“The Future of AI, Game, and Computer Graphics”

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Thanks & Self-Introduction

• Welcome to Japan

• Thanks for Prof. Ruck Thawonmas

• me

  2004-2011    AI Programmer  (FROM SOFTWARE)
  2011-Present  Lead AI Researcher  (SQUARE-ENIX)

  2007-Present  Chairman of IGDA JAPAN SIG-AI
  2008-Present  Research committee of DiGRA JAPAN
Works (2006-2012)

Chrome Hounds (2006)
Demon’s Souls (2009)
PokaPoka Airu Village (2011)
Armored Core V (2012)

Game Titles (AI technical Works)

Books
In these 10 years, field of game AI has been evolving and expanding.

This rapid changing makes a gap between academic AI research and AI development in Game Industry.

But game developers had not passed their research themes to academic researchers enough.
The Goal of Keynote is introducing many AI research themes in game industry (I!) to academic researchers (you!).
AI in Game World

Game World
(= Environment = Game Stage = Level Design)

AI Character
(= NPC)
AI in Game World

Game World
(= Environment = Game Stage)

AI Character
(= NPC)

Character AI
(Brain)

Procedural Techniques
(Auto-generation, Auto-Control)

Meta AI

Game Mechanism
CHARACTER AI
Life is in the World

http://www.gatat.net/04/12/2010/190000.html
http://www.123rf.com/photo_10039937_foggy-forest-at-the-morning-at-autumn.html
http://www.flickr.com/photos/rotrauds-kleine-welt/346698184/
Life is in Real World

Real World

Human

Human lives in Real World.
Life is in Real World

Human lives in Real World.
Human and Environment interact each other.
AI is in the Game World
AI is in Game World

Game World
(= Environment = Game Stage = Level Design)

AI Character
(=NPC)

AI lives in Game World.
AI is in Game World.

AI lives in Game World.
AI and Environment interact each other.
AI lives in Game World.
AI and Environment interact each other.
AI is in Game World

It makes “Information Flow” between AI and Environment.
C4 Architecture

MIT Media Lab.
Synthetic Characters Group
Researching Virtual Pet in Digital World.

D. Isla, R. Burke, M. Downie, B. Blumberg (2001),
Halo Agent Architecture

Genre: SciFi-FPS
Developer: BUNGIE Studio
Publisher: Microsoft
Hardware: Xbox, Windows, Mac
Year: 2002

Jaime Griesemer (GDC 2002), The Illusion of Intelligence: The Integration of AI and Level Design in Halo
http://www.bungie.net/Inside/publications.aspx
F.E.A.R. Agent Architecture

- **Genre**: Horror FPS
- **Developer**: Monolith Production
- **Publisher**: SIERRA
- **Hardware**: Windows
- **Year**: 2004

Agent Architecture Considerations for Real-Time Planning in Games (AIIDE 2005)
http://web.media.mit.edu/~jorkin/AIIDE05_Orkin_Planning.ppt
Killzone 2 Architecture

- Genre: FPS
- Developer: Guerrilla Games
- Publisher: SCE
- Hardware: PlayStation 3
- Year: 2009

Based on: Alex Champandard, Tim Verweij, Remco Straatman, "Killzone 2 Multiplayer Bots", [Link](http://files.aigamedev.com/coverage/GAICO9_Killzone2Bots_StraatmanChampandard.pdf)
Halo AI Retrospective: 8 Years of Work on 30 Seconds of Fun
Author: Damian Isla (AI Engineering Lead)
http://www.bungie.net/Inside/publications.aspx
Agent Architecture

AI

Recognition (Knowledge Making)

Decision Making

Motion Making

Memory

Game World

Sensor

Effecter
Agent Architecture

- AI
  - Recognition
  - Decision Making
  - Motion Making
  - Memory

- Sensor
- Effecter
- Game World
Character AI Research themes

(1) Agent Architecture (Framework)
(2) Sensor
(3) Recognition
(4) Memory
(5) Decision Making
(6) Motion Making
(...
Character AI Research themes

(1) Agent Architecture (Framework)
(2) Sensor
(3) Recognition
(4) Memory
(5) Decision Making
(6) Motion Making
( ) ...
Character AI Research themes

(1) Agent Architecture (Framework)
(2) Sensor
(3) Recognition
(4) Memory
(5) Decision Making
(6) Motion Making

( ) ...
In many cases, Visual Sensor is implemented as ray-casting model.
(2) Sensor

In many cases, Hearing Sensor is implemented as volume model.

土田善紀、細江一博
[CEDEC]5.1ch時代の3D音源・遮蔽・そしてその配置 〜OpenALでは何も出来ない〜
http://cedil.cesa.or.jp/session/detail/376
Knowledge Representation

Can AI recognize sufficiently the world by his sensors? \textbf{No.}

Information to help AI recognize the World (Object/Fact/Space) = \textbf{Knowledge Representation (KR)}
Knowledge Representation (Example: F.E.A.R.(2004))

In F.E.A.R.

Character, Object, Mission, Fact, Path, Node, Desire is presented as Unified Form “WMF”

WMF

Place (Value, Confidence)
Direction (Value, Confidence)
Stimulus (Value, Confidence)
Object (Value, Confidence)
Desire (Value, Confidence)
Time (Value, Confidence)

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http://www.jorkin.com/gdc2006_orkin_jeff_fear.zip
Facts AI recognized are stacked in Working Memory as WMFs in each field.
Using WMF Stacks

Facts AI recognized are stacked in Working Memory as WMFs in each field. By using WMF stack, AI can estimate some knowledge of the future.

I saw Character A in (60,60) at 10 sec ago.
I saw Character A in (80,40) at 30 sec ago.
I saw Character A in (100,20) at 50 sec ago.

AI can estimate the character A position in the future.
Knowledge Representation (KR)

How many kinds of KR are there?

Number of how AI should recognize a fact.

“KR”s is the base to make high intelligence
Variation of Knowledge Representation

**Dependency Graph**
- Army
- Steel
- Training House
- mine
- man
- tree

**Semantic Network**
- Vehicle has part Wheels
- Doors has part Automobile
- Automobile has part Motor
- Small has part Sports Car
- Sports Car nutrient Doors
- Corvette

**Rule-based Representation**

**World Representation**

**Enemy Representation**

**Target Lists**
- Target
  - Perceived data
    - location \((x, y, z)\) 0.85
    - action shoot 0.99
    - hitpoints 44 0.99
  - Derived data
    - Threat 0.8
    - Target weight 0.9
    - "intentions" "hurt_me"

- Allows AI to make mistakes

**WMF**

*Griesemer, J., "The Illusion of Intelligence: The Integration of AI and Level Design in Halo", 2002 http://www.bungie.net/images/inside/publications/presentations/publicationsdes/design/gdc02_jaime_griesemer.pdf*
World Representation (one of KR)

World Representation (WR) = KR for Game Stage
(Representation based on Waypoint or Navigation Mesh)

◆ FPS
◆ Guerrilla
◆ SCEE/SEGA
◆ PS2
◆ 2004/2005

（例）Waypoints with 8-direction LOS (visible distance) (Killzone)

Variation of World Representation

**Distribution Map**
- Left 4 Dead

**Waypoints with LOS**
- Killzone

**Territory Representation**
- Halo2

**Tactical Point System**
- Halo

**Tactical Map Clustering**
- Killzone2

**NavMesh-Waypoint Hierarchical Representation**
- Assassin’s Creed

References:
Agent Architecture

KR and WR enforce and expand sensors.
Agent Architecture

AI

- Recognition
- Decision Making
- Motion Making

Memory

Sensor

Effecter

Game World

Type of KR and WR = Type of Knowledge in Memory (via sensors)
... And one more concept
Affordance Representation

Affordance Representation
= Actions enable in the environment

The car is afford to move to one direction.
= movable to one direction for AI.

[Affordance Representation] for the car
- movable
- direction (10, 120, 40)

- Genre: SciFi-FPS
- Developer: BUNGIE Studio
- Publisher: Microsoft
- Hardware: Xbox, Windows, Mac
- Year: 2004
Affordance Representation

= Actions enable in the environment

Each object has Affordance Representation.

[CEDEC2011]
Namiki Kosuke, "Affordance-oriented AI for PokaPoka Airu Village"
http://cedil.cesa.or.jp/session/detail/697
Affordance Representation

= Actions enable in the environment

Genre: Action
Developer: FROM SOFTWARE
Publisher: CAPCOM
Hardware: PSP
Year: 2011

Each object has Affordance Representation.
= Each object suggests “Enabled-Action” to AI.

[CEDEC2011]
Namiki Kosuke, "Afforance-oriented AI for PokaPoka Airu Village"
http://cedil.cesa.or.jp/session/detail/697

http://www.4gamer.net/games/100/G010022/20110906085/
Affordance Representation = Afforded Action-List in the Environment (via sensor)
Agent Architecture

- Recognition
- Decision Making
- Motion Making
- Memory
- KR
- Attack-able to Enemy A
- Eat-able to Object B
- Movable to Car C
- Walk-able on Bridge D
- Eat-able to Object E

Game World

- Sensor
- Effector

Knowledge Representation
World Representation
Affordance Representation

Affordance Representation = Afforded Action-List in the Environment (via sensor)
(4) Memory Structure & Management

Memory has two hierarchical structure:
(a) time-hierarchical structure
(b) logic-hierarchical structure
(4) Memory Structure & Management

Memory has two hierarchical structure
(a) time-hierarchical structure
(b) logic-hierarchical structure
(4) Memory Structure & Management

Memory has two hierarchical structure
(a) time-hierarchical structure
(b) logic-hierarchical structure
Information propagate through hierarchical-Memory-Structure.
Information propagate through hierarchical Memory Structure.

- Working Memory
- Short-term Memory
- Long-term Memory
- Fixed (Static) Memory
Information propagate through hierarchical-Memory-Structure.
Information propagate through hierarchical-Memory-Structure.
Multiple-Time-Scale-hierarchical-Memory-Structure.
Information

Frame Update

Memory

Working Memory

Short-term Memory

Long-term Memory

Fixed (Static) Memory

1 Frame Update

60 Frame Update

No Update

Time Scale Increasing
Memory has two hierarchical structure
(a) time-hierarchical structure
(b) logic-hierarchical structure
(5) Decision Making

Decision Making Techniques are classified to 6 types

- Rule-based AI
- State-based AI
- Behavior-based AI
- Goal-based AI
- Task-based AI
- Utility-based AI

“Something-Based” means a Decision-Making-Method use Something as unified-form of thinking.
Decision Making Techniques are classified into 6 types:

- Rule-based AI
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- Task-based AI
- Utility-based AI

"Something-Based" means a Decision-Making-Method uses "Something" as a unified form of thinking.
(5) Decision Making

**Rule-based AI**

Traits also affect how they respond to social interactions initiated by others.

- How a Sim responds to a social depends on a series of production-rules:
  - TryingToBe.Funny $\rightarrow$ Neutral
  - TryingToBe.Funny $\&\&$ Repetition $\rightarrow$ Boring
  - TryingToBe.Funny $\&\&$ LTR $< -20$ $\rightarrow$ Insulting
  - TryingToBe.Funny $\&\&$ Target.GoodSenseOfHumor $\rightarrow$ Funny

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- **Genre:** Simulation
- **Developer:** Maxis
- **Publisher:** EA
- **Hardware:** PC, PS3
- **Year:** 2009

http://www.gdcvault.com
Decision Making

State-based AI

Genre: SciFi-FPS
Developer: id Software
Publisher: GT Interactive
Hardware: PC
Year: 1996

http://www.idsoftware.com/

A Practical Analysis of FSM within the domain of first-person shooter (FPS) computer game
http://ai-depot.com/FiniteStateMachines/FSM-Practical.html
(5) Decision Making

**Task-based AI**

**Methods (Continued)**

- Partially ordered method: a 4-tuple
  
  \[ m = (\text{name}(m), \text{task}(m), \text{precond}(m), \text{subtasks}(m)) \]

  - \( \text{name}(m) \): an expression of the form \( n(x_1, \ldots, x_n) \)
    
    \( x_1, \ldots, x_n \) are parameters - variable symbols
  
  - \( \text{task}(m) \): a nonprimitive task
  
  - \( \text{precond}(m) \): preconditions (literals)
  
  - \( \text{subtasks}(m) \): a partially ordered set of tasks \( \{t_1, \ldots, t_i\} \)

**HTN (Hierarchical Task Network)**

- HTN PLAN (non-interruptible) - [BOT] Tremethick
  
  **DECOMPOSITION**

  **TASK LIST**

  - (\text{forget} active_plan **)
  
  - (\text{remember} – active_plan medic_rescue \{\text{Soldier:TimmermanV}\})
  
  - (\text{log_color} magenta “Medic reviving nearby entity.”)
  
  - (\text{broadcast} friendly 30.0 10.0 medic_resaving \{\text{Soldier:TimmermanV}\})
  
  - (\text{select_target} \{\text{Soldier:TimmermanV}\})
  
  - (\text{walk_segment} (2370 2369 2368 2367 2366 2365 ... 5416) standing auto (1) (1) (1))
  
  - A (\text{select_weapon} wp_online_mp_bot_revive_gun)
  
  - (\text{use_item_on_entity} \{\text{Soldier:TimmermanV}\} crouching)
  
  - (\text{forget} active_plan **)

  **ACTIVE TASK INFO**

  - AIHTNPrimitiveTaskSelectWeapon

**Individual AI : Application**

- Genre: FPS
  
  - Developer: Guerrilla Games
  
  - Publisher: SCE
  
  - Hardware: PlayStation 3
  
  - Year: 2009

(5) Decision Making

**Behavior-based AI**

- **Genre:** SciFi-FPS
- **Developer:** BUNGIE Studio
- **Publisher:** Microsoft
- **Hardware:** Xbox, Windows, Mac
- **Year:** 2004

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**Behavior-Tree** (has become very popular method.)

1. Hierarchical Structure of Box
2. Each box has some behaviors
3. Each box has one selection-rule (random, sequential, priority-order...)
4. Finally, one behavior is selected at end-of-tree.

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(5) Decision Making

Utility-based AI

The Sims’ Motive Engine

- Toilet
  - Mood +26
  - Urinate (+40 Bladder)
  - Clean (+30 Room)
  - Unclog (+40 Room)

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

Mood +18

Key:
- Genre: Simulation
- Developer: Maxis
- Publisher: EA
- Hardware: PC
- Year: 2000

Ken Forbus, “Simulation and Modeling: Under the hood of The Sims” (Northwestern University)
http://www.cs.northwestern.edu/~forbus/95-pd/textures/The_Sims_Under_the_Hood_files/frame.htm
Goal-based AI

Goal-Oriented Action Planning (GOAP)

Chaining = Matching “Precondition” and “Result”

Jeff Orkins, "Goal-Oriented Action Planning"  
http://web.media.mit.edu/~jorkin/goap.html

Precondition  
Action  
Result  

No Condition  
Pick up weapon  
Has weapon  

Planner  

Has weapon  
Load Weapon  
Weapon Loaded  

Chaining

Weapon Loaded  
Attack  
Target A Dead  

Chaining  
Goal Dead
(5) Decision Making

**Goal-based AI**

**Hierarchical Goal Oriented Planning**

- Goal
  - Goal
  - Goal
  - Goal
  - Goal
  - Goal
  - Goal
  - Goal
  - Goal
  - Goal

**Genre**: Robot Action  
**Developer**: FROM SOFTWARE  
**Publisher**: SEGA  
**Hardware**: XBox360  
**Year**: 2006

CEDEC2006「クロムハウンズにおける人工知能開発から見るゲームAIの展望」（三宅陽一郎）
[http://cedil.cesa.or.jp/session/detail/50](http://cedil.cesa.or.jp/session/detail/50)
(6) Motion Making

AI

Recognition

Decision Making

Motion Making

KR

Enable-Action-List

WR

Sensor

Effecter

Game World

Knowledge Representation

World Representation

Affordance Representation
In this field, there are many, many models between DM and Motion Making.
(6) Motion Making

Decision Making

- Rule-based AI
- State-based AI
- Behavior-based AI
- Goal-based AI
- Task-based AI
- Utility-based AI

Gap

discrete

Motion Making

continuous
(6) Motion Making

- Rule-based AI
- State-based AI
- Behavior-based AI
- Goal-based AI
- Task-based AI
- Utility-based AI

Decision Making

Research Theme

Gap: discrete

continuous
(6) Motion Making

AI

Recognition → Decision Making → Motion Making

KR

Enable-Action-List

Body & Animation Representation

Sensor

Effecter

Knowledge Representation

World Representation

Affordance Representation

Game World
(1) Architecture
(2) Knowledge/World/Affordance Representation
(3) Memory Structure & Memory management
(4) Sensor
(5) Decision Making

...and Synthesis of all these things to make “Real” intelligence.
CHARACTER NAVIGATION
Character Navigation

Moving Character in the Environment

Genre: FPS
Developer: TURTLEROCK STUDIO
Publisher: Valve Software
Hardware: PC
Year: 2000

The Official Counter-Strike Bot by Michael Booth (GDC2004)
http://aigamedev.com/insider/presentation/official-counter-strike-bot/
Navigation Problem

Game Stage becomes bigger and complex.

Number of meshes has been increasing.

Problems:
(1) How to make large scale navigation meshes.
(2) How to maintenance large scale meshes.
(3) How to debug large scale meshes.
Navigation Mesh Auto-generation

40000-70000 meshes
Auto-generation from collision models
But mesh quality is not good.

Genre: Robot Action
Developer: FROM SOFTWARE
Publisher: SEGA
Hardware: XBox360
Year: 2006

CEDEC2006「クロムハウンズにおける人工知能開発から見るゲームAIの展望」（三宅陽一郎）
http://cedil.cesa.or.jp/session/detail/50
AI in Game World

Game World
(= Environment = Game Stage)

Procedural Techniques
(Auto-generation, Auto-Control)

AI Character (=NPC)

Character AI (Brain)

Meta AI

Game Mechanism
META-AI
Meta-AI

Autonomous Game Mechanism
(Game Mechanism AI)

Ever, Game Mechanism is fixed at release. It makes game content volume limited.

But Game has become bigger and complex.

Make game mechanism intelligent!

Meta AI = Intelligent Game Mechanism
- Recognize Game Status in real-time
- Control (Act on, Influence) Game Status dynamically

http://www.valvesoftware.com/publications.html
AI in Game World

Game World
(= Environment = Game Stage = Level Design)

AI Character (=NPC)

Sensor & Recognition

Meta AI

action
Left 4 Dead

AI Director controls NPC spawning distribution and game-play-pacing.

Using nav-mesh for recognizing and controlling Real-time status of game.

- **Genre**: Online Action
- **Developer**: VALVE SOFTWARE
- **Publisher**: VALVE SOFTWARE
- **Hardware**: PC
- **Year**: 2008

Left 4 Dead – AI Director

Meta AI recognize game status in real-time

Predicting player’s route and spawning monsters dynamically.

“Flow Distance”

- Travel distance from the starting safe room to each area in the navigation mesh
- Following increasing flow gradient always takes you to the exit room
- “Escape Route” = shortest path from start safe room to exit
- Used as a metric for populating enemies and loot, and for answering questions such as “is this spot ahead or behind the Survivor group”

AI Director decide when enemies are spawned.

**DESIRERD POPULATION**

**USER'S INTENSITY**

**ACTUAL POPULATION**

Al Director makes users relax, and break relax repeatedly.

Use Survivor Intensity to modulate the Infected population

- **Build Up**
  - Create full threat population until Survivor Intensity crosses peak threshold

- **Sustain Peak**
  - Continue full threat population for 3-5 seconds after Survivor Intensity has peaked

- **Peak Fade**
  - Switch to minimal threat population ("Relax period") and monitor Survivor Intensity until it decays out of peak range
  - This state is needed so current combat engagement can play out without using up entire Relax period. Peak Fade won’t allow the Relax period to start until a natural break in the action occurs.

- **Relax**
  - Maintain minimal threat population for 30-45 seconds, or until Survivors have traveled far enough toward the next safe room.

Michael Booth, "Replayable Cooperative Game Design: Left 4 Dead," Game Developer's Conference, March 2009  [http://www.valvesoftware.com/publications.html]
Procedural

PROCEDURAL TECHNIQUES
AI in Game World

Game Mechanism

Meta AI

Game World (= Environment = Game Stage = Level Design)

Procedural Techniques
(= Auto-generation, Auto-Control)

AI Character

Character AI (Brain)
Recent game has many, many asset data such as Terrain, Characters, Weather, Object, Trees, lines....

- It’s too hard work and needs big budget.
- Fixed data makes fixed Game Content.

Dynamically generate contents in game in real-time

Procedural Techniques
- make terrain, buildings, and vegetation dynamically.
- make scenario and lines in game in real-time.
DUNIA ENGINE : FarCry2 Procedural Engine

- Genre: FPS
- Developer: Ubisoft
- Publisher: Ubisoft
- Hardware: PC
- Year: 2008

Procedural techniques (for 50kmx50km island)
- Vegetation and its animation auto-generation
- Fire-propagation
- Weather

http://www.farcry2-hq.com/downloads,18,dunia-engine-nr1.htm
Game Mechanism

Game World (fixed)
(= Environment = Game Stage = Level Design)

AI Character (=NPC)

AI is a part of level design, and game system (mechanism) controls AI characters.
AI is a part of level design, and game system (mechanism) controls AI characters.
Game Structure (1995-)

AI Character becomes autonomous. AI by itself sense and take actions.
Game World becomes more dynamical by procedural techniques.
Game Structure (2008-)

Meta AI makes game mechanism itself more dynamical.
... AND THE FUTURE?
Game Structure (2012-)

Game Mechanism
- Meta AI

Game World
- Procedural Techniques (Auto-generation, Auto-Control)
- AI Character
- Autonomous AI

Three AI Component will connect each other and makes new game.
Imagine

• Imagine “Meta AI uses Procedural Techniques”

• Imagine “Meta AI uses autonomous AI”

• Imagine “Procedural AI generation”

• .... To be continued
THANK YOU SO MUCH!