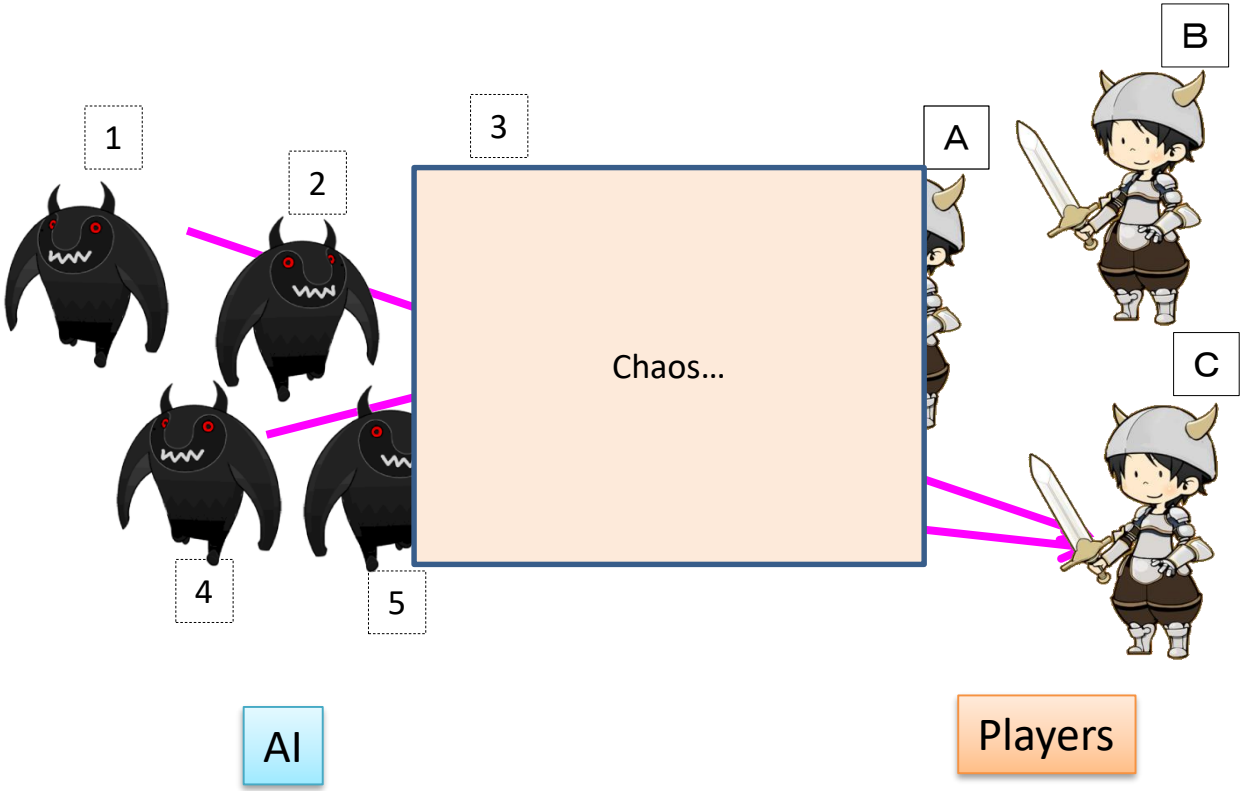
Cooperation



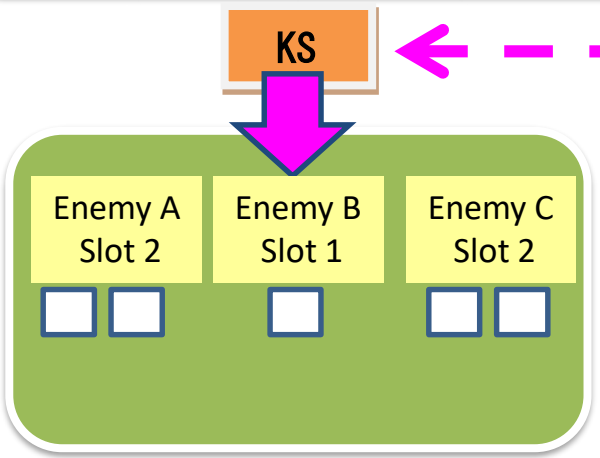
Cooperation

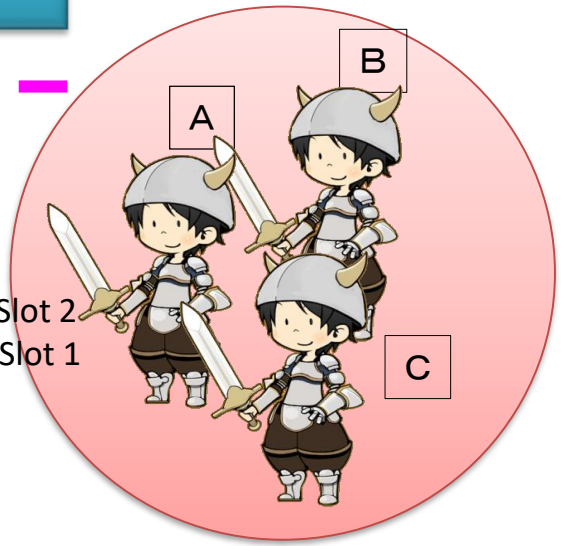


集団の協調

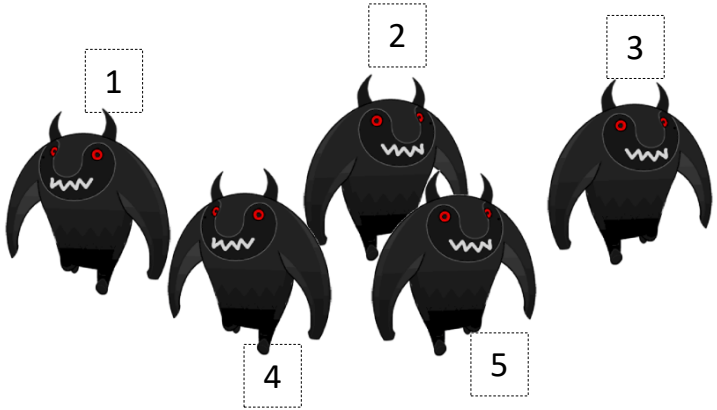


Cooperation

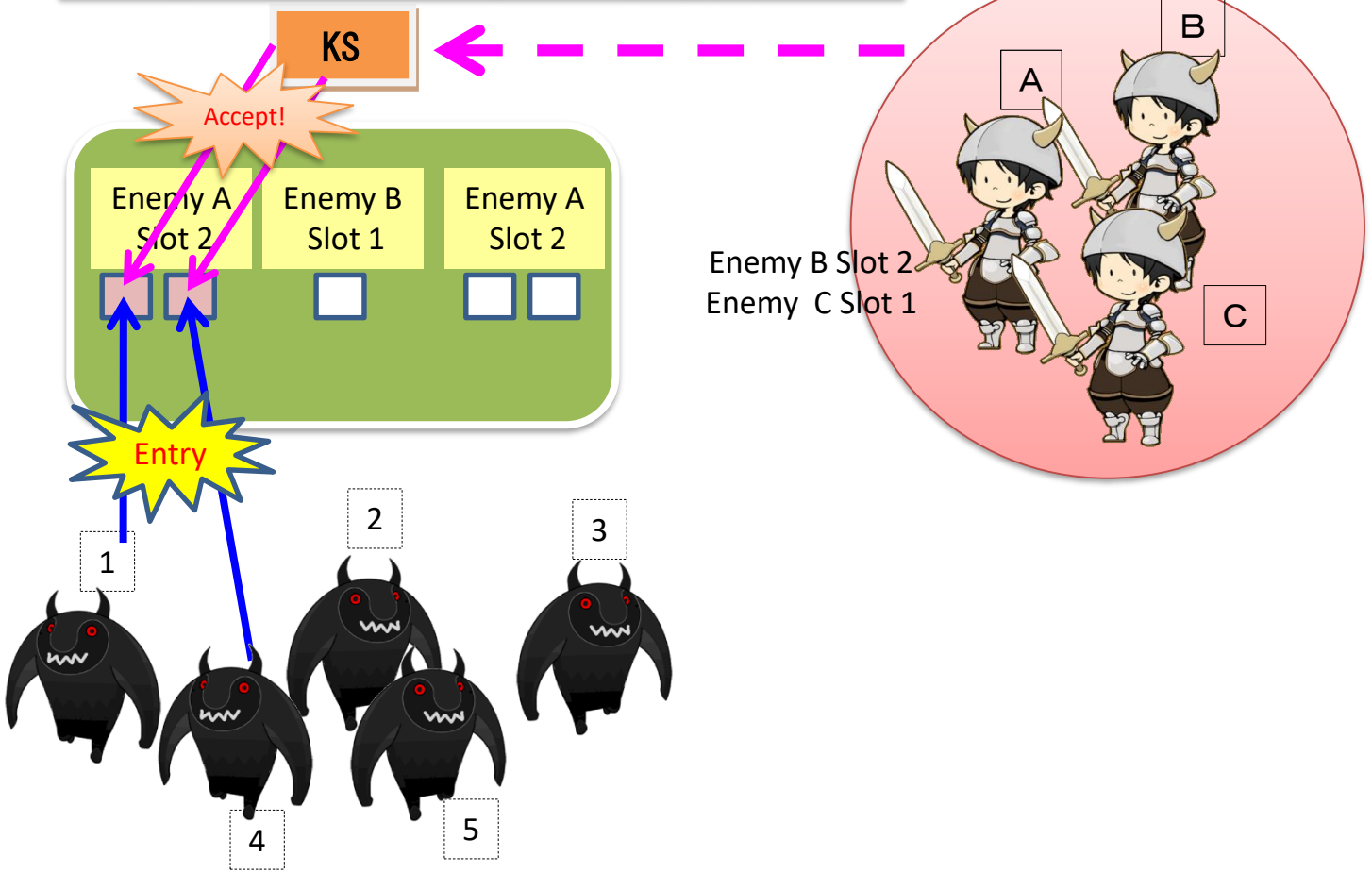




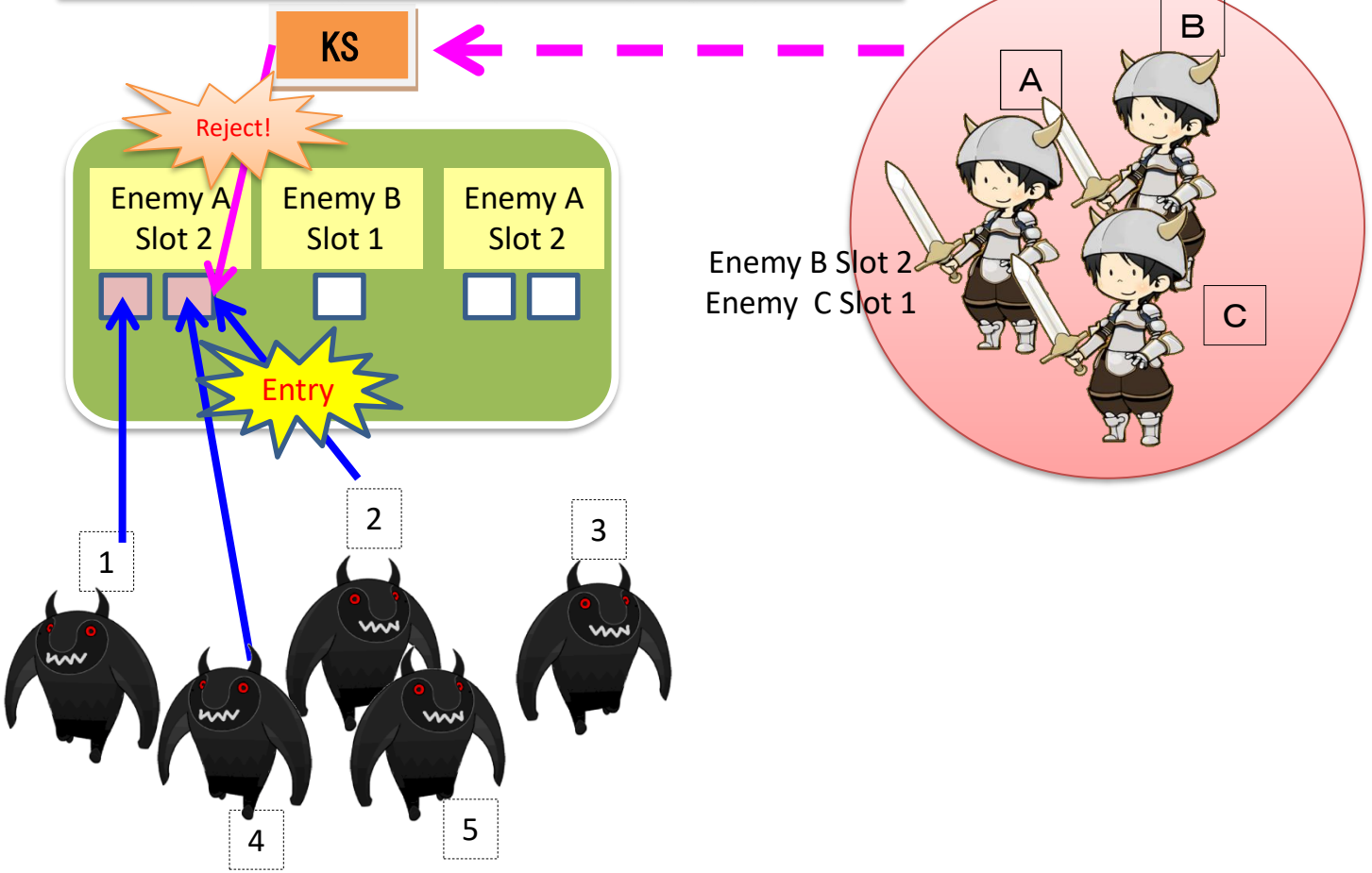
Enemy B Slot 2
Enemy C Slot 1



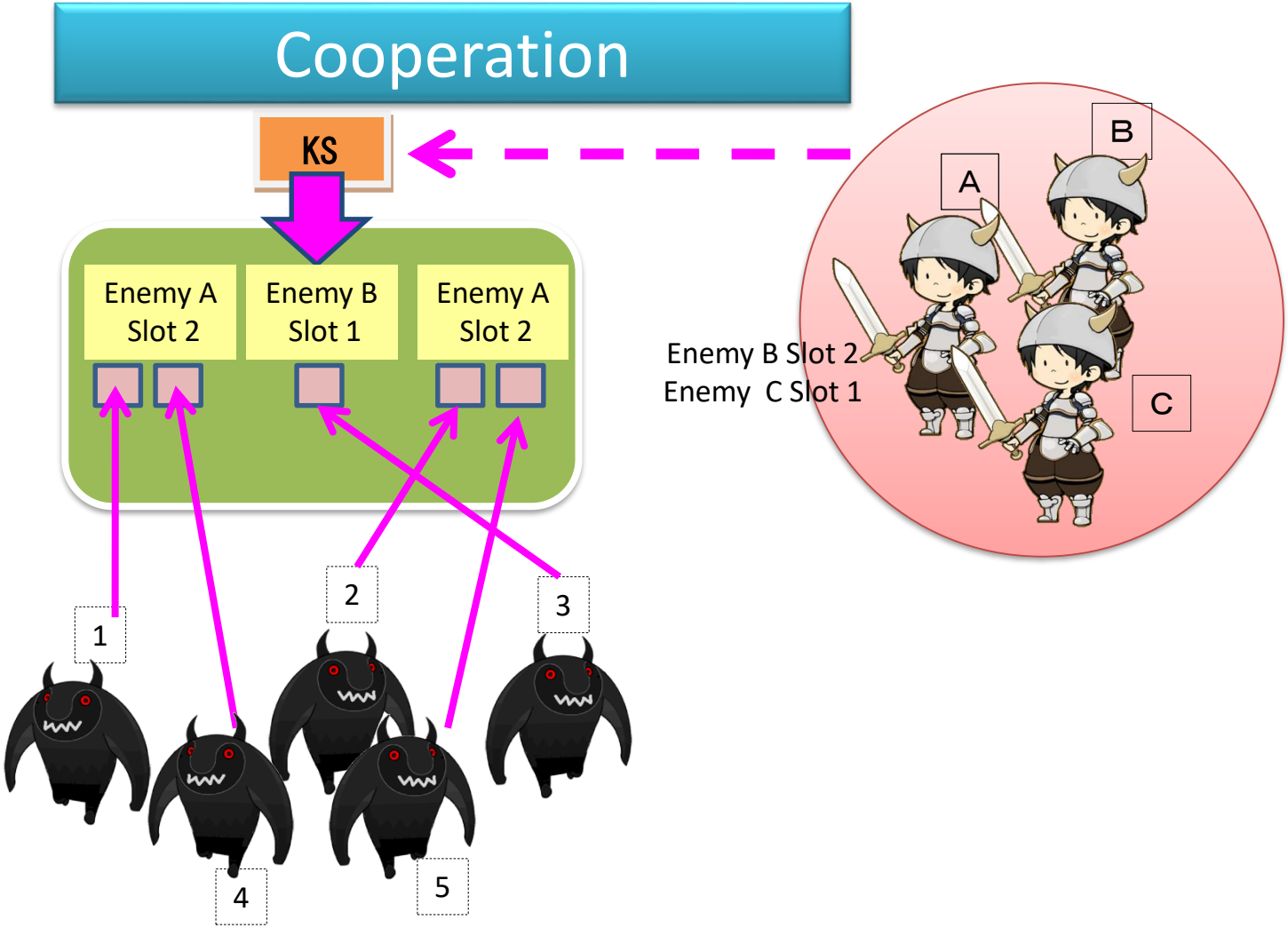
Cooperation



Cooperation



Cooperation



Digital Game AI

Contents

This slide has many movies that can be replayed by pushing a button ▶

Chapter 9

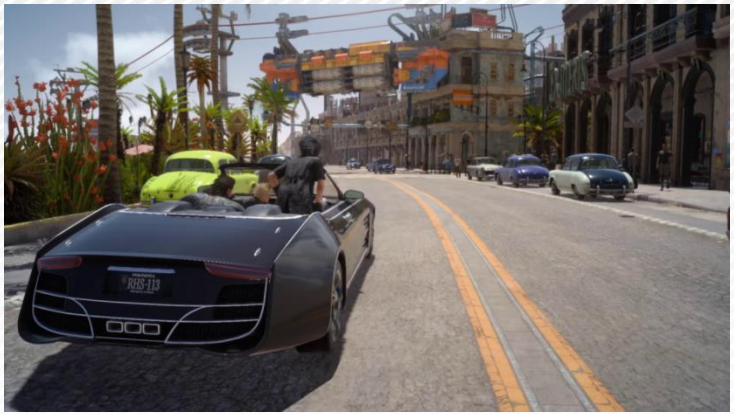
AMBIENT AI

(NON-PLAYER CHARACTER IN THE TOWN)

Not Just Planning: STRIPs for Ambient NPC Interactions in Final Fantasy XV
by Hendrik Skubch, Square Enix
(nucl.ai Conference 2015)
https://archives.nucl.ai/recording/not-just-planning-strips-for-ambient-npc-interactions-in-final-fantasy-xv/

Ambient NPCs in FF XV

- Goal: Convey culture by filling the world with life



Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

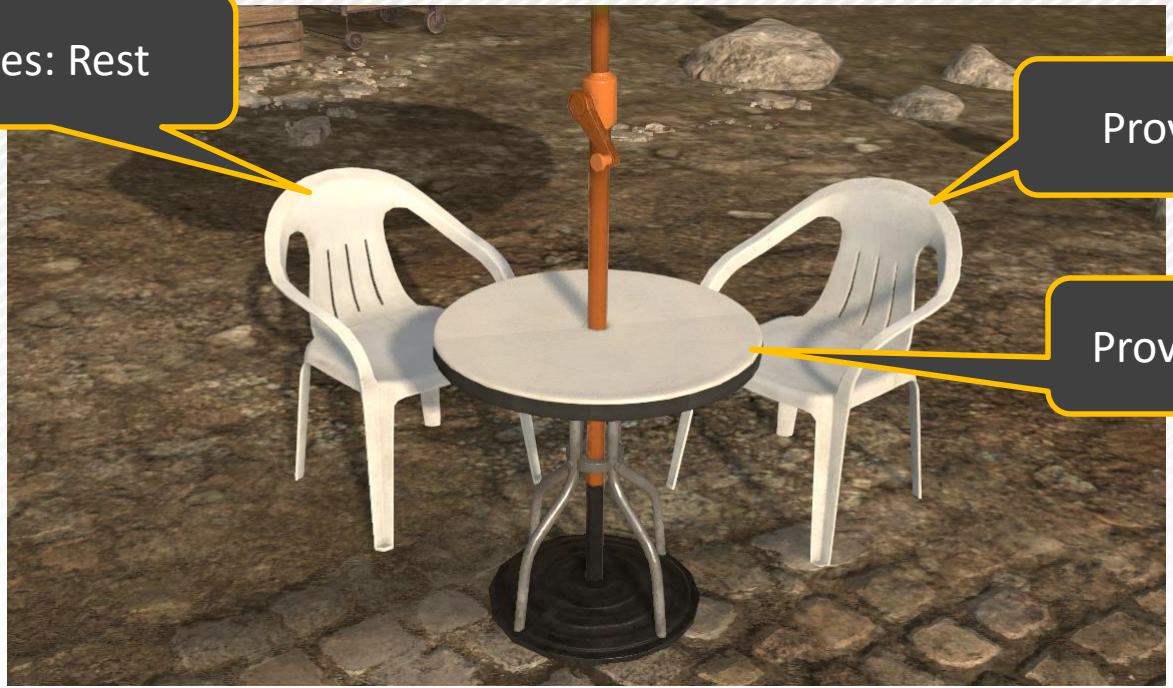
Ambient AI

Classic Smart Objects

The Good Old Fridge:

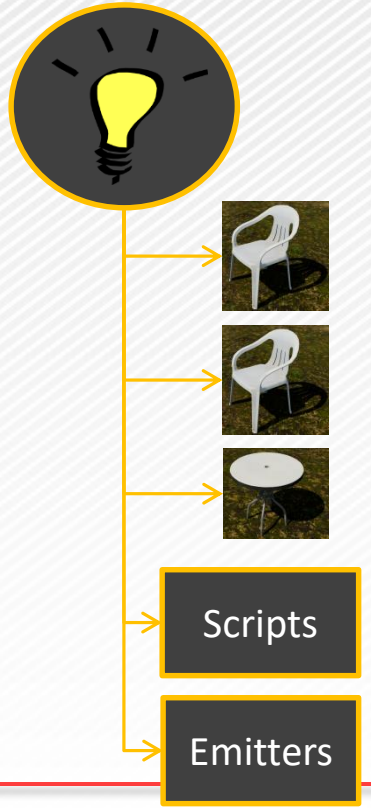
- SmartObject: emits information
- Contains all necessary data for interacting:
  - Animations
  - AI state machine
  - Sound
  - etc

Multiple Smart Objects



From SmartObjects to SmartLocations

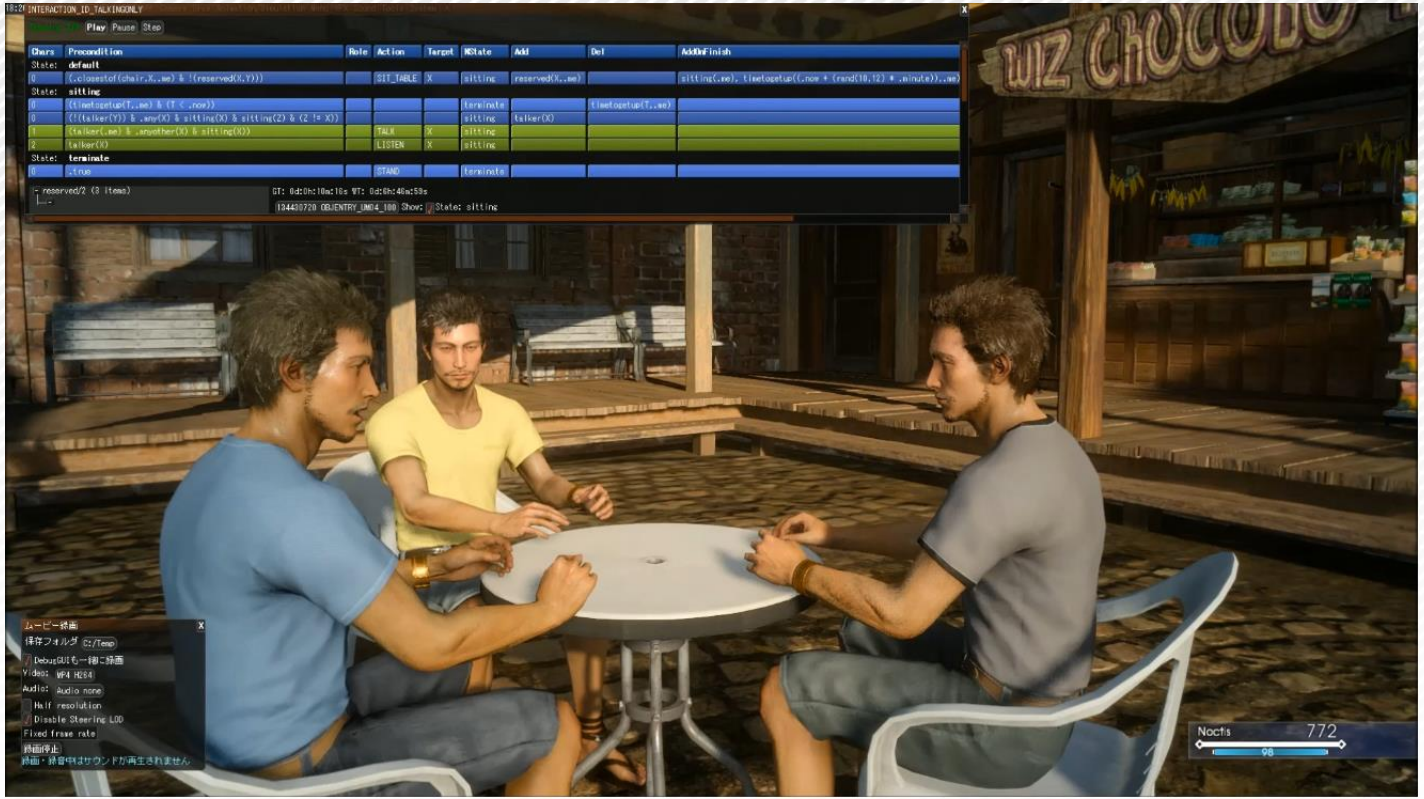
- Generalize SmartObjects to SmartLocations
  - Instead of the chairs being smart, have a single invisible object own the chairs and the table.
  - Put the “smartness” into this single object.



SmartLocation: Two Chairs and a Table

Interaction Type: Rest
Has: 2 Chairs, 1 Table

SmartLocation: Movie



SmartLocation: Movie

SmartLocation: Movie

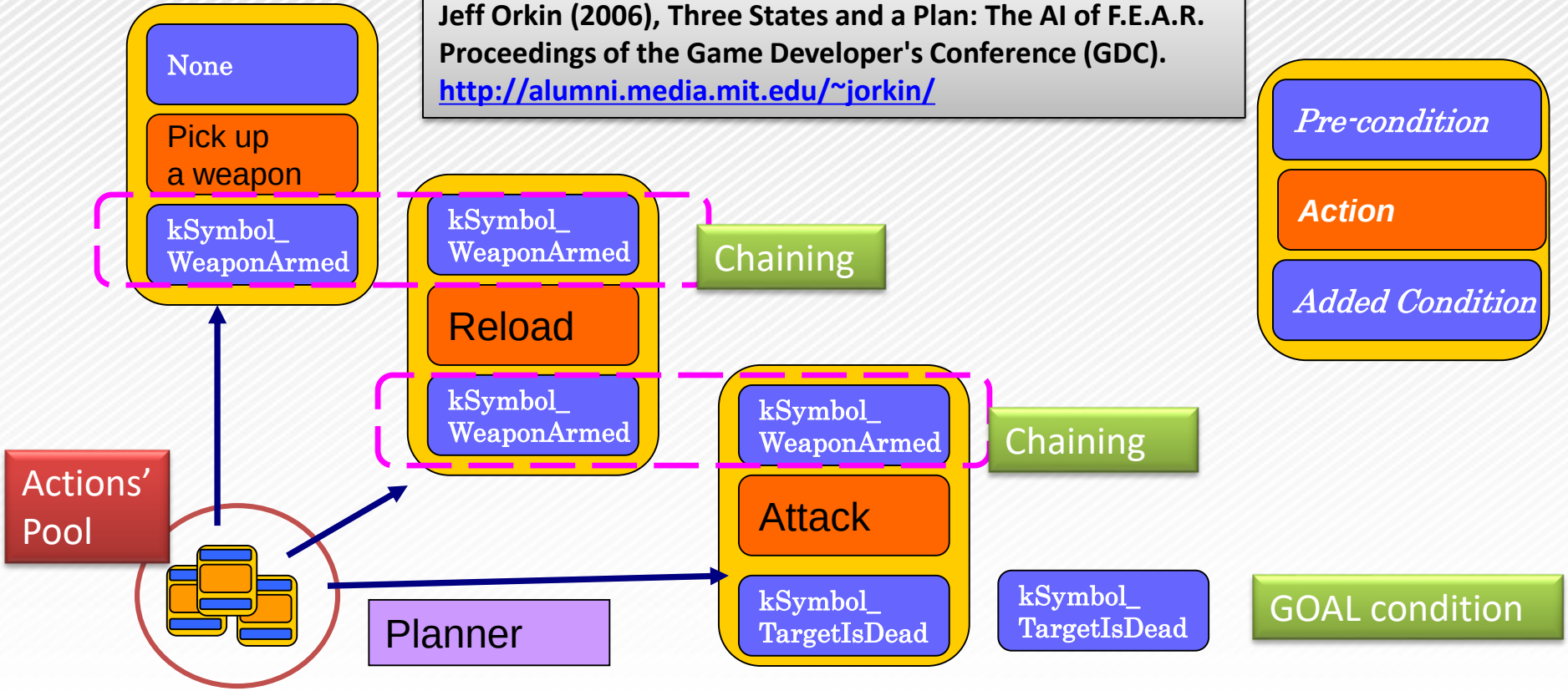
Scripting – Foundations

- STRIPS
  - Symbolic language to describe problem domains, especially for planning
  - Foundation for GOAP
  - Domain described in terms of states, actions and goals.
  - Ancient: 1971

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

GOAP (Goal-Oriented Action Planning)

Jeff Orkin (2006), Three States and a Plan: The AI of F.E.A.R. Proceedings of the Game Developer's Conference (GDC).
http://alumni.media.mit.edu/~jorkin/



Scripting – Foundations

Classic example from academia:

Action: pickup(X)
Pre: onTable(X) & clear(X) & !holding(Y)
Add: holding(X)
Del: onTable(X), clear(X)

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

A Conversation with Two NPCs

Sitting Down

Rule 1:

Action:	sit(X)
Pre:	closestOf(chair,X,me) & !reserved(X,Y)
Add:	reserved(X,me)
Add-Deferred:	sitting(me) & timeToGetUp(now+rand(10,15)*minute,me)
Next State:	sitting

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

Talking

Rule 3:

State:	sitting
Action:	talk(X)
Pre:	talker(me) & anyOther(X) & sitting(X)
Del-Deferred:	talker(me)

Talk to a random sitting person if picked by the prior rule

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

Roles – Adding a Waiter

Calling the waiter:

Rule:

Role:	customer
State:	sitting
Action:	wave(W)
Pre:	!have(me,Food) & table(T) & !orderState(Any,T,me) & roleOf(W,waiter) & infrontOf(W,me) & !waving(Any)
Add:	waving(me)
Add-Deferred:	orderState(wantOrder,T,me)
Del-Deferred:	waving(me)

Select a waiter in front of an NPC (and thereby select an NPC)

Roles – Adding a Waiter

Example rule for the waiter:

Rule:	
Role:	waiter
State:	idle
Action:	goto(Table)
Pre:	orderState(wantOrder,Table,Someone)
Add-Deferred:	waiterAtTable(me,Table)
NextState:	takeOrder

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

Roles – Adding a Waiter

Roles – Adding a Wai (Video)

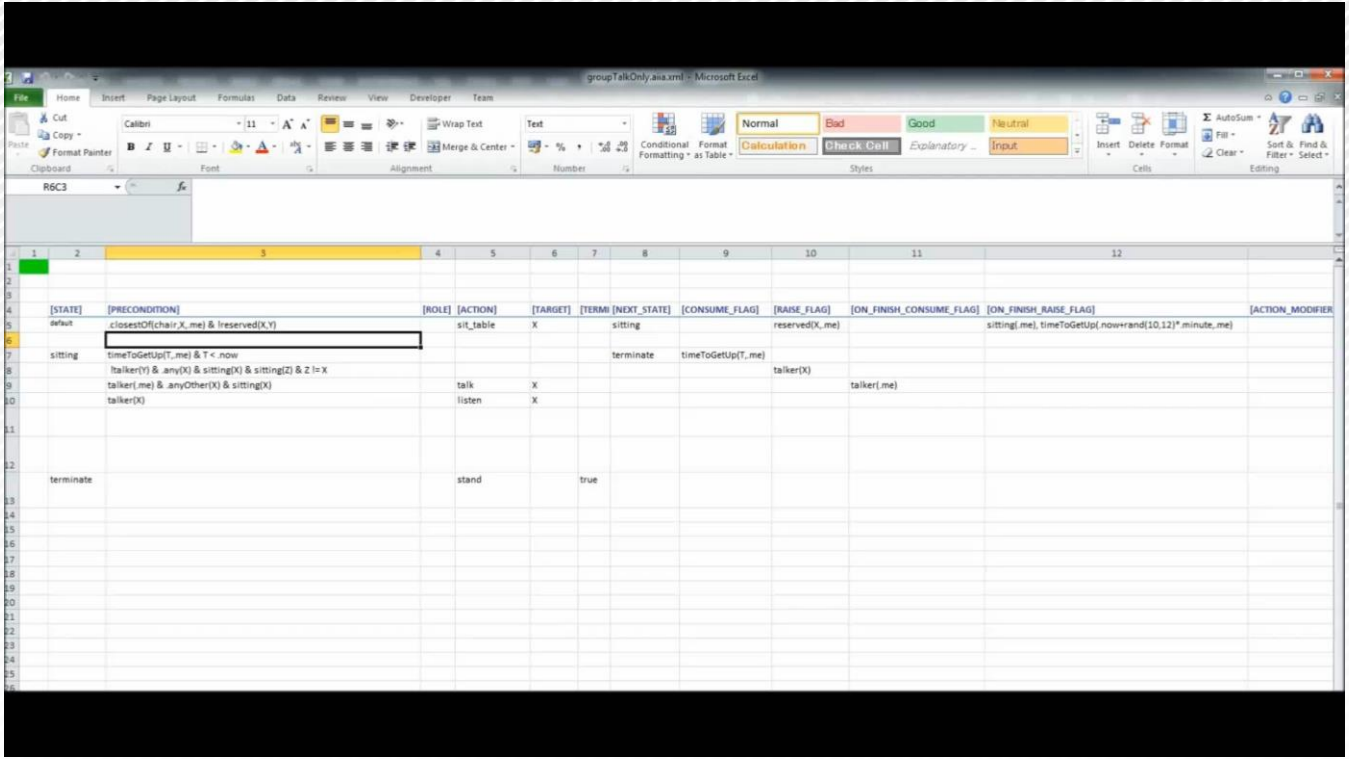
Editor

The complete script for the conversation example:

[STATE]	[PRECONDITION]	[ROLE]	[ACTION]	[TARGET]	[TERMINATE]	[NEXT_STATE]	[CONSUME_FLAG]	[RAISE_FLAG]	[ON_FINISH_CONSUME_FLAG]	[ON_FINISH_RAISE_FLAG]	[ACTION_MODIFIER]
default	.closestOf(chair,X,.me) & !reserved(X,Y)		sit_table	X		sitting		reserved(X,.me)		sitting(.me), timeToGetUp(.now+rand(10,12)*.minute,.me)	
sitting	timeToGetUp(T,.me) & T < .now					terminate	timeToGetUp(T,.me)				
	!talker(Y) & .any(X) & sitting(X) & sitting(Z) & Z != X							talker(X)			
	talker(.me) & .anyOther(X) & sitting(X)		talk	X					talker(.me)		
	talker(X)		listen	X							
terminate			stand		true						

Editor

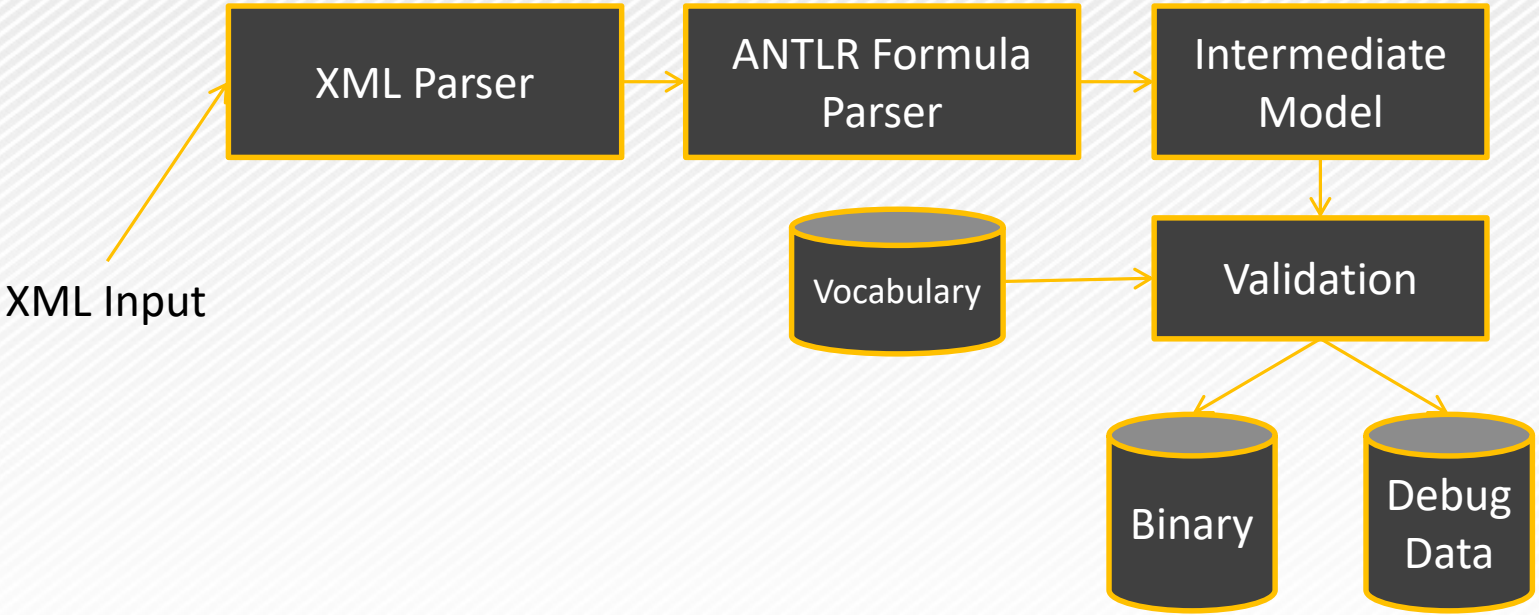
The complete script for the conversation example:



groupTalkOnly.aia.xml - Microsoft Excel

	[STATE]	[PRECONDITION]	[ROLE]	[ACTION]	[TARGET]	[TERMI	[NEXT_STATE]	[CONSUME_FLAG]	[RAISE_FLAG]	[ON_FINISH_CONSUME_FLAG]	[ON_FINISH_RAISE_FLAG]	[ACTION_MODIFIER
5	default	closestOf(chair,X,me) & !reserved(X,Y)		sit_table	X		sitting		reserved(X,me)		sitting(.me), timeToGetUp(.now+rand(10,12)*.minute,me)	
6												
7	sitting	timeToGetUp(T,me) & T < .now					terminate	timeToGetUp(T,me)				
8		!talker(Y) & .any(X) & sitting(X) & sitting(Z) & Z != X							talker(X)			
9		talker(.me) & .anyOther(X) & sitting(X)		talk	X					talker(.me)		
10		talker(X)		listen	X							
12	terminate			stand		true						

Compiler

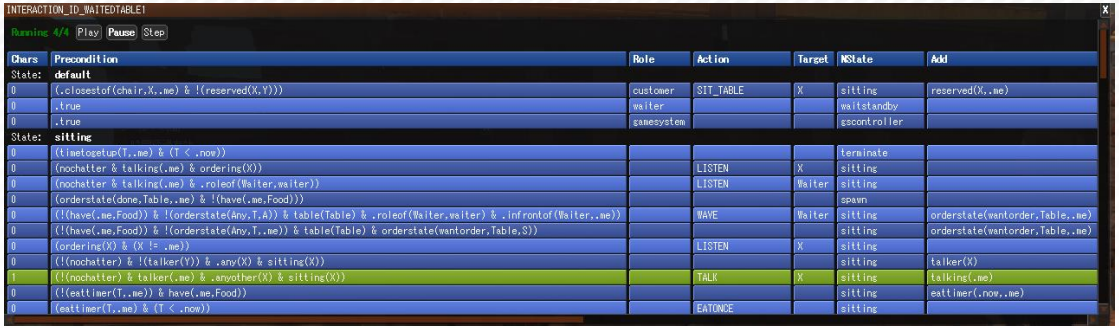


Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch, GAME AI PRO 3

Runtime Debugging

Debug View:

- Pausing
- Stepping
- Tuple Space Inspection



Ambient AI

Ambient AI (movie)

Digital Game AI

Contents

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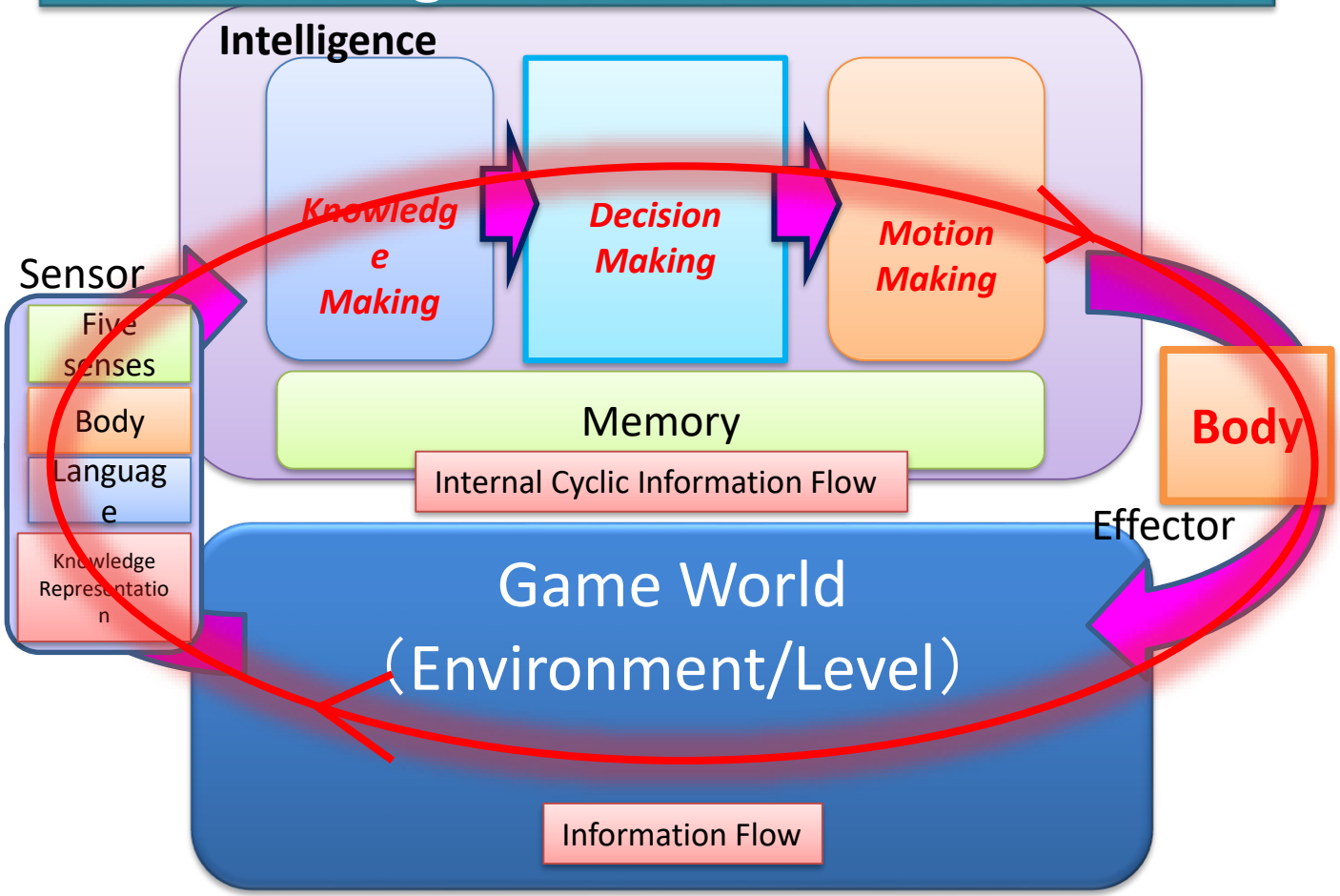
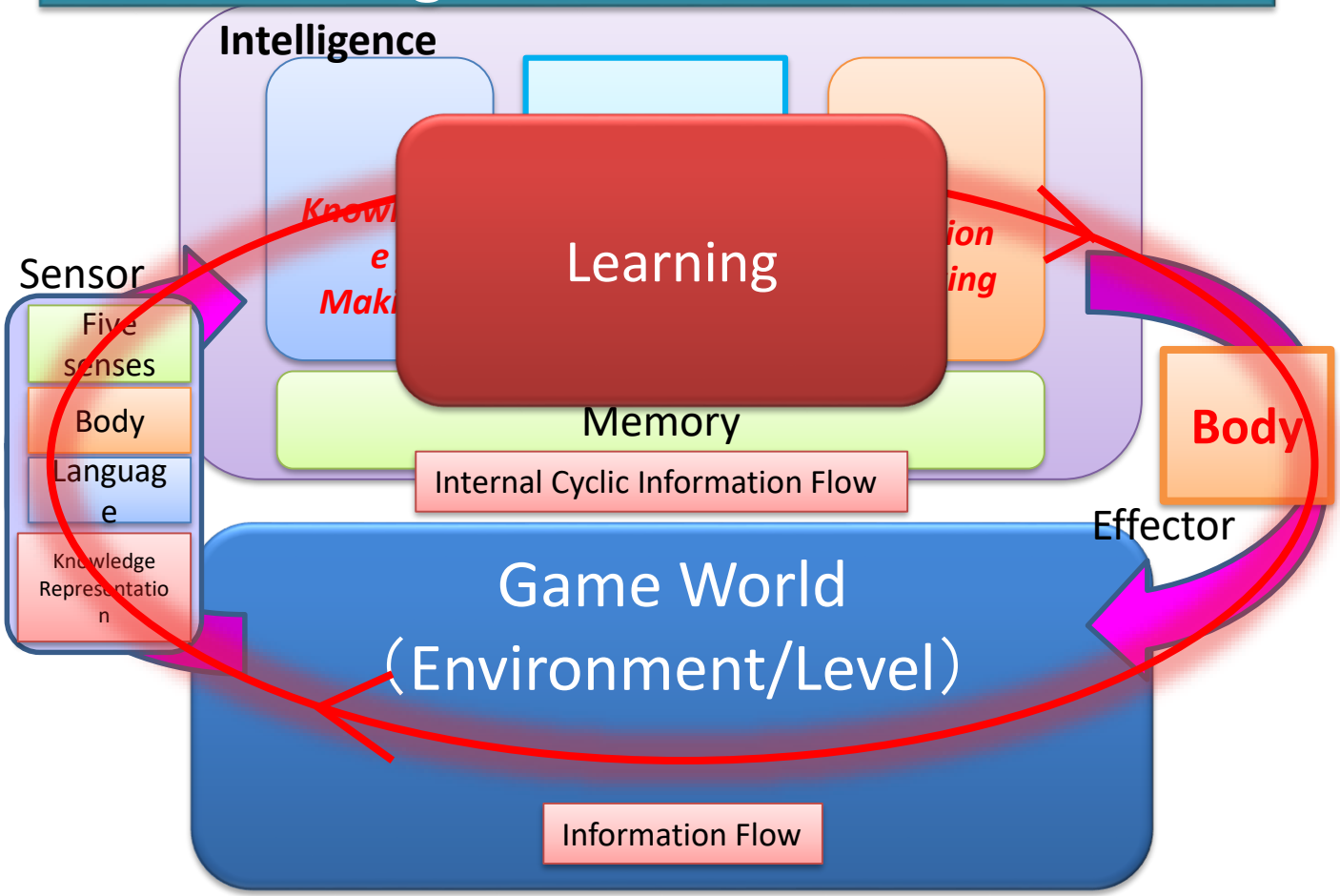
CHAPTER 11.
LEARNING SYSTEM FOR A CHARACTER

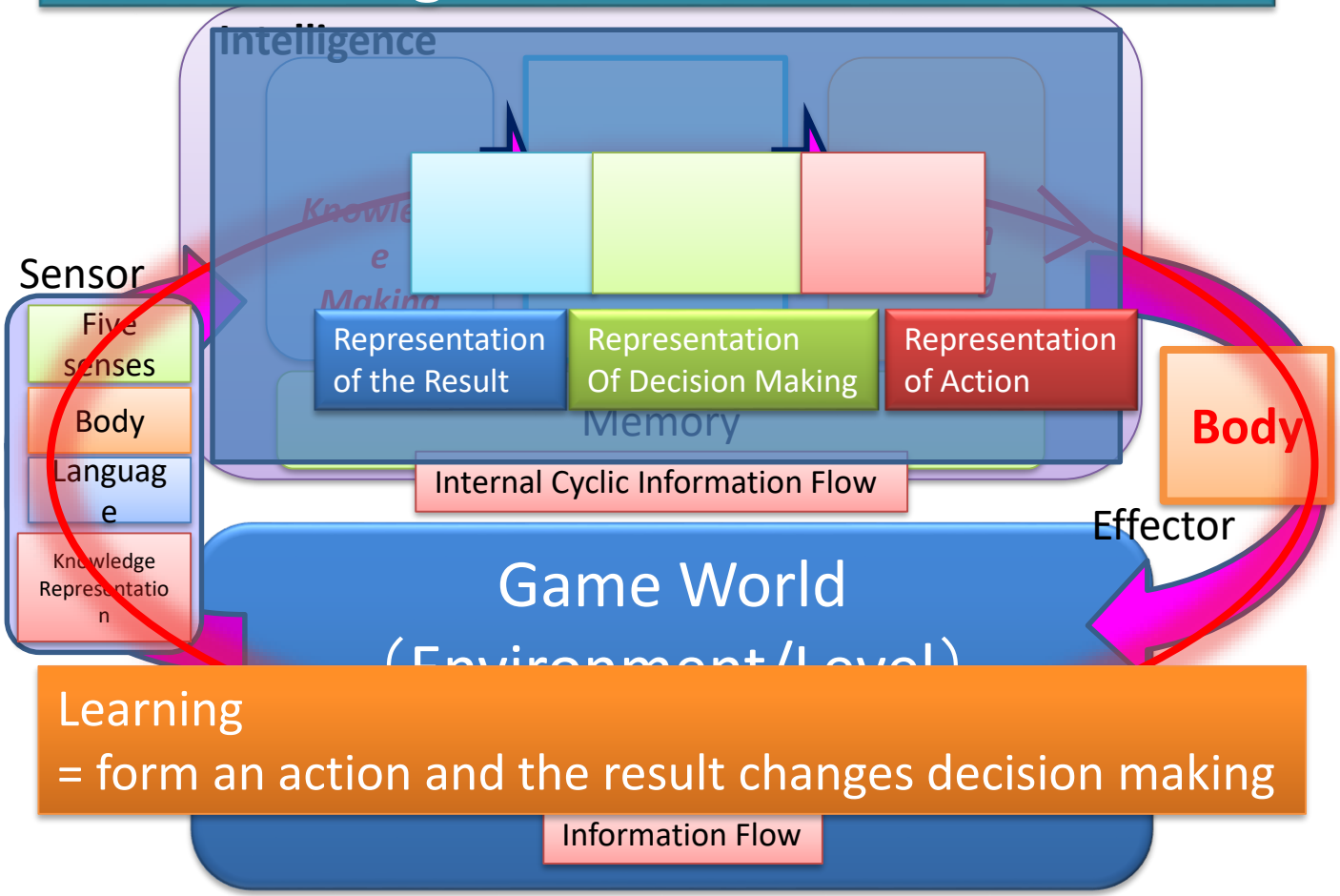
Agent Architecture



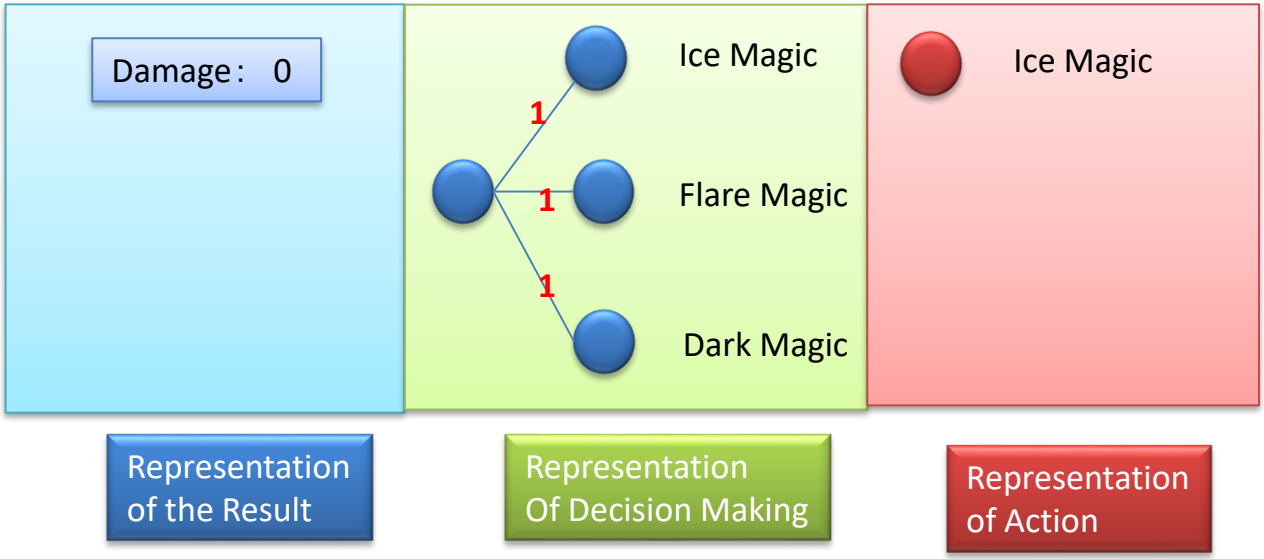
Agent Architecture



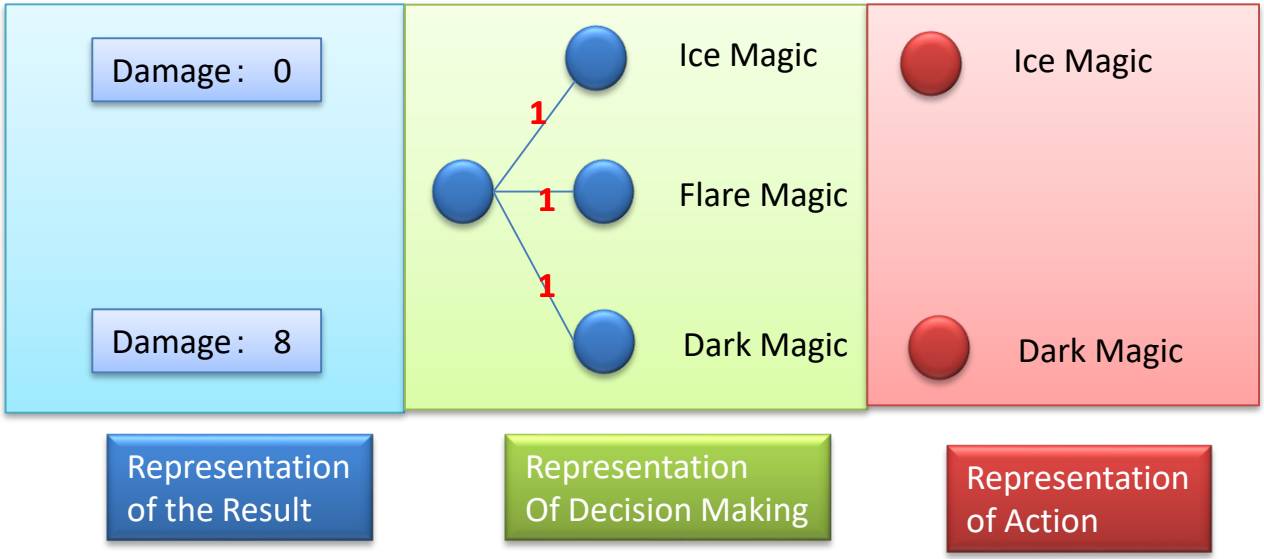
Agent Architecture



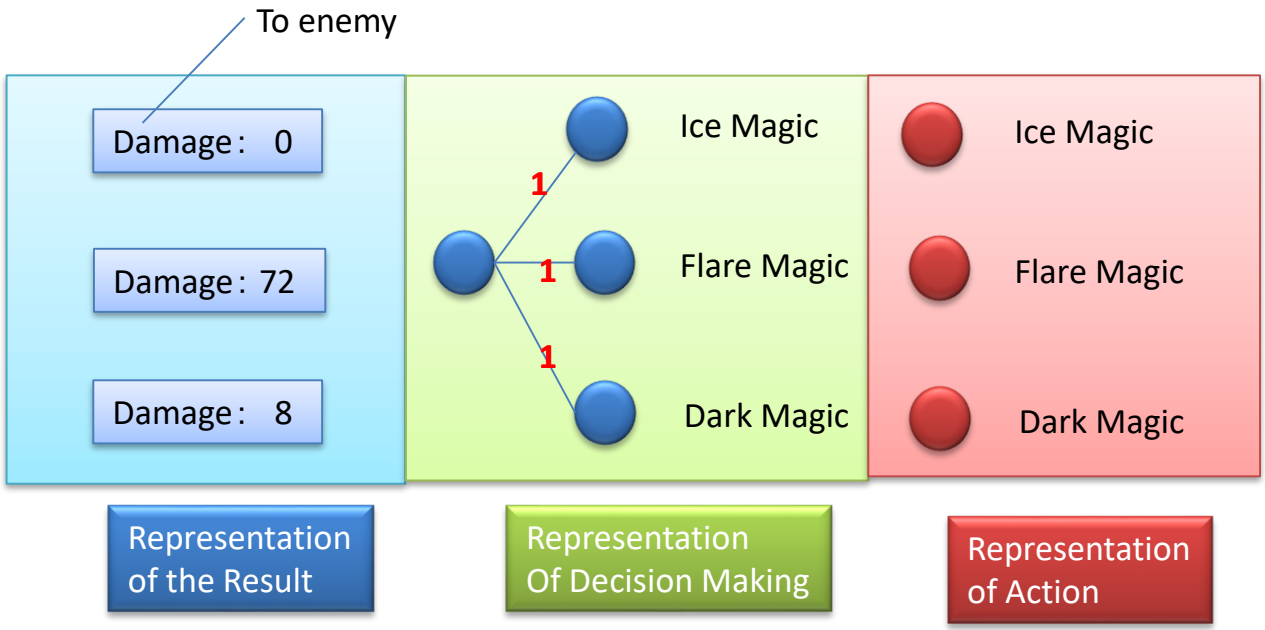
Principle of learning for chracter



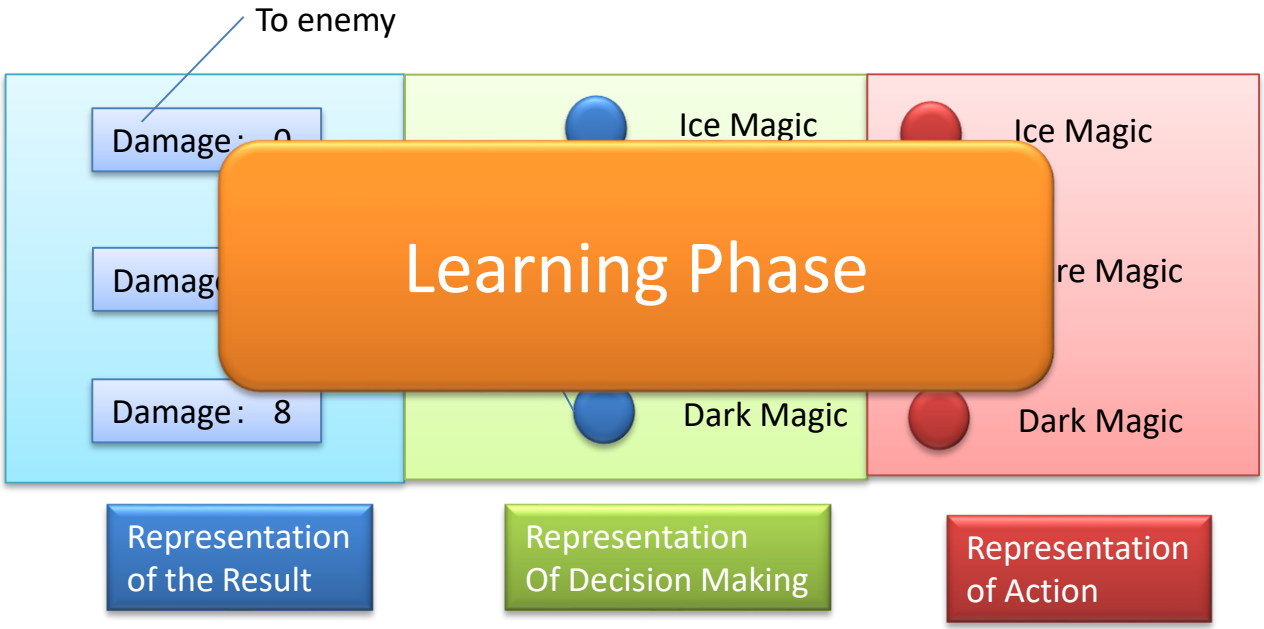
Principle of learning for chracter



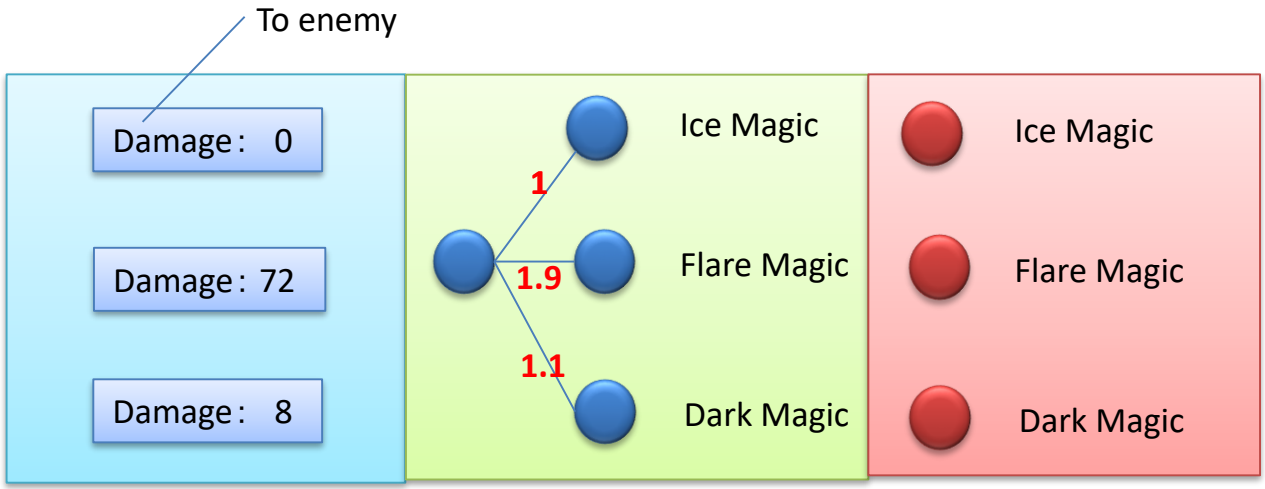
Principle of learning for chracter



Principle of learning for chracter

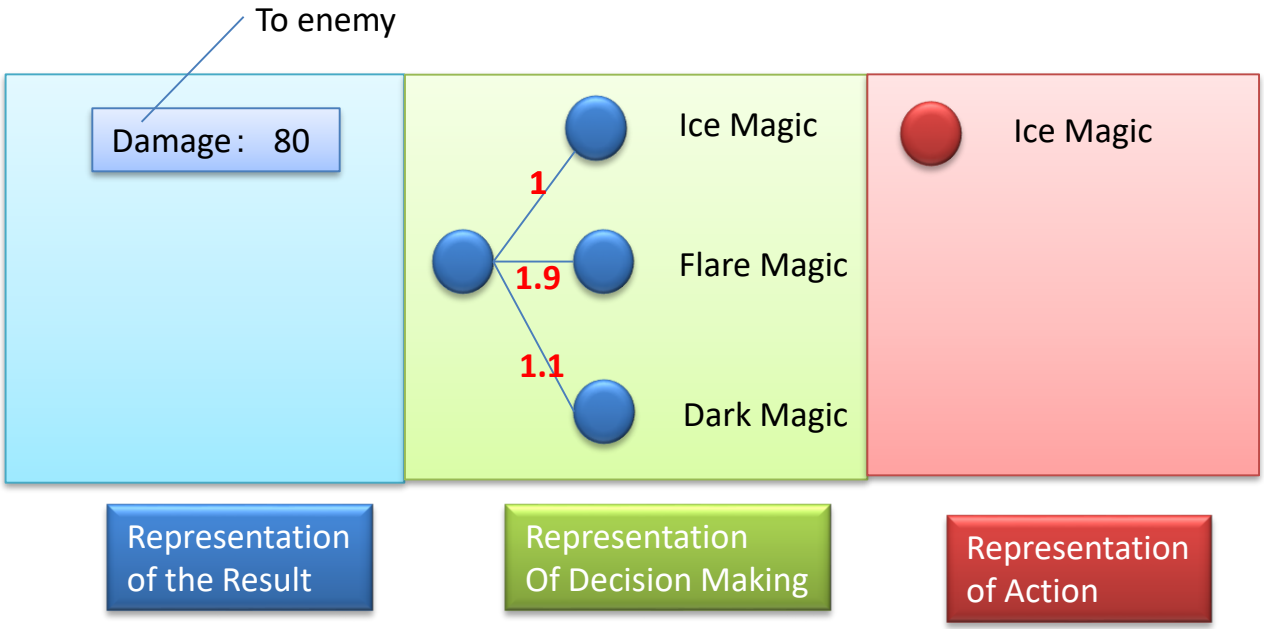


Principle of learning for chracter

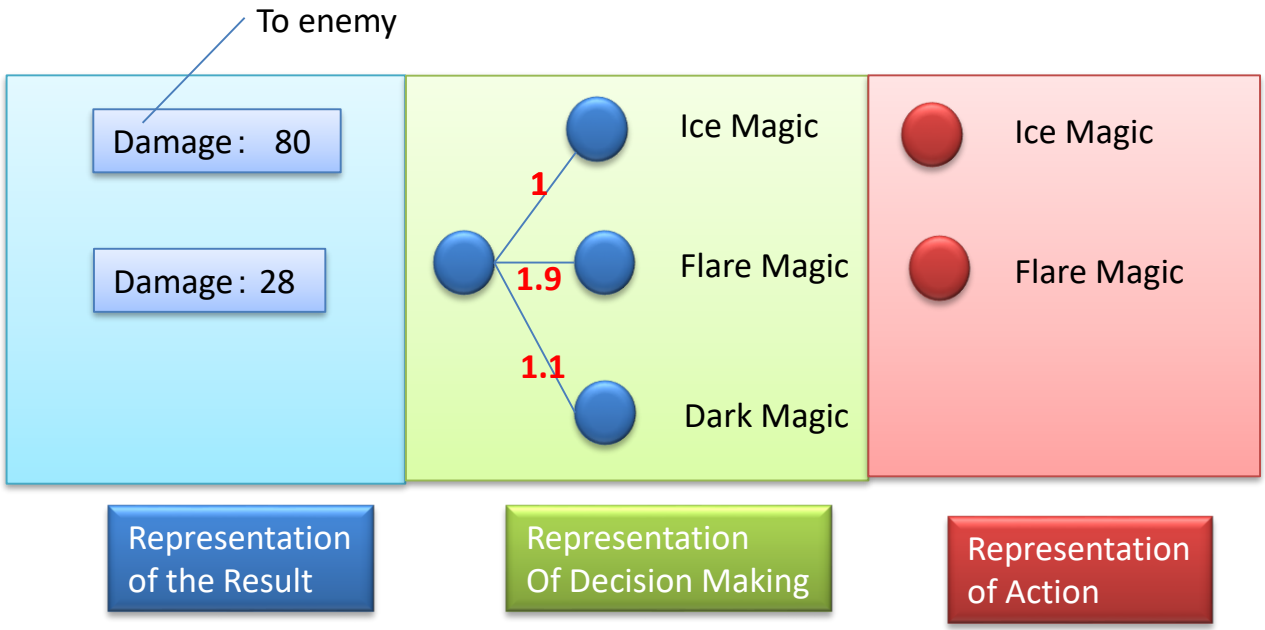


（Example） Ice Magic 1+0/ (72+8) = 10/10
Flare Magic 1+ 72/(72+8) = 19/10
Dark Magic 1+ 8/ (72+8) = 11/10

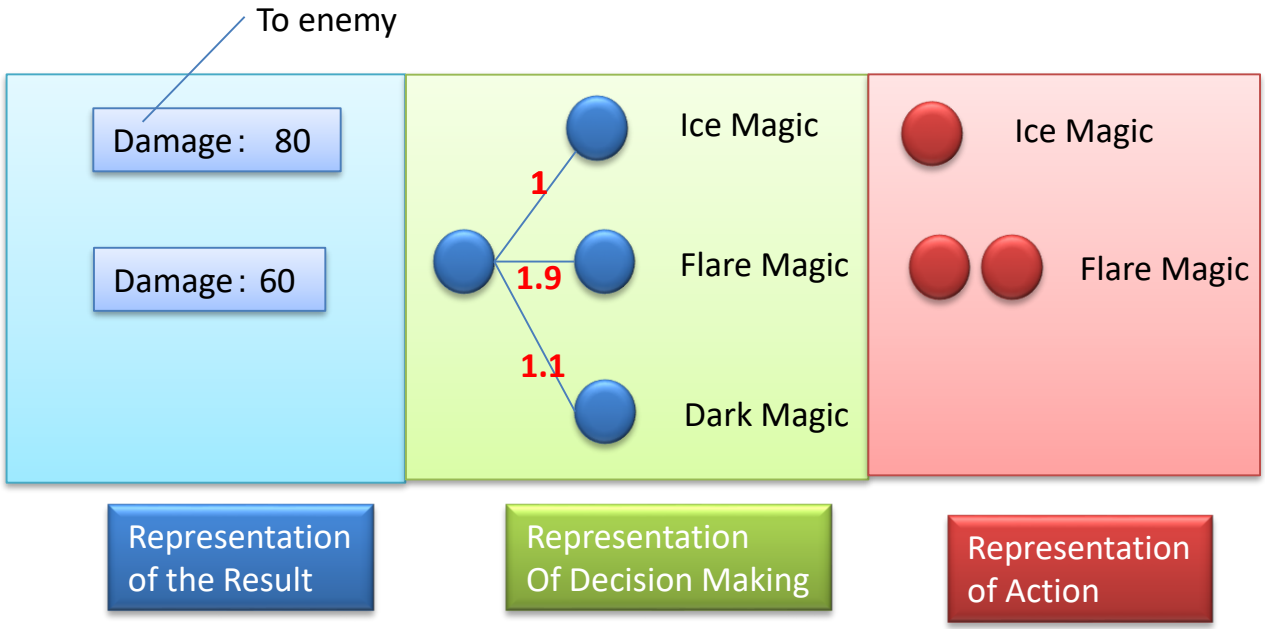
Principle of learning for chracter



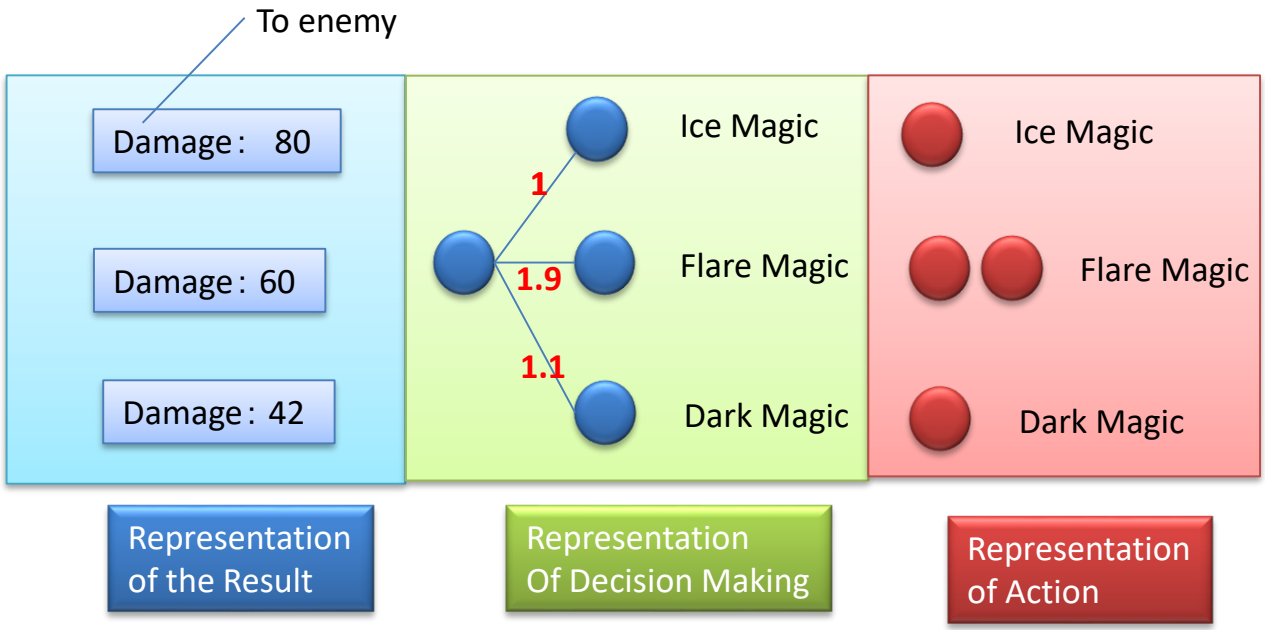
Principle of learning for chracter



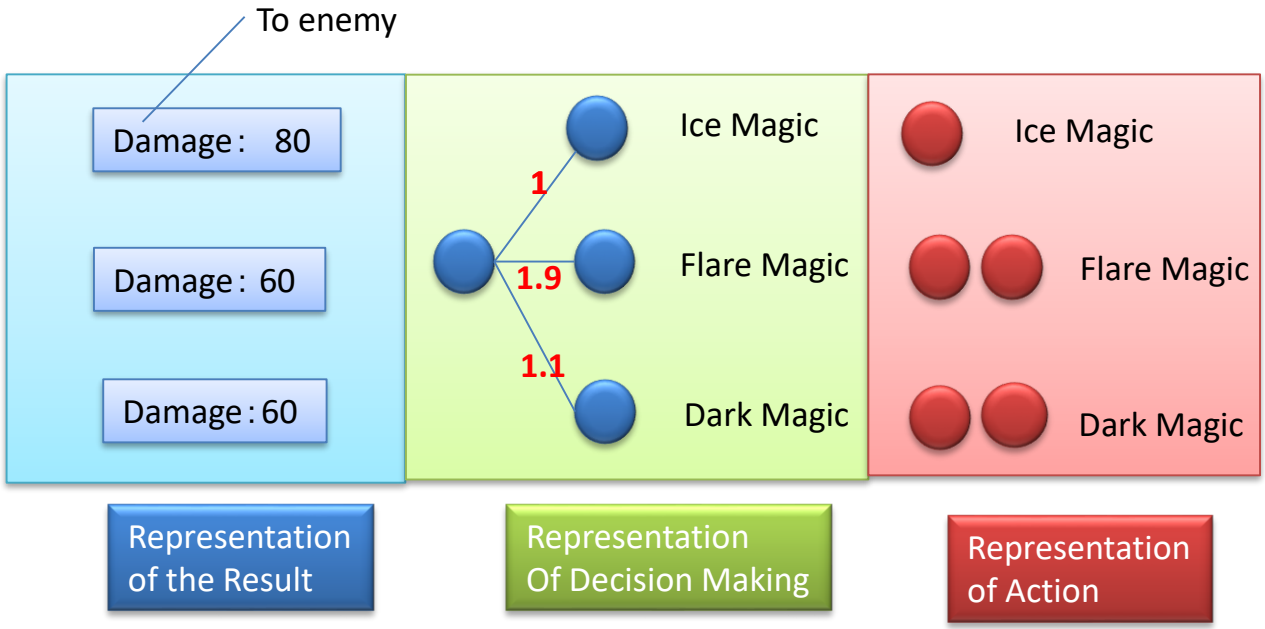
Principle of learning for chracter



Principle of learning for chracter

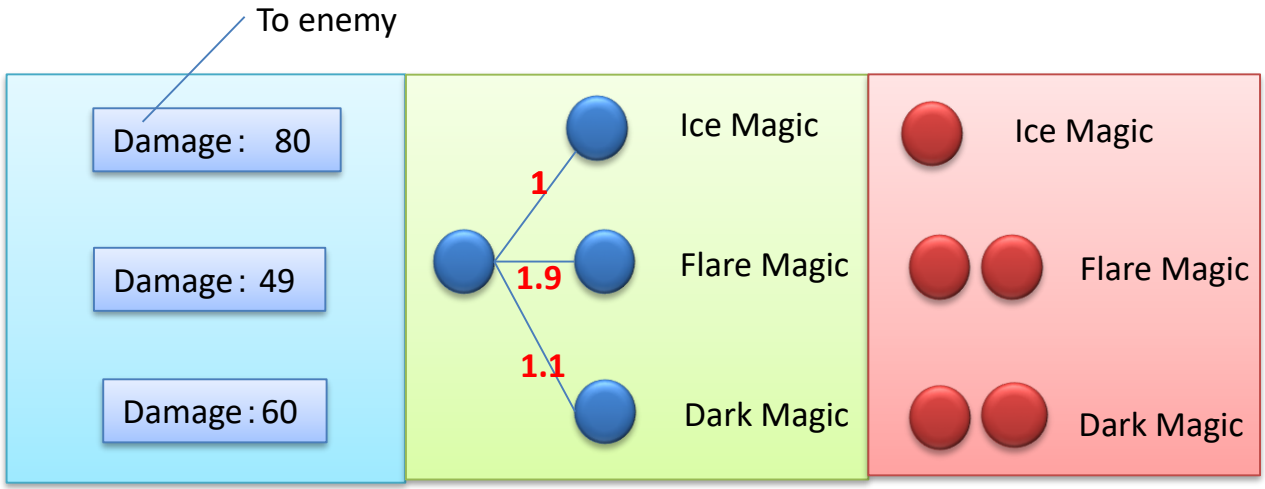


Principle of learning for chracter



Principle of learning for chracter

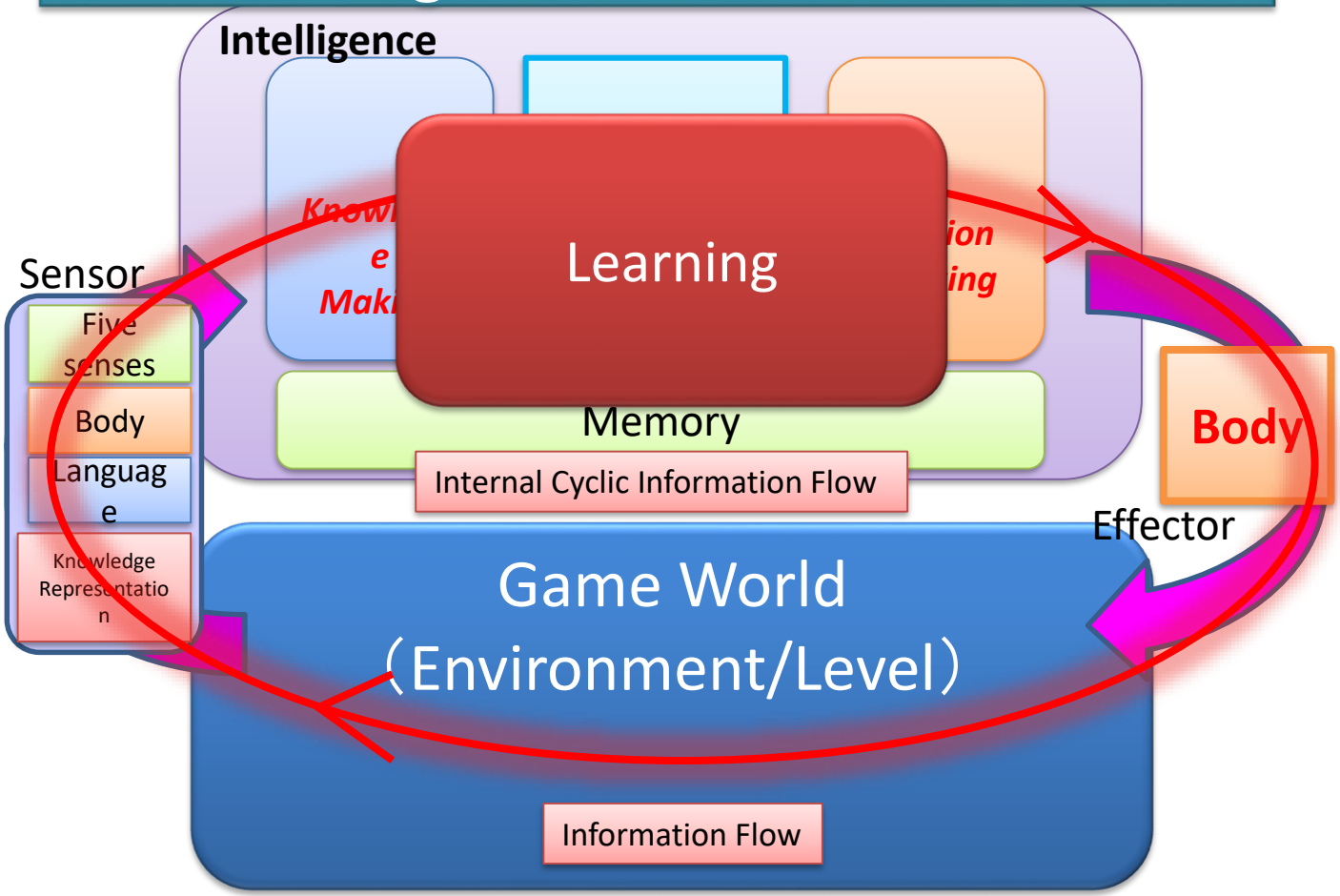
Principle of learning for chracter



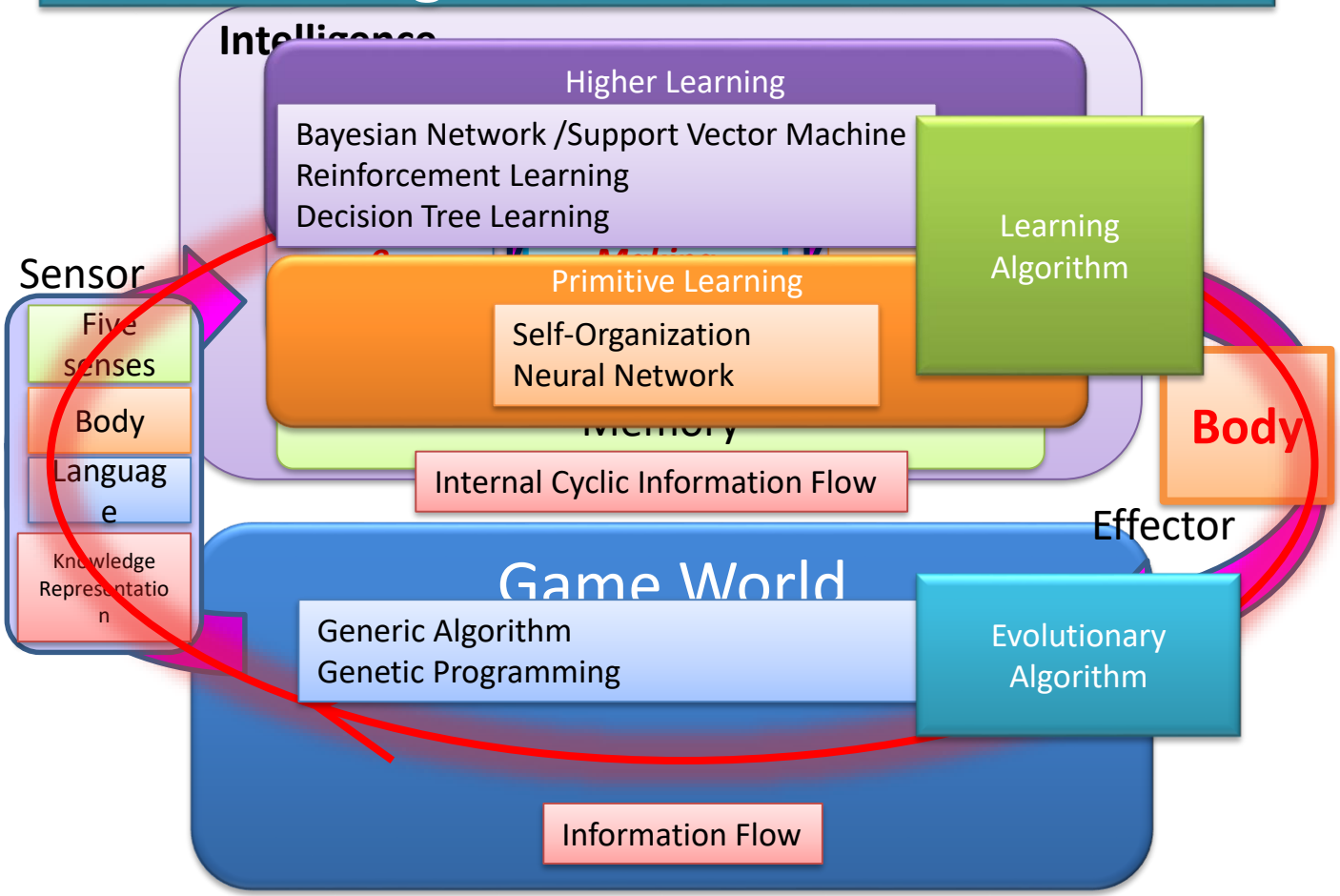
（例） Ice Magic 1+ 80/ (80+60+60) = 1.4
Flare Magic 1.9 + 60/ (80+60+60) /3 = 2.2
Dark MAgic 1.1 + 60/ (80+60+60) /2 = 1.4

CHARACTER EVOLUTION

Agent Architecture



Agent Architecture



Learning・Evolutionary Algorithm

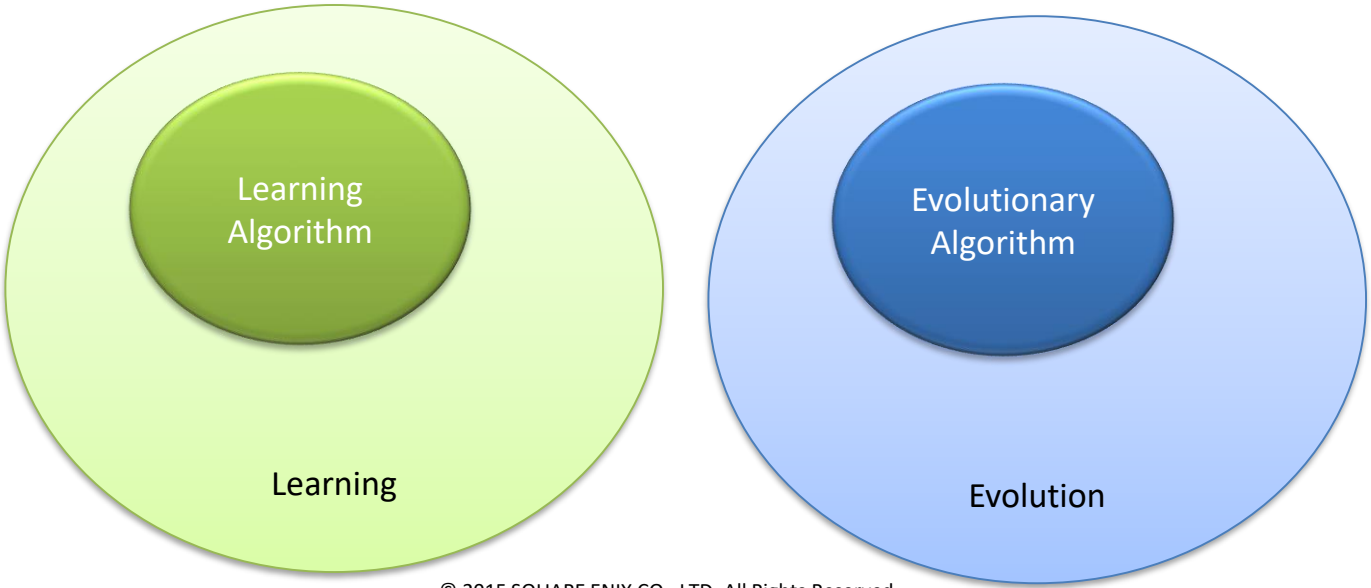
- Bayesian Network
- Support Vector Machine
- Reinforcement Learning
- Decision Tree Learning
- Self-Organization
- Neural Network
- Generic Algorithm
- Genetic Programming

Learning Algorithm
（for individual character）

Evolutionary Algorithm
（for character group）

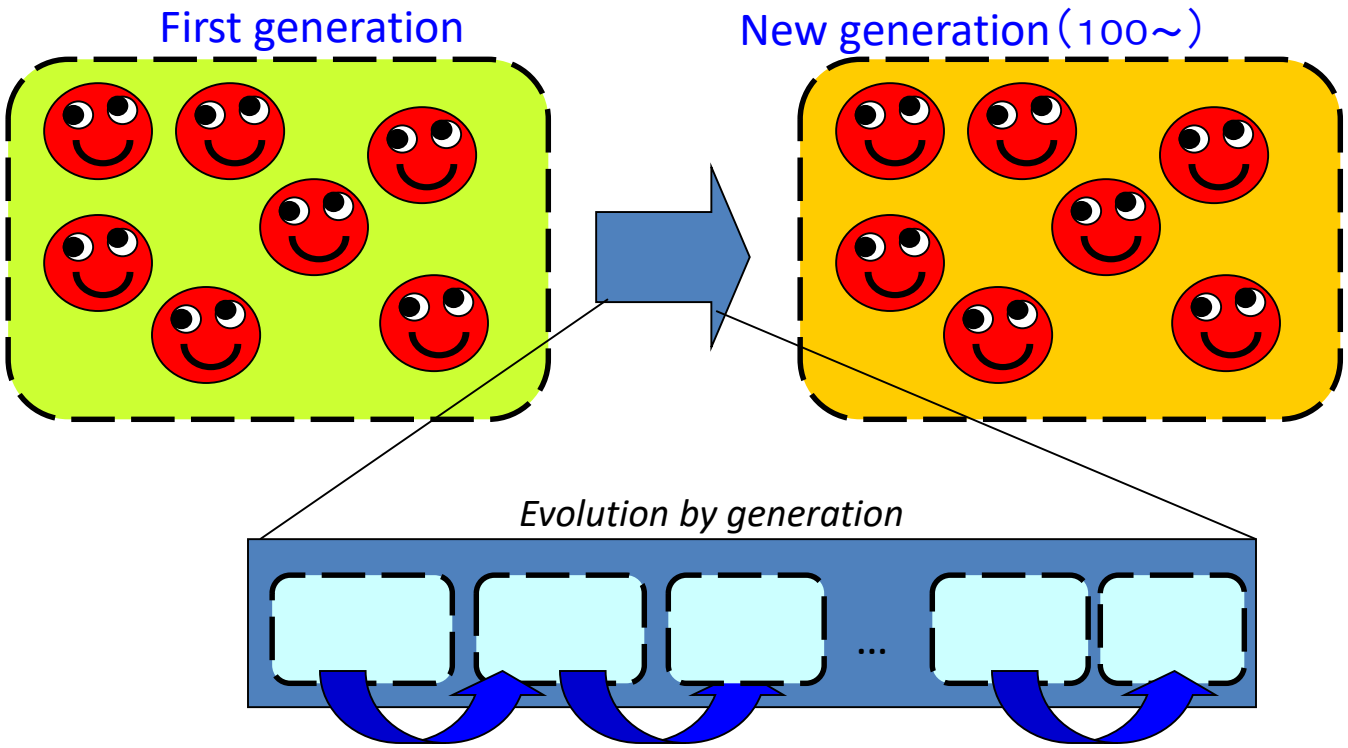
Learning・Evolutionary Algorithm

- 「Leaning = Learning algorithm」is not true.
- 「Evolution＝Evolutionary algorithm」is not true



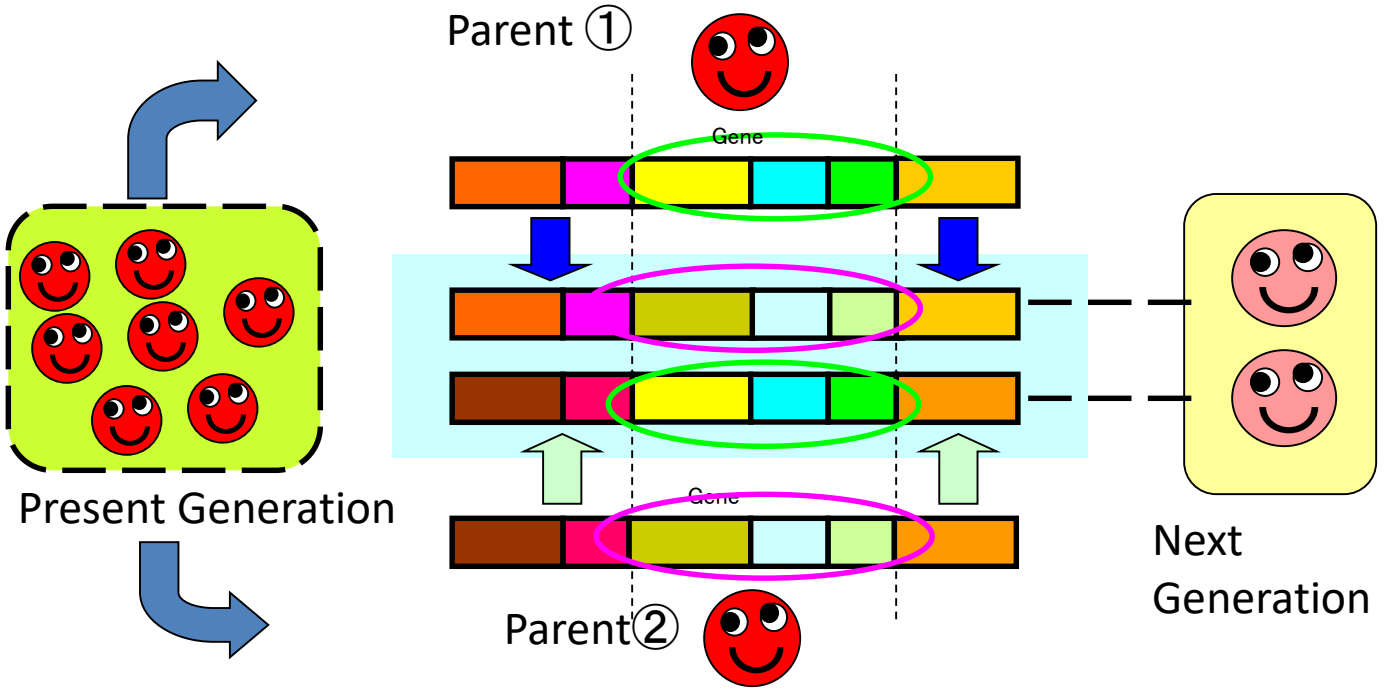
Genetic Algorithm

Make a group evolve in one direction



One generation produces a next generation

Genetic Algorithm



Pick up two parents from base group

(selection)

Crossover two genes

(crossover)

Produce new generation

(production)

The iteration makes a desired generation in the environment

②Simulation and Evaluation

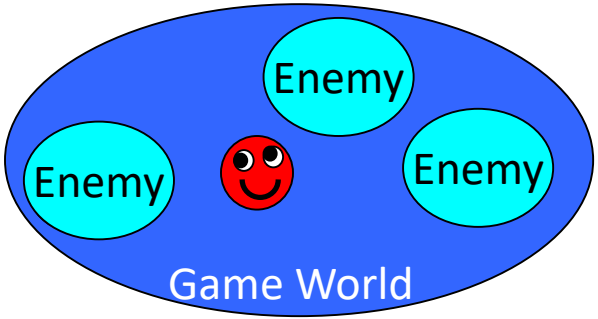
In the environment, after all NPC take actions, they are evaluated.

Evaluation function

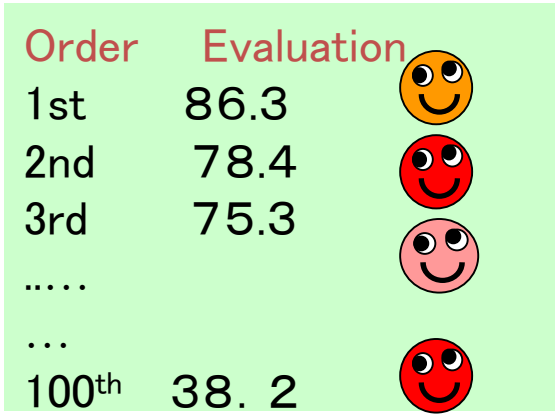
（Example）If you want to make strong NPC

*Evaluation function ＝0.7*Number of enemy it defeated ＋0.3* HP Remains*

If you want to make survival NPC *Evaluation function ＝ time to survive*



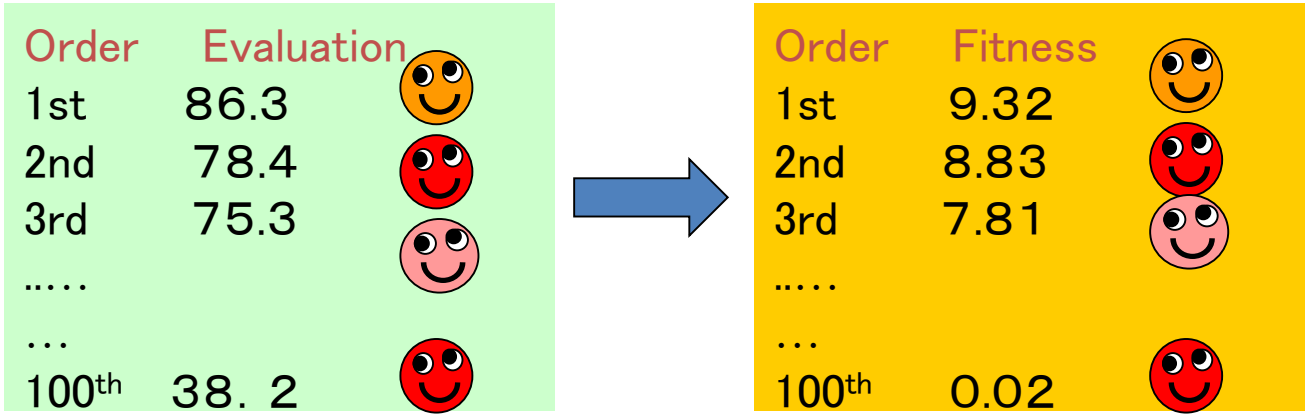
How an NPC adjusts to the world ?



Evaluate a gene by the result in the world of the NPC who has the gene.

From Evaluation Value to Fitness Value

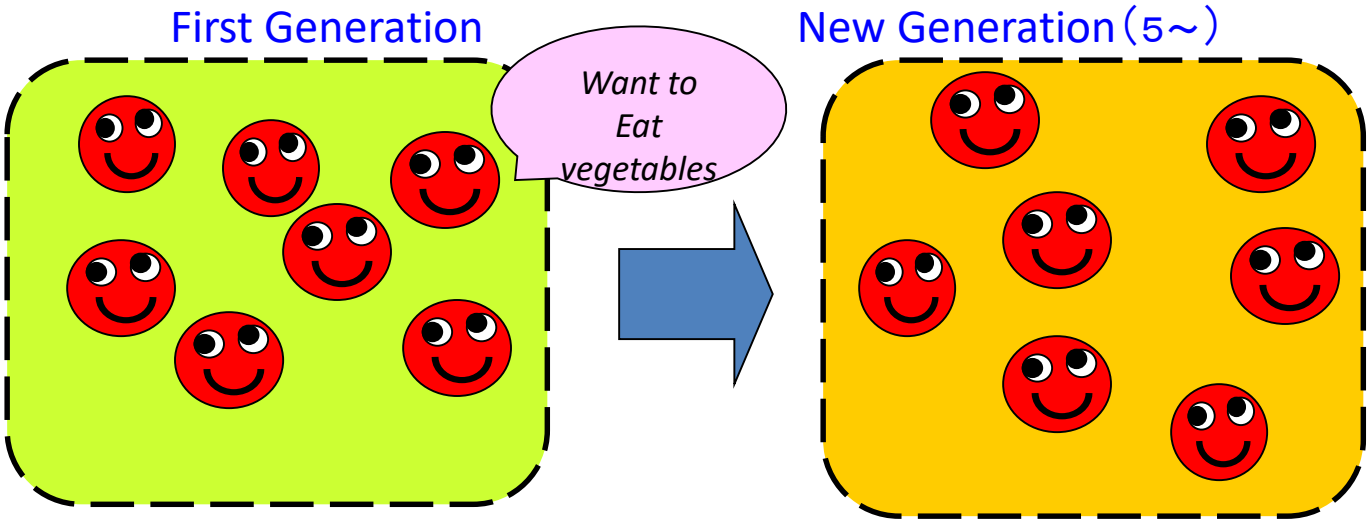
Transform evaluation value to fitness value



Evaluation value is score.
Fitness value shows how the agent fit the world.

The best AI game in the world that uses Generic Algorithm
(Classical and great work)

(Example)④ Astronoka



Initially, they are trapped easily…

They learn to avoid many traps.

MuuMuu,「Astronoka」(Enix, 1998)

http://dlgames.square-enix.com/jp/psga/2008/astronoka/
http://www.muumuu.com/product.html

What is Astronoka?

Player grows vegetables in a field.

NPC comes to eat them.

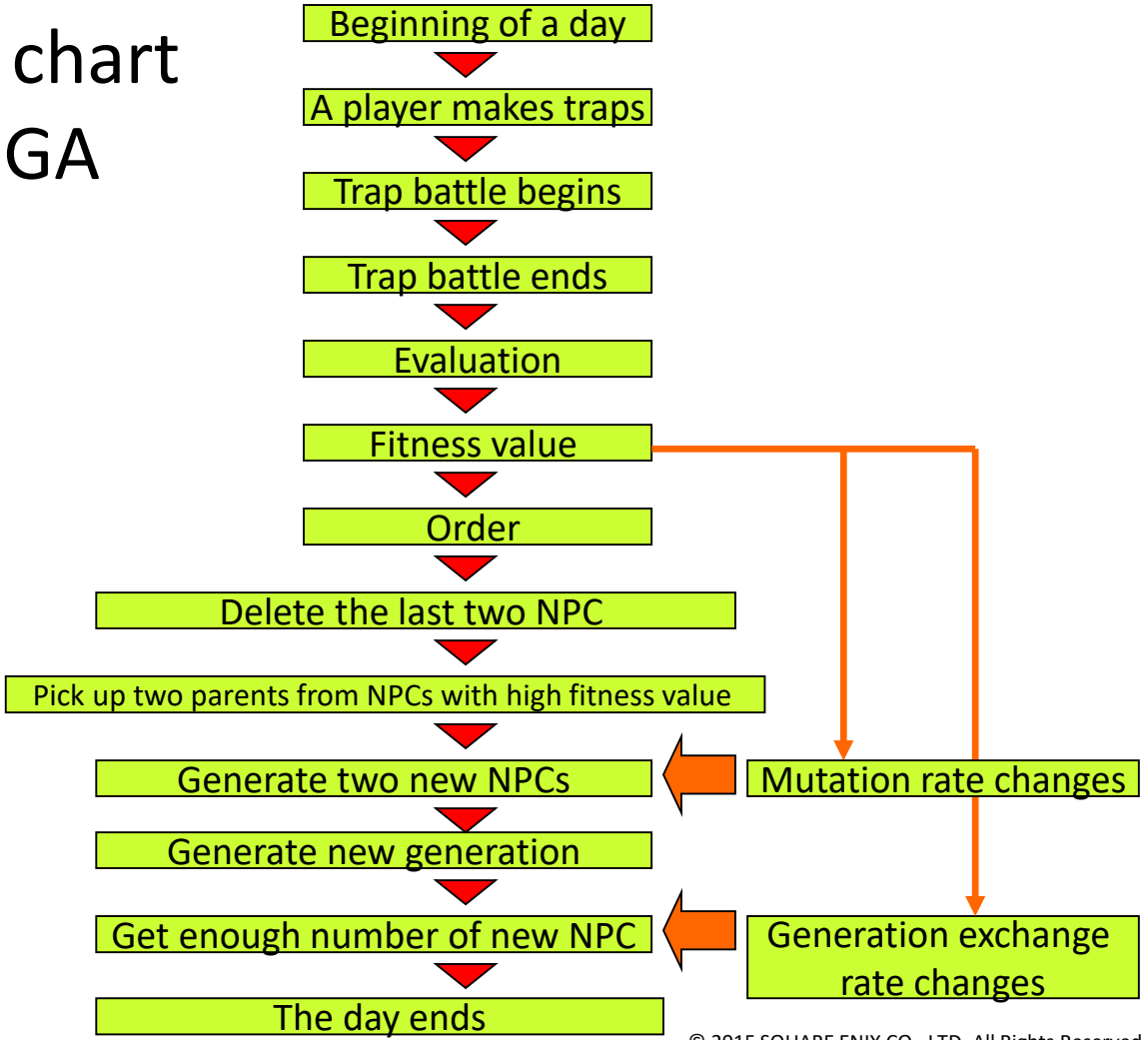
Player makes traps around the field to protect vegetables.

Player gets a prize by growing good vegetables ！

MuuMuu,「Astronoka」（Enix, 1998）

http://dlgames.square-enix.com/jp/psga/2008/astronoka/
http://www.muumuu.com/product.html

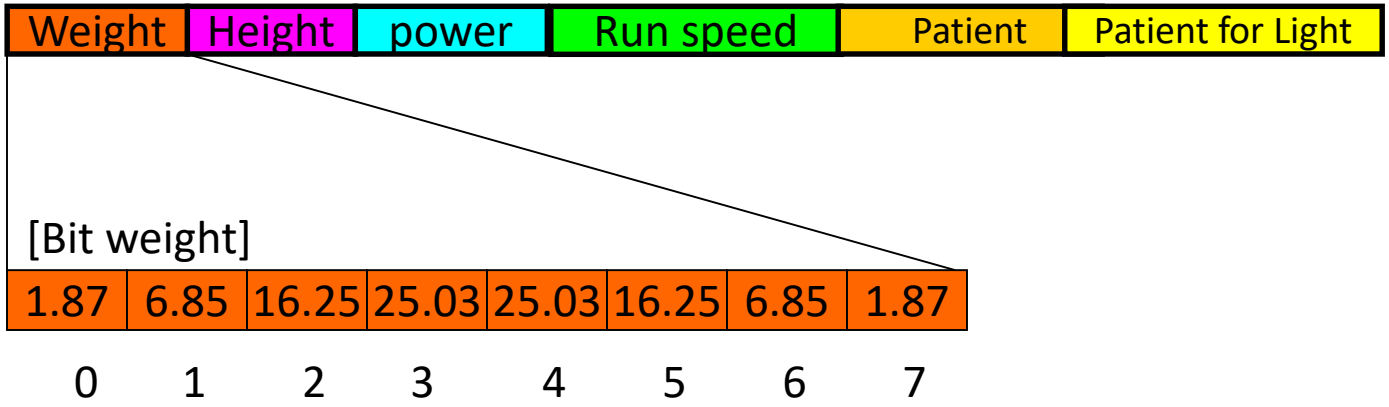
Flow chart of GA



4－① Gene mapping

Gene code and initial parameter set

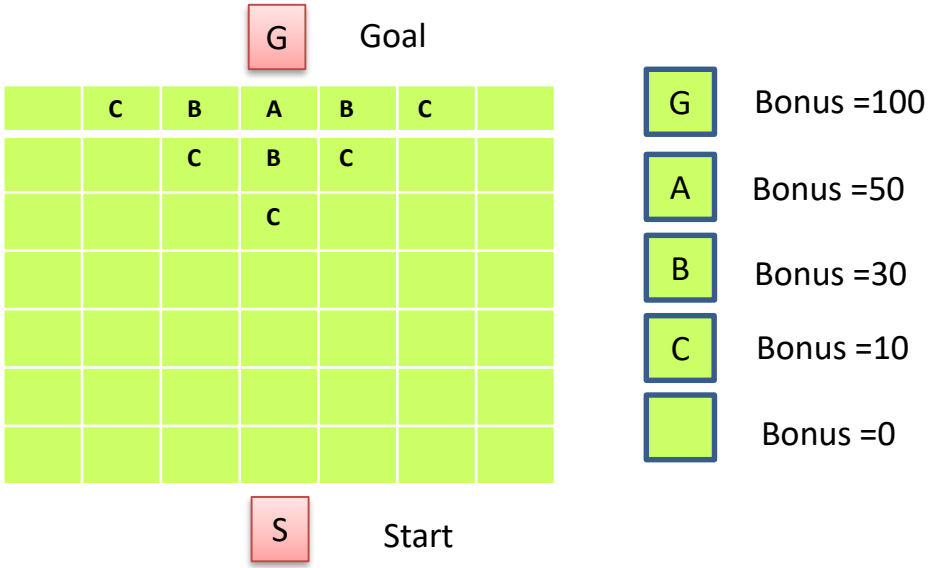
[NPC attribute（56 parameter）]



56 x 8 ＝448 bit

4－② Simulation and evaluation

Evaluation score is proportional to how long NPC go into the field avoiding and breaking traps.

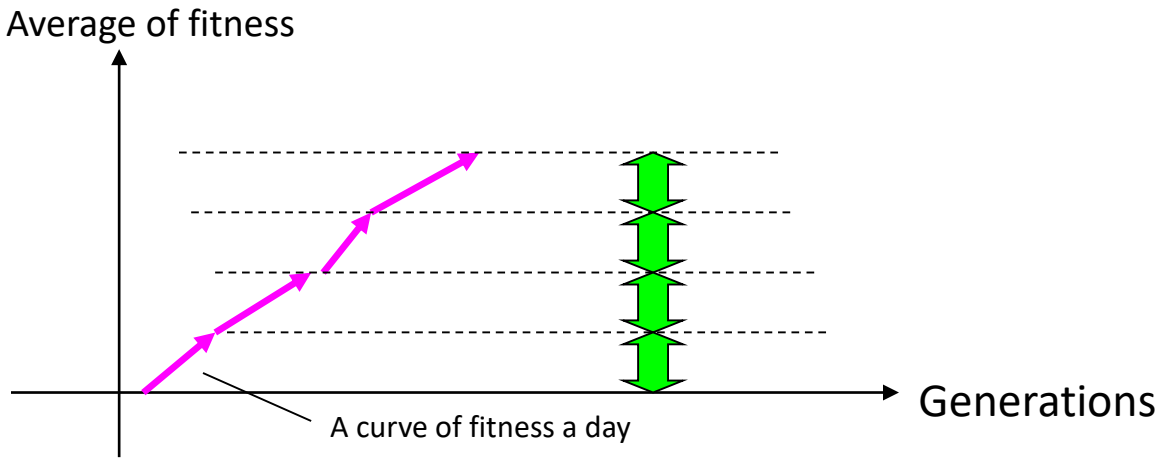


Fitness＝Score＋Time*0.3＋Enjoy param*0.5＋Trap_Score＋Safety＋HP*0.5

Time for clear

GA improvement in Game system

(1) To give a feeling of evolution to users,
the game system evolves 5 generations a day by GA.
(2) To make constant speed of evolution of one day,
the game system controls the number of iterations of GA evolution.



Summary

- AI in digital games has split into three AI.
- Each AI has different techniques.
- The whole AI system in game is constructed by integrating three AI.
- Character AI includes many other academic fields, and it has deep relations with the ecology of living things.
- Game AI is now spreading over many research fields.

Digital Game AI

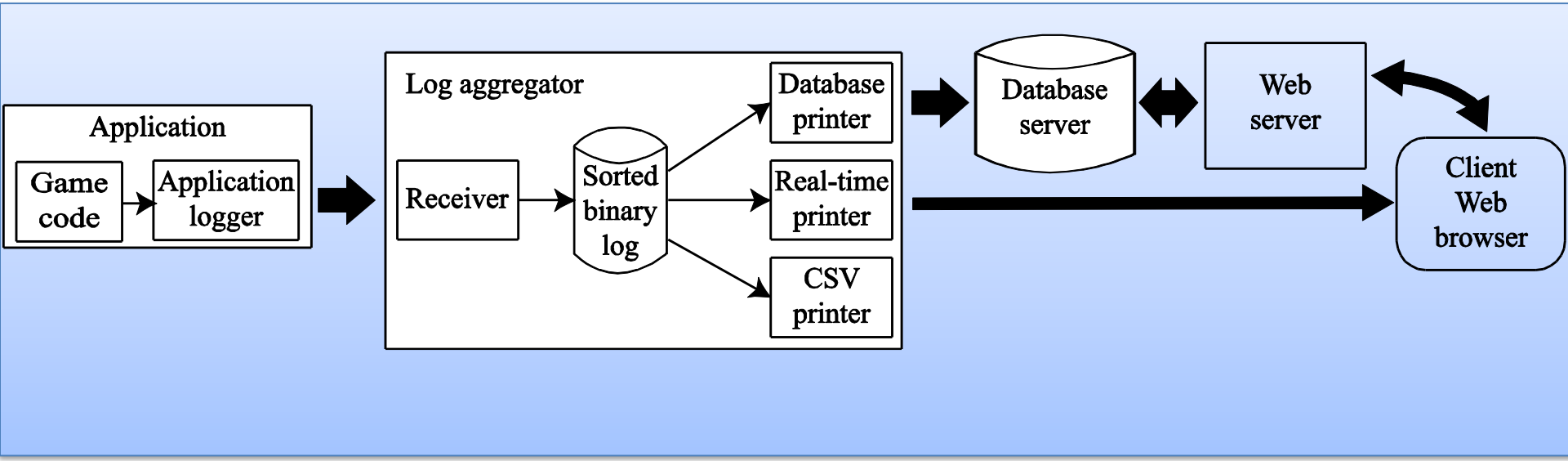
Contents

This slide has many movies that can be replayed by pushing a button ▶

Chapter 9

DATA LOGGING AND VISUALIZATION

Logging System



Data flow from game to web-browser visualization

Logging Visualization in FINAL FANTASY XV
Matthew W. Johnson, Fabien Gravot, Shintaro Minamino, Ingimar Gudmundsson, Hendrik Skubch, and Miyake Youichiro

Statistics of PQS Query

SID_5755243f9b36a728a8e501c8
SID_5755232dec64381d7898d95b
SID_5755229b9b36a728a8dec575
SID_57551dfdf606f2297435e50b
SID_57551a8fec64381d788501d0
SID_575519539b36a728a8d767be
SID_5755186071d7922100543b7f
SID_575517daf606f2297435de76
SID_575515646d21381690a37947
SID_575513116d21381690a072b4
SID_57551022f606f229743575a9
SID_57550bfa9b36a728a8cb45bf
SID_57550b5271d79221004f529e
SID_575508dcec64381d78772325
SID_57550890f606f22974350100
SID_575507e5f606f2297434a201
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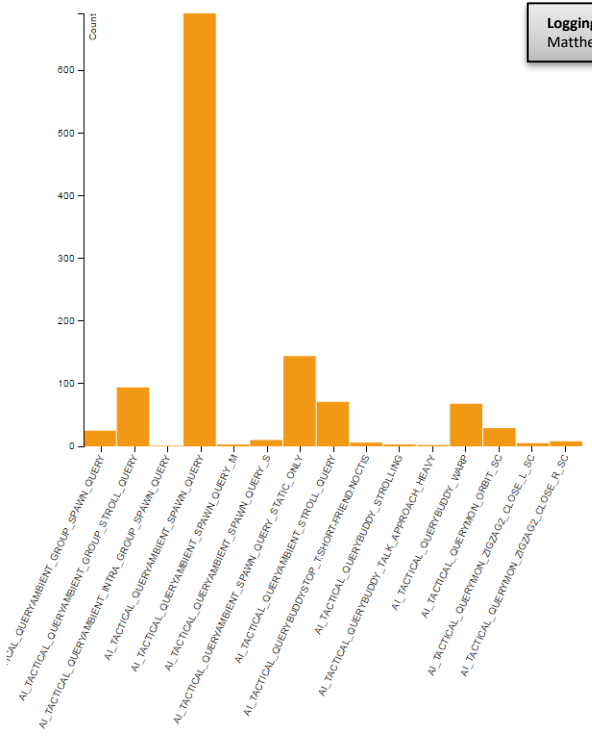

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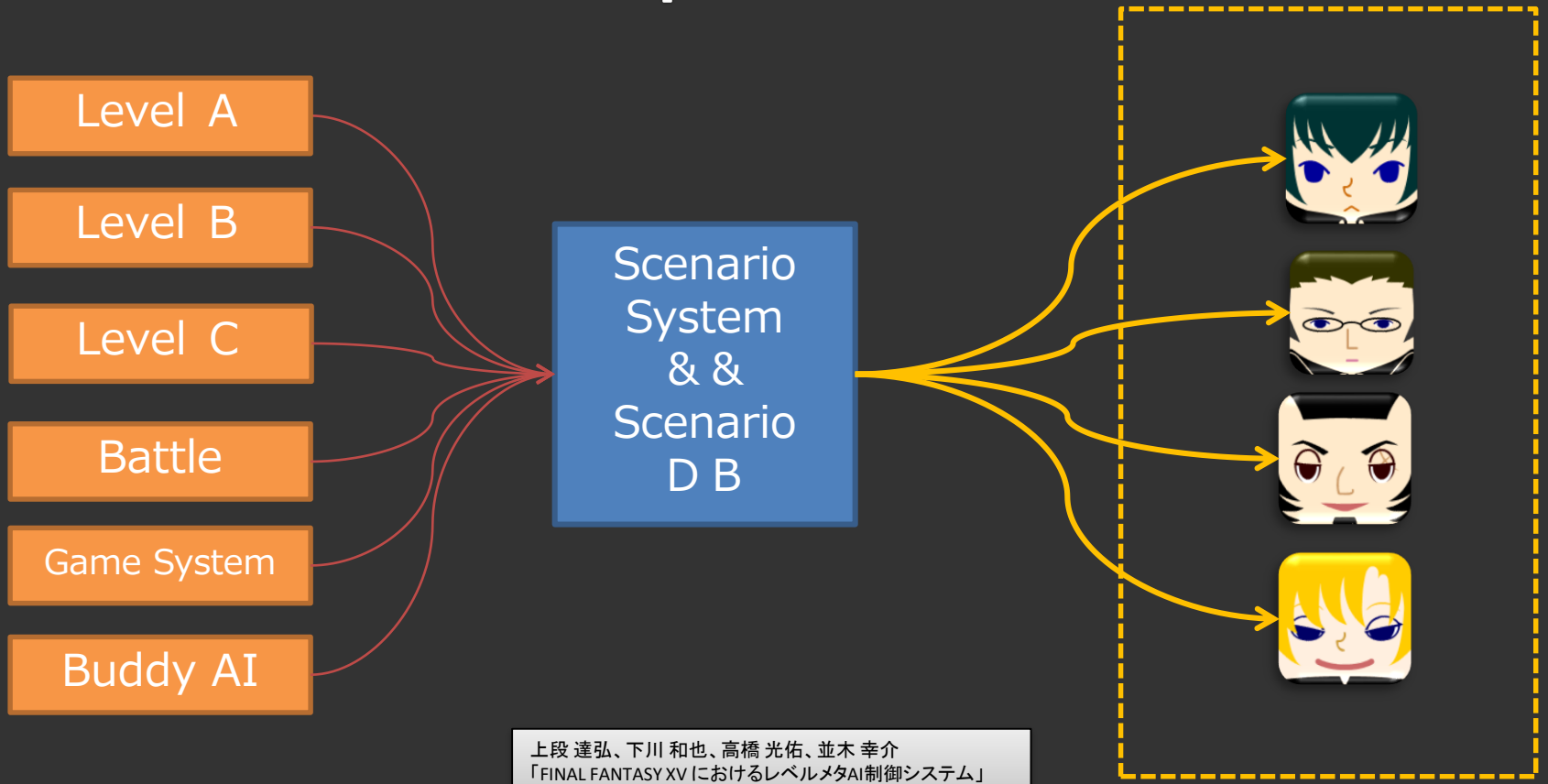
Query's variation

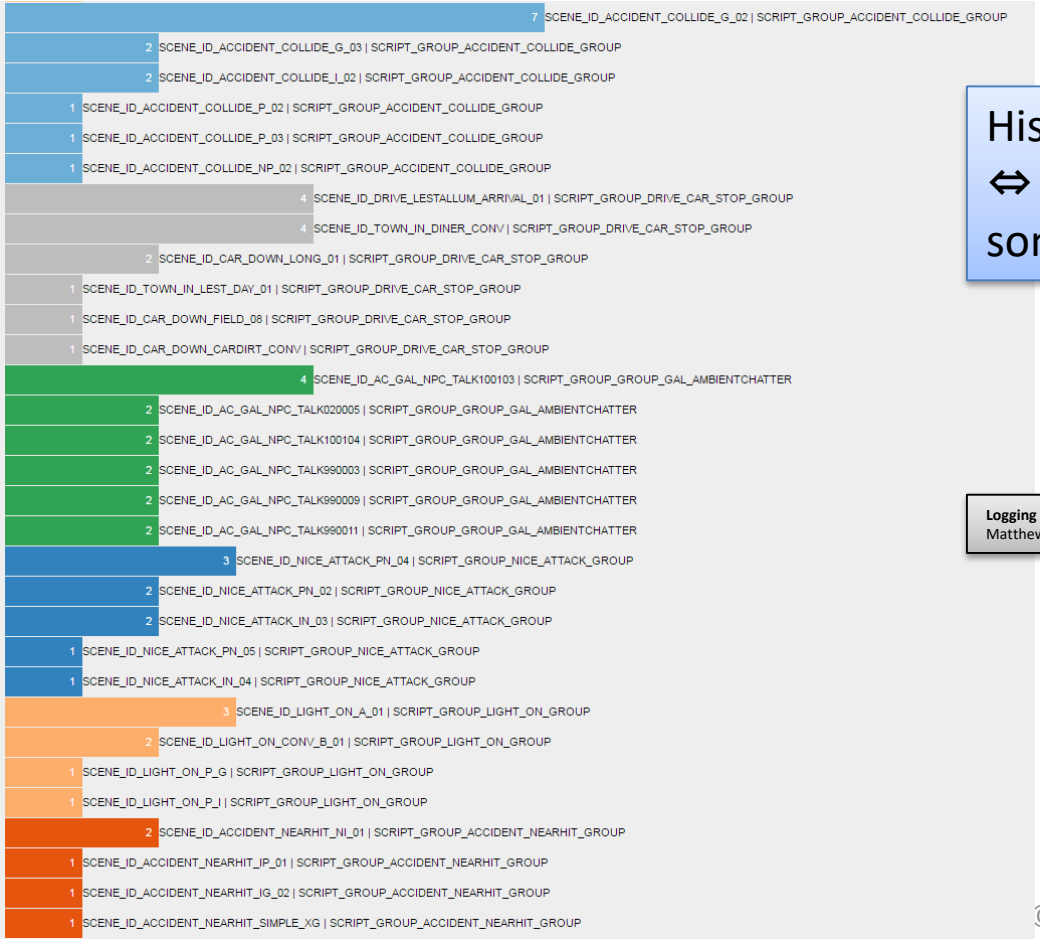
PQS（point querying system）Statistics in a town

Conversation request



上段 達弘、下川 和也、高橋 光佑、並木 幸介
「FINAL FANTASY XV におけるレベルメタAI制御システム」
https://cedil.cesa.or.jp/cedil_sessions/view/1544

Statistics of number of calling scenarioes



Histogram of calling a scenario
⇔ This histogram is used to adjust some para meters to call a scenario.

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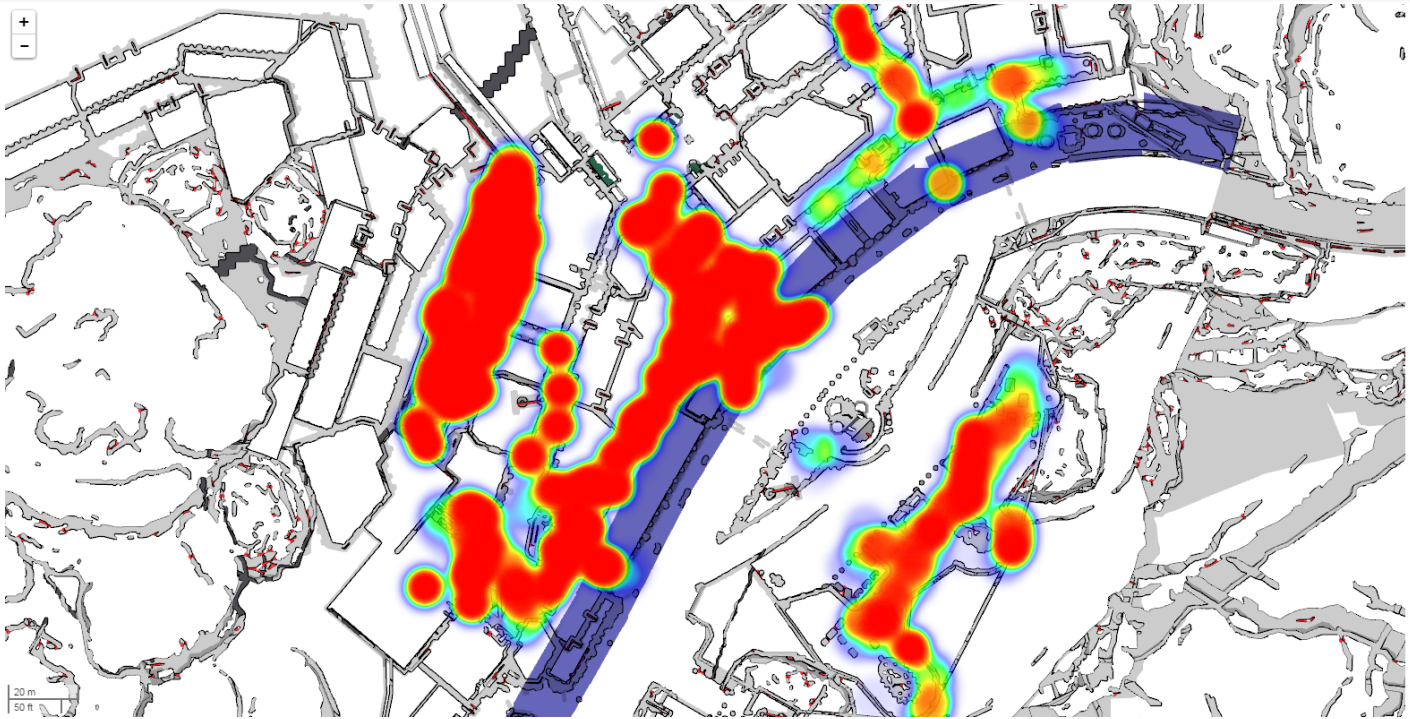
Heat map of animation



Heat map of character's animation called in each aria.（This data is used to design animation packages. Which animations should be one package ）

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Digital Game AI

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Chapter 10

SUMMARY

Session summary

- In the chapter of introduction of decision making, we show an overview of the contemporary techniques.
- The original decision making concept to satisfy many different requirements for character are explained.
- Device points of design and implementation for graph-based AI logic tool are introduced.
- The case studies of AI technologies in the game FINAL FANTASY XV are showed by using slides and movies.

AI Technologies in FFXV	What problem can be solved by using it ?
Meta-AI	Controlling a game
Navigation AI	Recognizing a terrain
Navigation mesh	Finding a global path
Smart waypoint	Finding a local path
PQS（Point Query System）	Finding a tactical point
Character AI	Character’s brain
Agent Architecture	Framework of character’s intelligence
Decision Making (State machine)	State-based decision making
Decision Making (Behavior tree)	Behavior-based decision making
Decision Making（AI Graph）	Hybrid decision making
Animation Graph	Defining transition between animations
Body Layer	Controlling body status
Learning by motion simulation	Abstract motion’s features by simulation
Data Mining and Visualization	Representing a game inner status in real-time

Memory usage

- Memory

  AI Graph 20M～

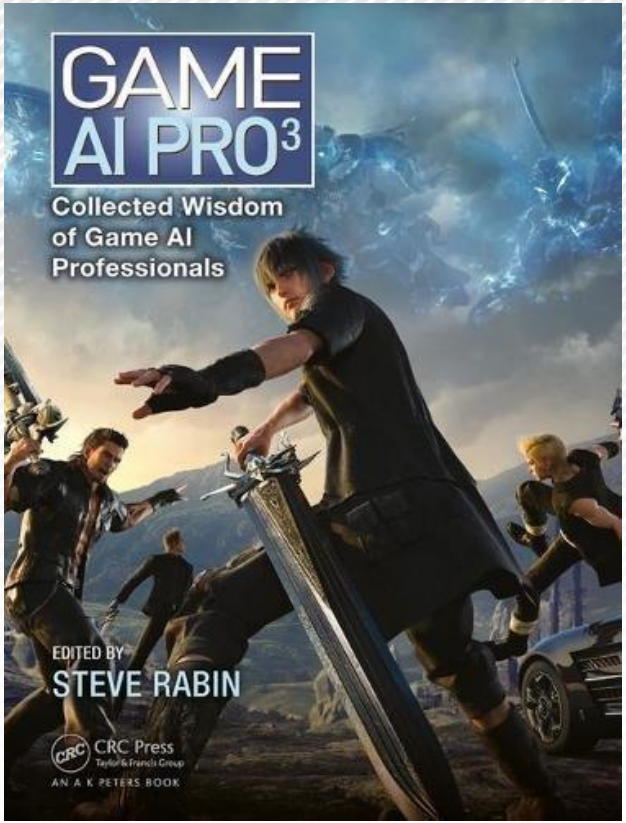
  Navmesh 20M～

AI	262,144
AI_GRAPH	14,918,634
AI_GRAPH_CONTEXT	9,803,152
AI_NAVIGATION	4,757,092
AI_NAVIGATION_COLLISION	104,448
AI_NAVIGATION_RECAST	0
AI_NAVIGATION_DETOUR	2,867,176
AI_NAVIGATION_AUTOGENERATION	63,311
AI_NAVIGATION_MESH_DATA	22,789,528
AI_NAVIGATION_LAYER_DATA	384,256
EBONY_AI_SPATIAL_ANALYSIS	0
EBONY_AI_STEERING	81,568
EBONY_AI_TACTICAL_POINT_SYSTEM	229,588
EBONY_AI_HEATMAP	2,880
EBONY_AI_AMBIENTAI	145,696
EBONY_AI_INTERACTIONS	375,236
EBONY_AI_DANGERAVOIDANCE	0

FINAL FANTASY XV AI Summary

FINAL FANTASY XV AI Summary (movie)

SQUARE ENIX articles in Game AI PRO 3



Predictive Animation Control Using Simulations and Fitted Models.
Ingimar Hólm Guðmundsson, Skubch Hendrik, Fabien Gravot and Yoichiro Miyake

Ambient Interactions: Improving believability by leveraging Rule-based AI
Hendrik Skubch

Logging Visualization in FINAL FANTASY XV
Matthew W. Johnson, Fabien Gravot, Shintaro Minamino, Ingimar Gudmundsson, Hendrik Skubch, and Miyake Youichiro

Guide to Effective Autogenerated Spatial Queries
Eric Johnson

A Character Decision-Making System for FINAL FANTASY XV by combining Behavior Trees and State Machines
Youichiro Miyake, Youji Shirakami, Shimokawa Kazuya, Kousuke Namiki, Tomoki, Komatsu, Tatsuhiro Joudan, Prasertvithyakarn Prasert, Takanori Yokoyama

References

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- Youichiro Miyake: Square Enix AI academy: AI workshop for blackboard architecture, SIGGRAPH Asia 2015 Symposium on Education, Article No. 9
- Youichiro Miyake: AI techniques for contemporary digital games, SIGGRAPH Asia 2015 Courses, Article No. 3
- Youichiro Miyake: Square Enix AI academy: AI workshop for blackboard architecture, SIGGRAPH ASIA 2016 Symposium on Education: Talks, Article No. 10
- Youichiro Miyake: A Multilayered Model for Artificial Intelligence of Game Characters as Agent Architecture, Mathematical Progress in Expressive Image Synthesis III, Springer
- Isamu Hasegawa, Remi Driancourt, Hiromitsu Sasaki, Youichiro Miyake: Real-Time Technologies of FINAL FANTASY XV Battles, SIGGRAPH 2016, https://www.youtube.com/watch?v=xvMgGGMPzFU (20min-)

These are available on https://dl.acm.org/author_page.cfm?id=99658685879

FINAL FANTASY XV Core AI Team in 2015

- SQUARE ENIX
- Youichiro Miyake

（AI Graph）Youji Shirakami 、Kazuya Shimokawa
（Monster AI & Learning）Kosuke Namiki, Tomoki Komatsu
（Animation）Noriyuki Imamura
（AI Navigation & Simulation）Fabien Gravot, Hendrik Skubch,
Ingimar Holm Gudmundsson, Matthew W. Johnson
（Buddy AI, Meta AI）Prasertvithyakarn Prasert, Tatsuhiro Joudan
（Data Logging） Shintaro Minamino
(AI Mode) Kosuke Takahashi

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LUMINOUS STUDIO

Business Division 2

Advanced
Technology
Division