Faculty of Mathematics and Physics
Charles University
1st March 2023

UT2004 bots made easy!

Pogamut 3

Lab 03 – Navigation, Items, Communication

Warm Up!

- Fill the short test for this lessons

  6 minutes limit

  https://tinyurl.com/42sk3nxw

  `O vs. 0, i vs. l vs. 1`

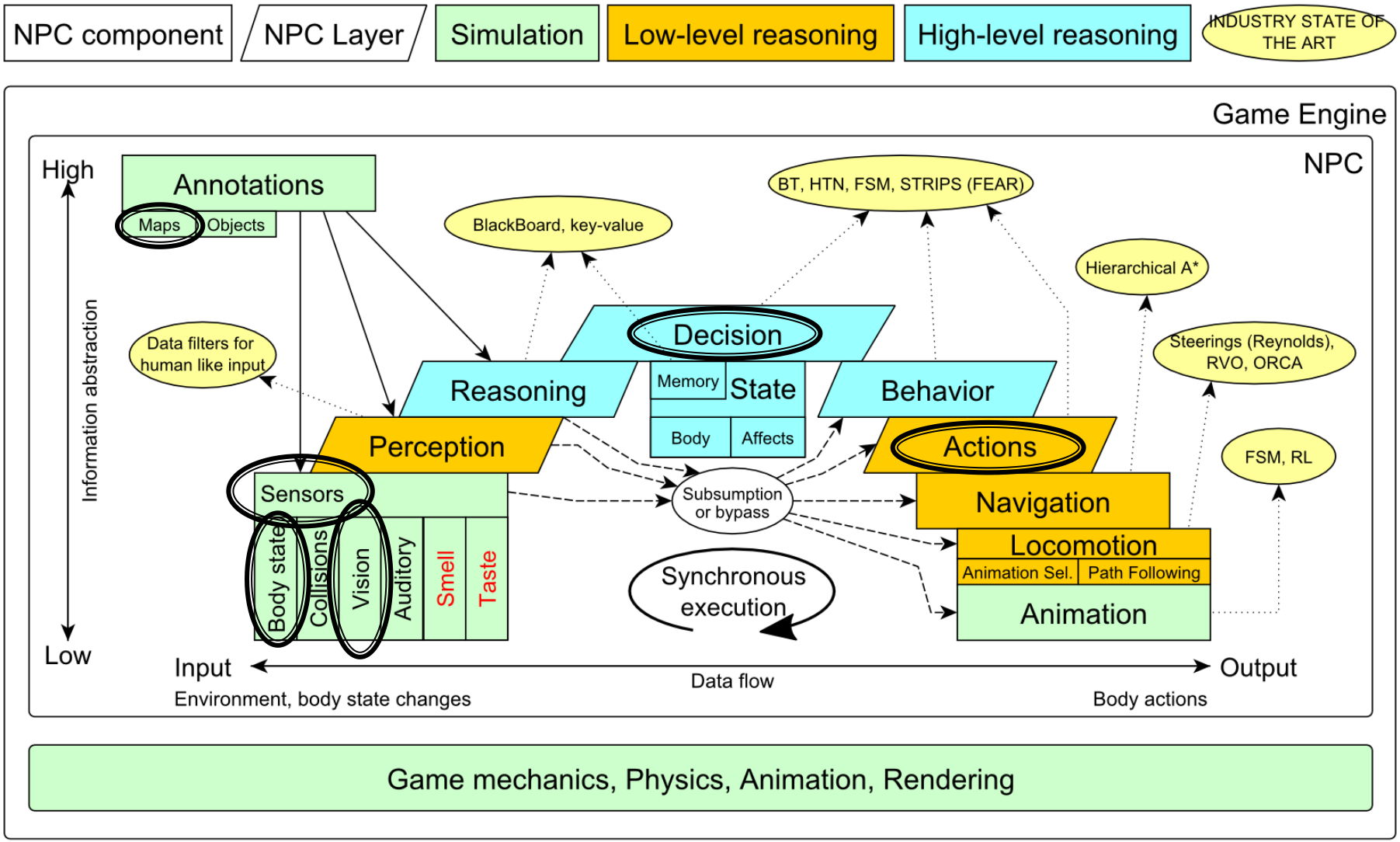
  Permalink

  https://docs.google.com/forms/d/e/1FAIpQLSfSbAPWPbwqY16dq8dLOsYtbIiyeh9zomenpMvK4nW4hutA_w/viewform

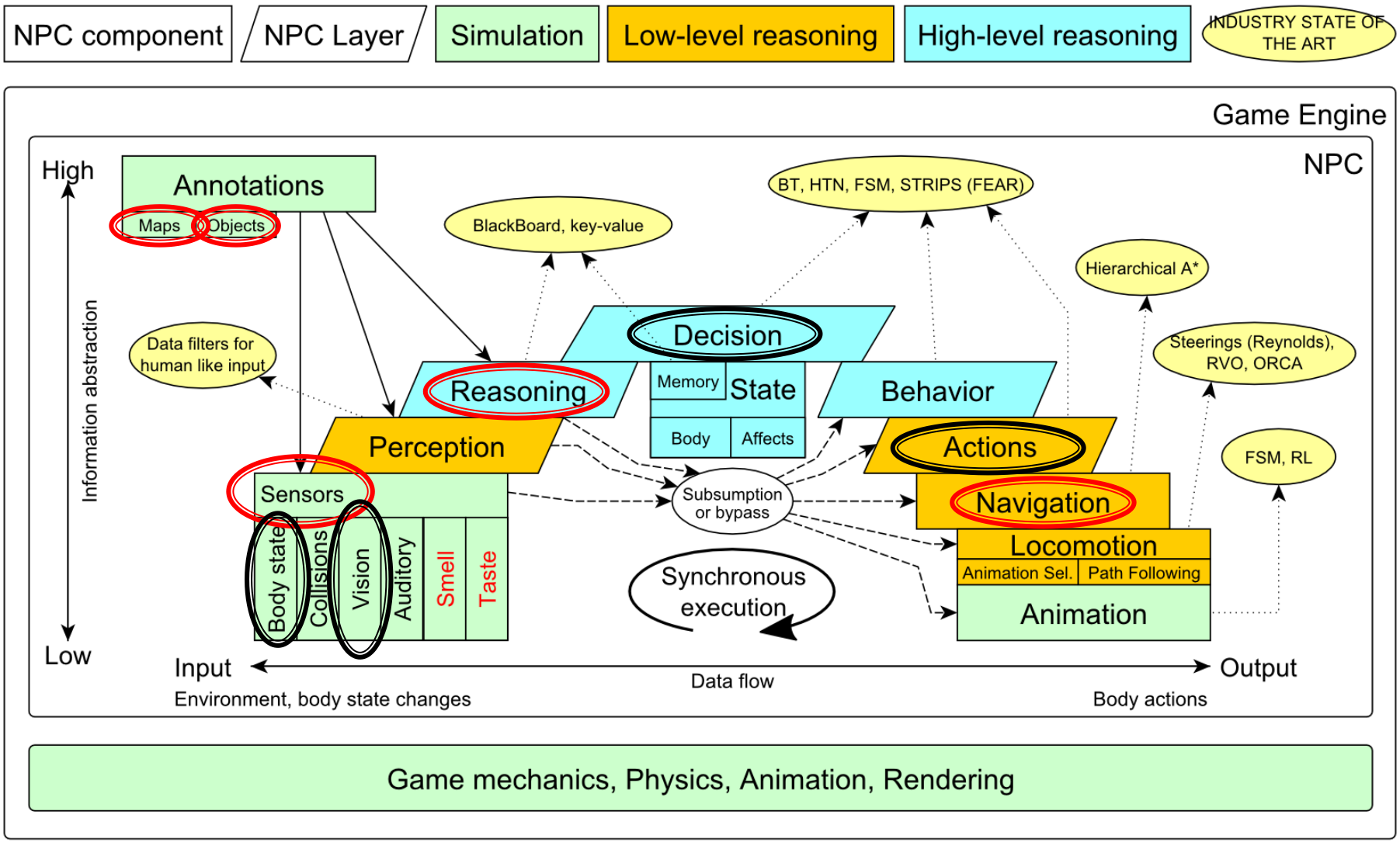
Today's menu

1. **Big Picture**
2. ItemPickerSquad Homework
3. World Abstraction
4. Navigation Environment Abstraction
5. Items
6. Navigation
7. Team Communication

Big Picture
Already covered



Big Picture
Today



Homework 03

ItemPicker Squad

3 bots, many items to pick, time is ticking

Homework 03
Gotta COLLECT 'em all!

- You have to implement an `ItemPickerBot` squad that will be able to collect all "interesting" items on the map; **3 bots** in a team
- You will have to communicate **as if you are not running in the same JVM**
- 3 maps to play on
  - DM-1on1-Albatross, DM-Rankin-FE, DM-1on1-Roughinery-FPS
- Interesting items: **Weapons, Armors, Shields**
- BASE: implement a picking squad that shares info about items they picked
- ADVANCED: **make sure** that a situation "two bots are pursuing the same item" never happens + if two bots want the same item, then one that is nearer will pursue it
  - 10 advanced points
  - Deadline for advanced points: see the website
- Squad template (includes UT2004 patch)
  - https://tinyurl.com/77a3uewt
  - Full link: https://drive.google.com/file/d/1qsJp3-HXtWzLCkK9liSUfhOeJu2KwzKN/view?usp=sharing

World Abstraction

`Item, Navpoint`

+ modules, helper classes and events

Pogamut 3 World Abstraction

New Stuff

Objects - `IWorldObject`

- `Player`
- `Self`
- *New* `Item`
- *New* `NavPoint`

Events - `IWorldEvent`

- `GlobalChat`
- *New* `HearPickup`
  - I've heard someone else
- *New* `ItemPickedUp`
  - I've picked up something

- Modules:
  - this.players, this.info
  - *New* this.items, this.navPoints
- *New* Helper classes
  - `MyCollections` – operations over collections
  - `DistanceUtils` – operations over distances
- Registering `IWorldEvent` listener example

```
@EventListener(eventClass = ItemPickedUp.class)
public void pickedUp(ItemPickedUp chatEvent) { … }
```

You can register callback to any class that is implementing `IWorldEvent` using this template.

Environment Abstraction

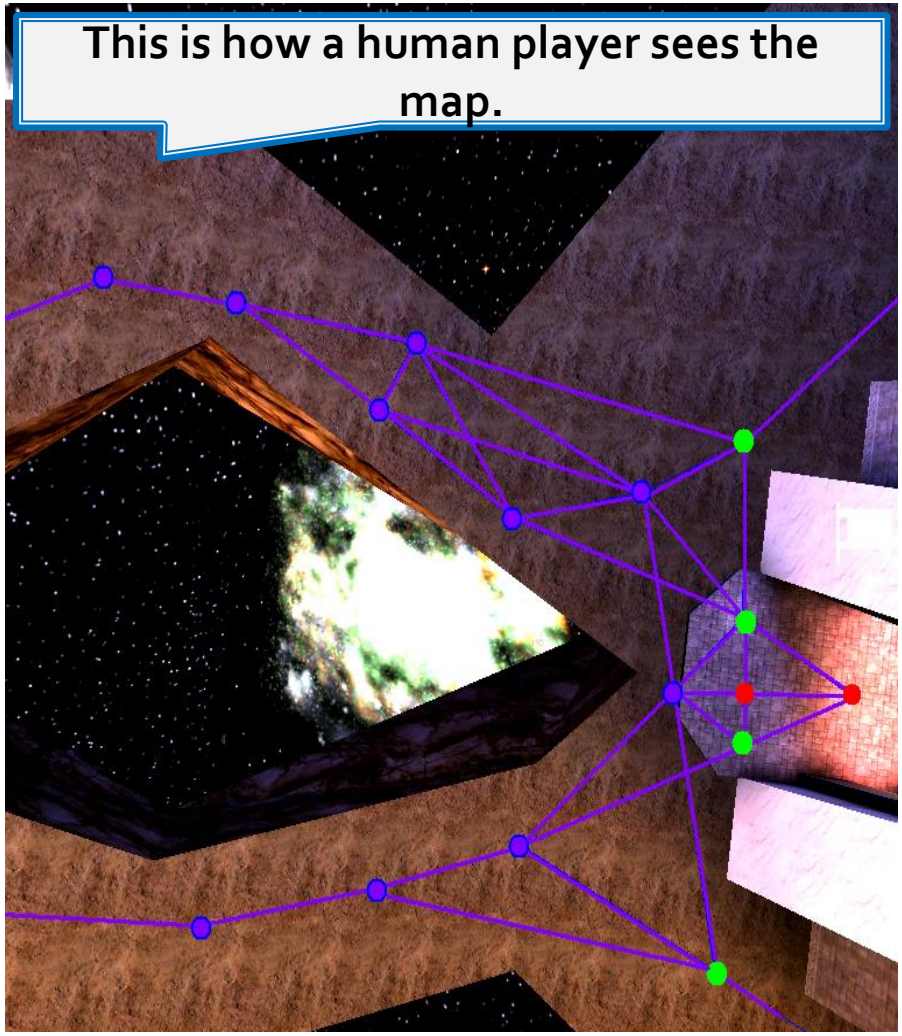
Navigation Graph

+

Navigation Mesh

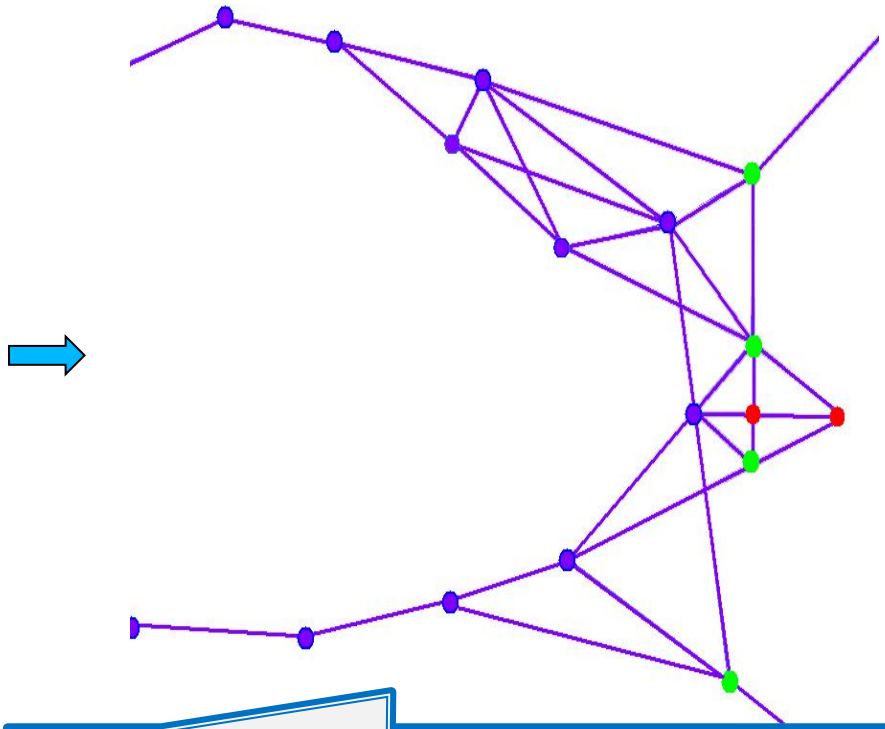
Navigation Graph

Original UT2004 navigation abstraction



This is how original UT2004 bots "see" this map.

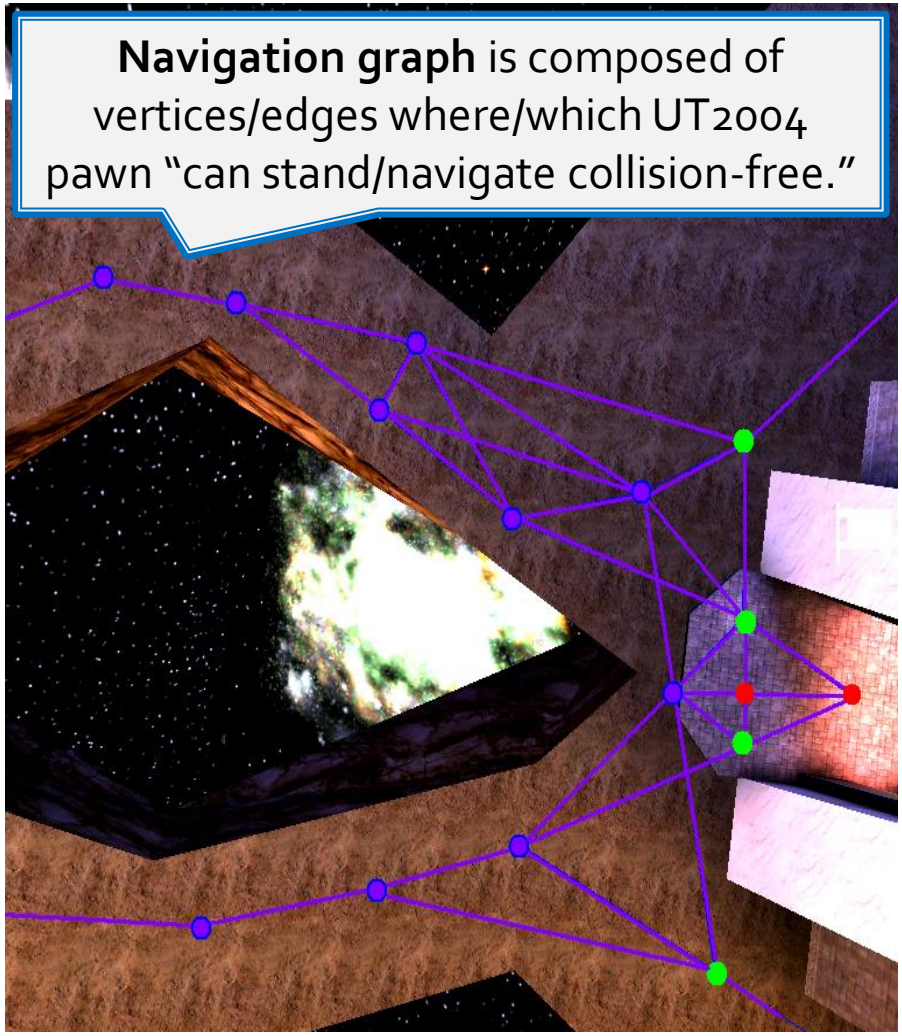
#Navpoints in a map = 100 – 5000



This is how the bot sees the environment!

Navigation Graph

Original UT2004 navigation abstraction



This is how original UT2004 bots "see" this map.

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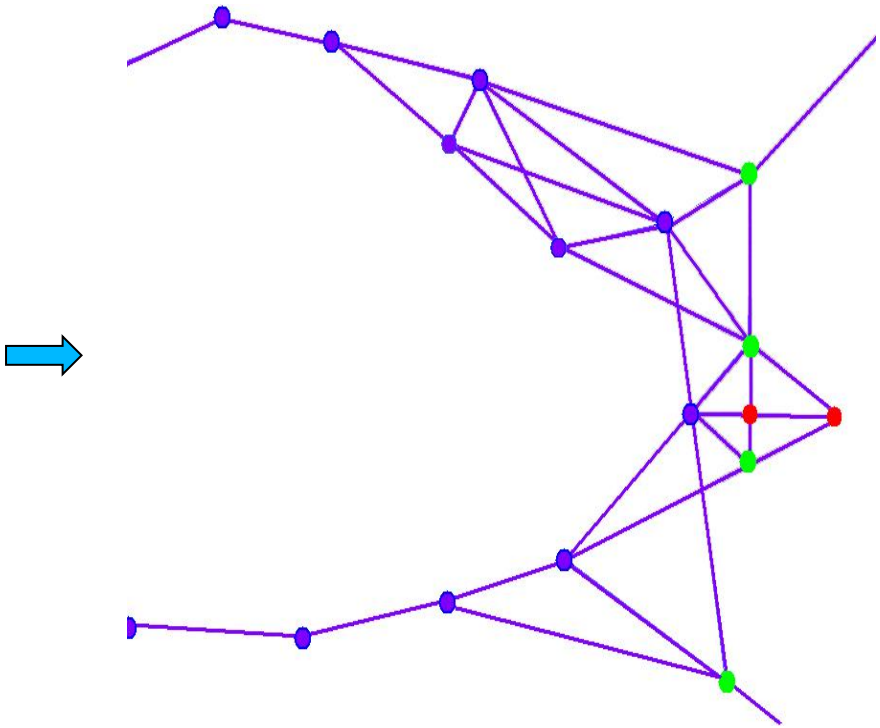
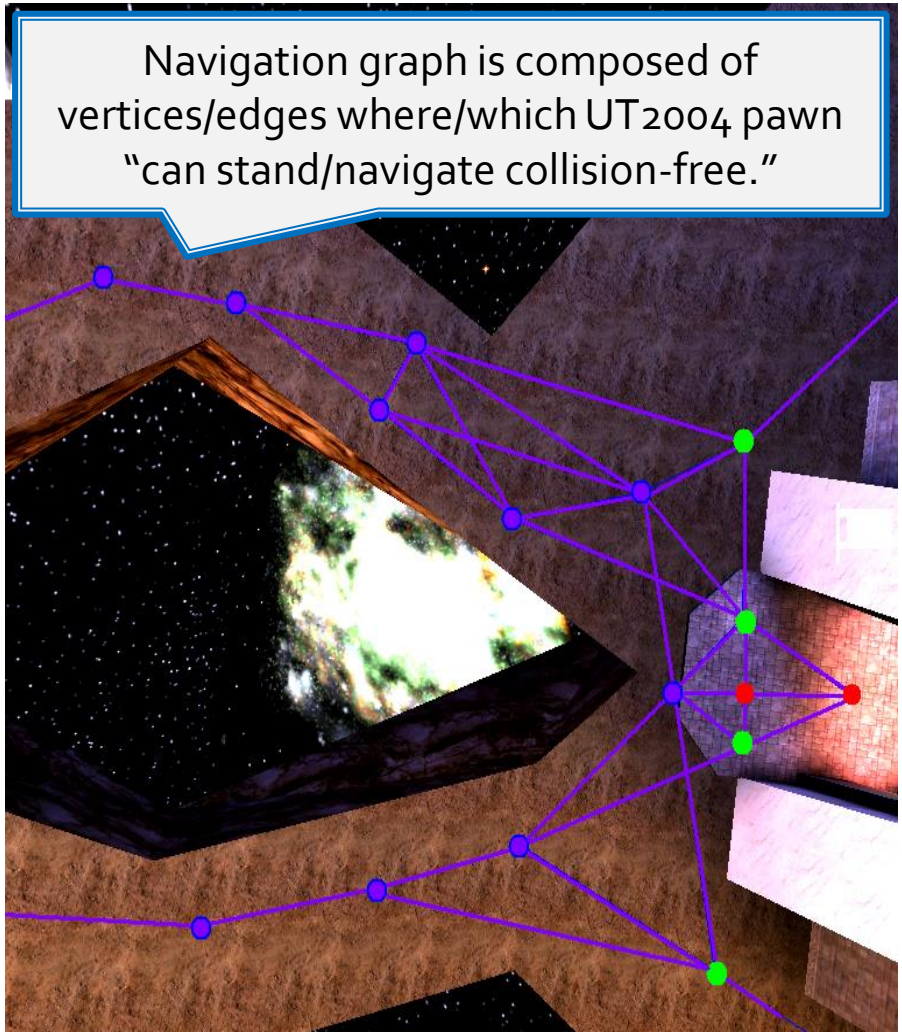


Navigation Graph

Original UT2004 navigation abstraction



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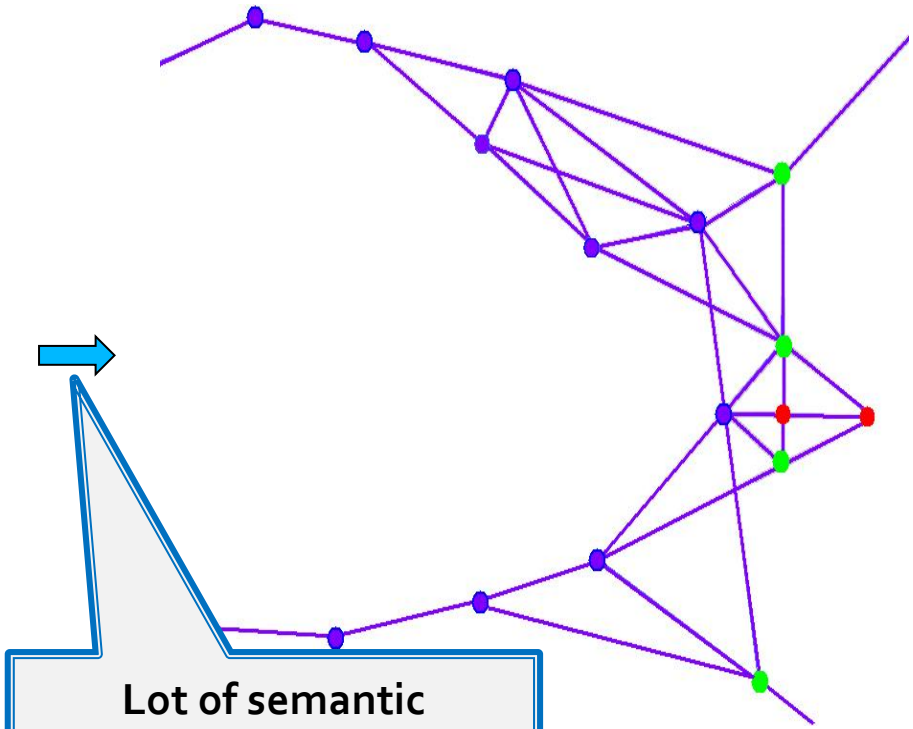
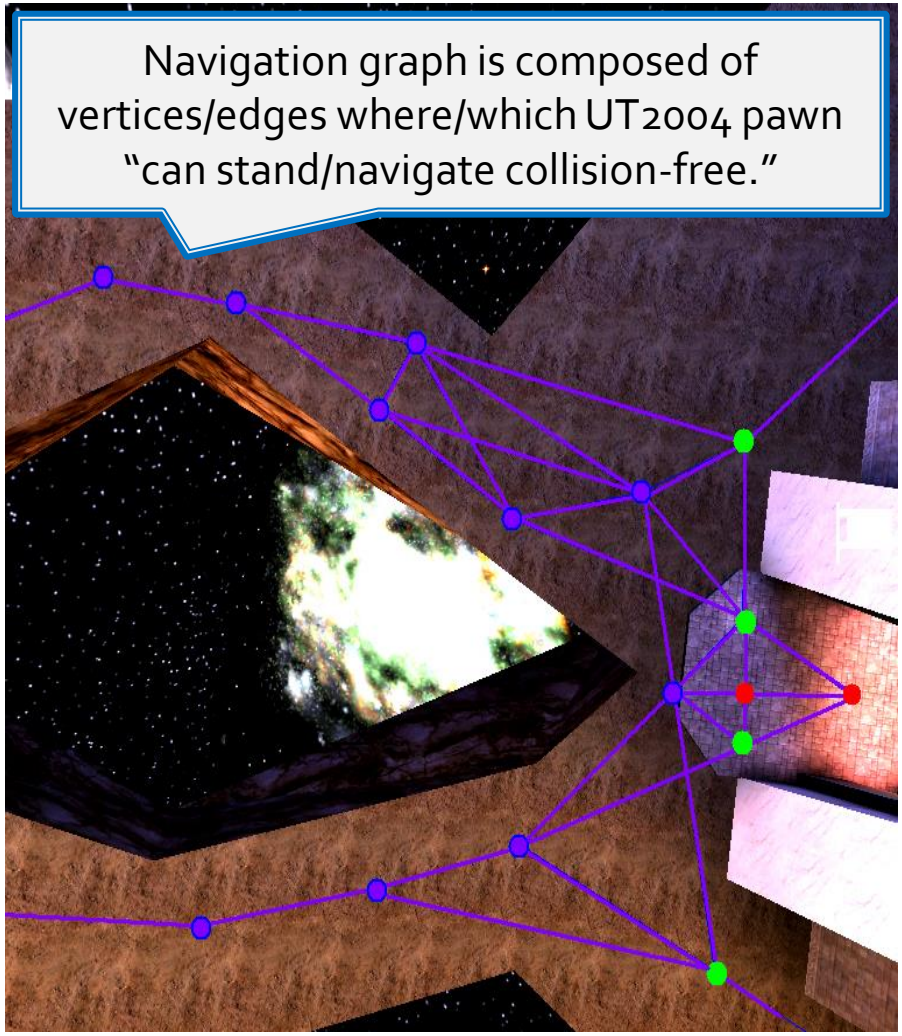


Lot of semantic information is lost (e.g. walls, holes, visibility)!

Navigation Graph

Original UT2004 navigation abstraction



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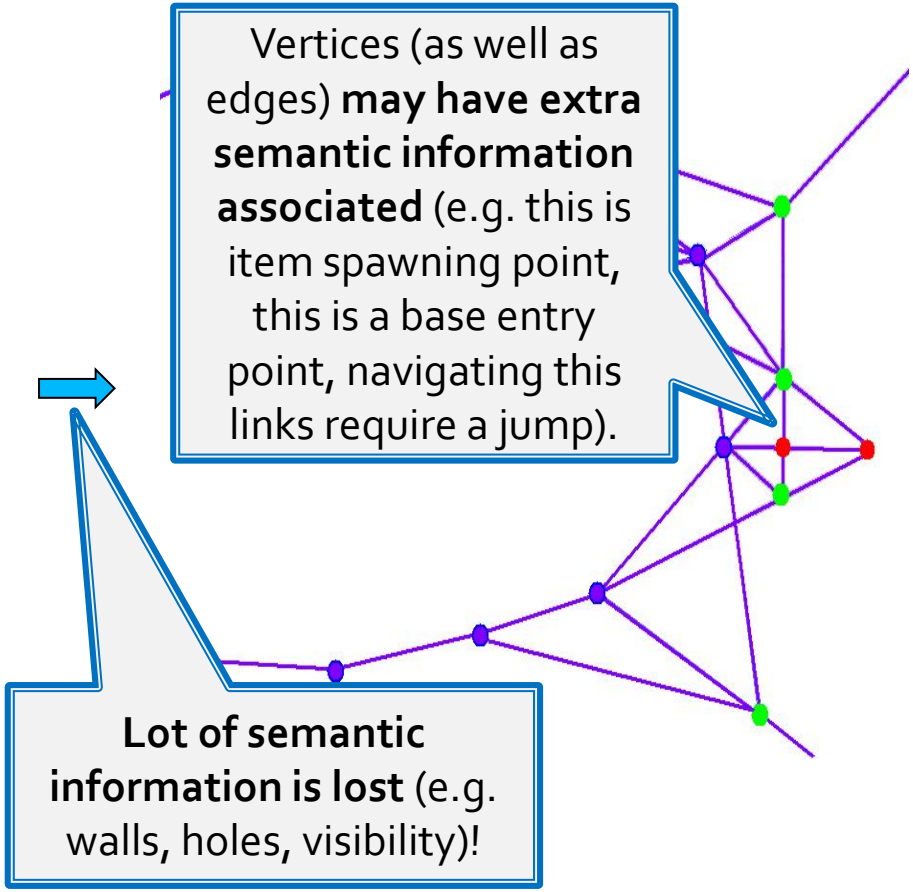


Navigation Graph

Low-level API

Classes of interest:

`NavPoints` – module wrapping navpoints

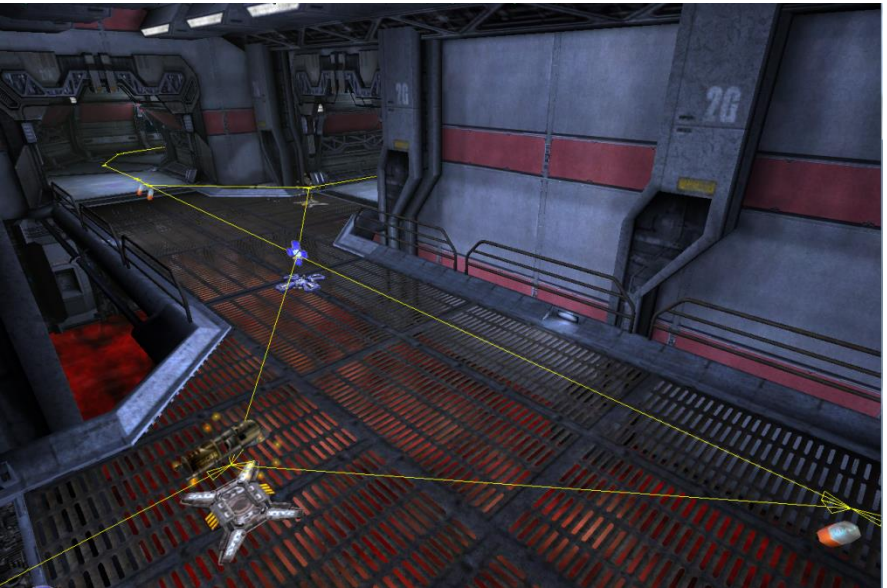
`NavPoint`, `NavPointNeighbourLink` – navgraph data

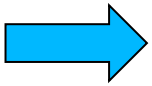
`Item` == usually item spawning point!

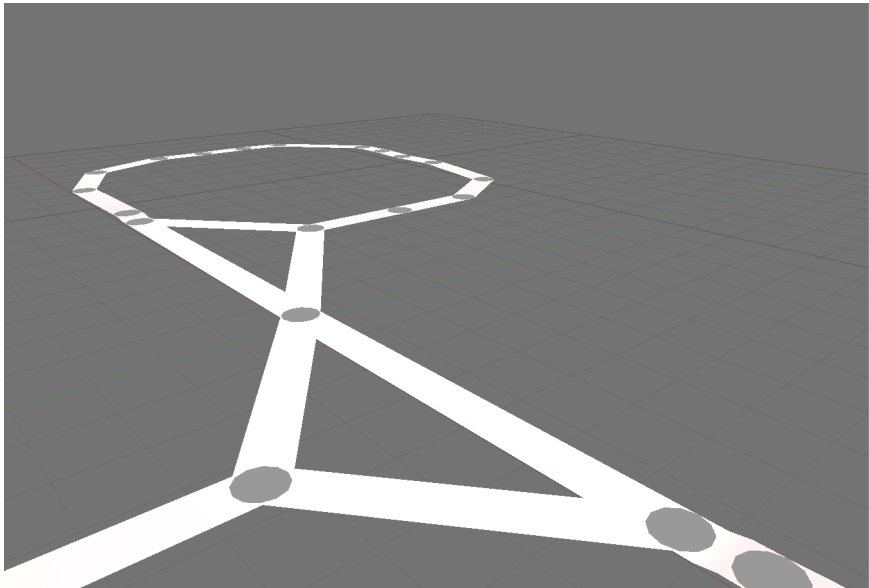
`NavigationGraphBuilder`

Methods of interest:

```
this.navPoints.getNavPoints()
this.items.getAllItems ()
this.world.getAll(NavPoint.class)
this.world.getAll(Item.class)
someNavPoint.getOutgoingEdges()
someNavPoint.getIncomingEdges()
```





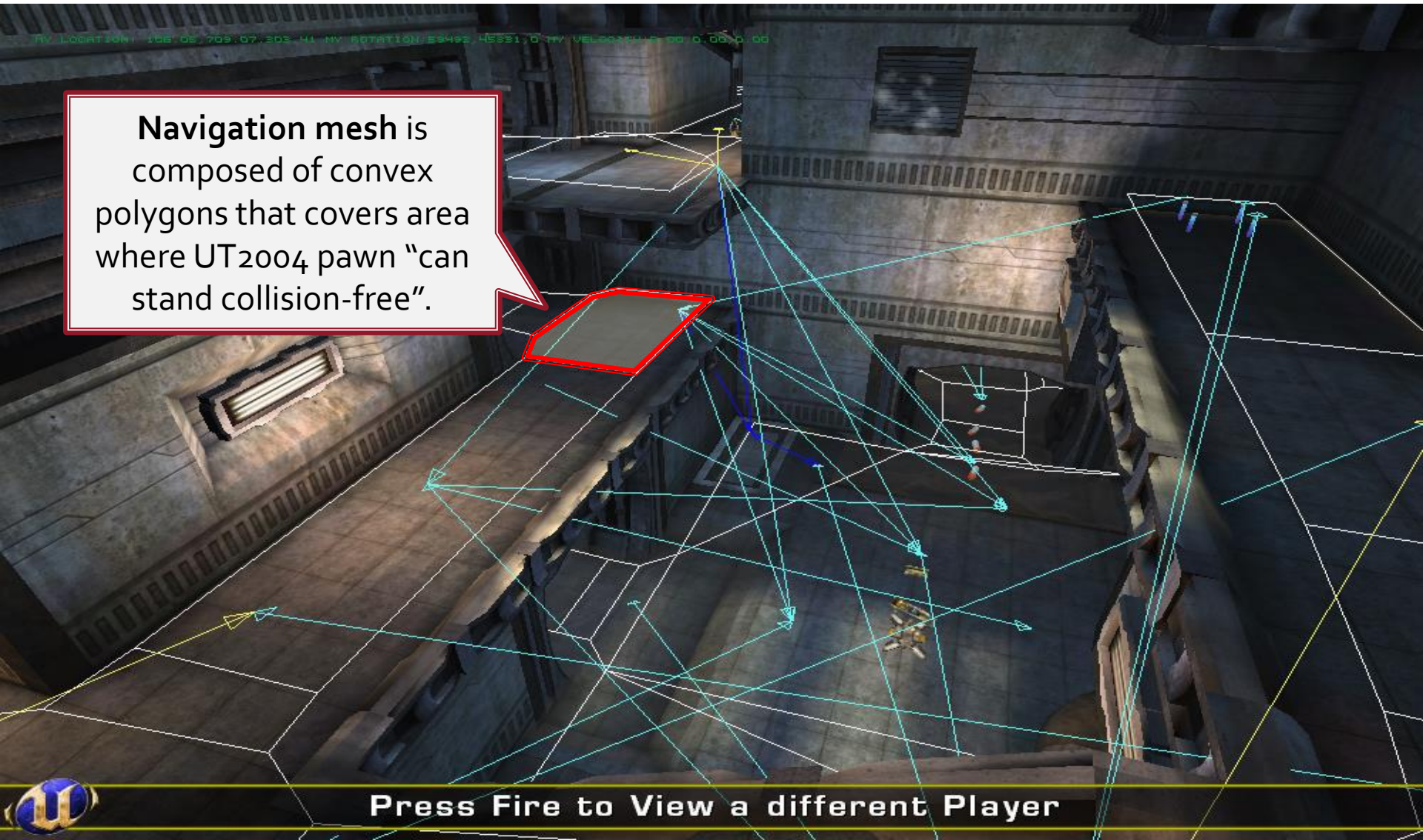


Navigation Mesh

Custom navig. abstr. computed from the map geom.

Navigation Mesh

Custom navig. abstr. computed from the map geom.



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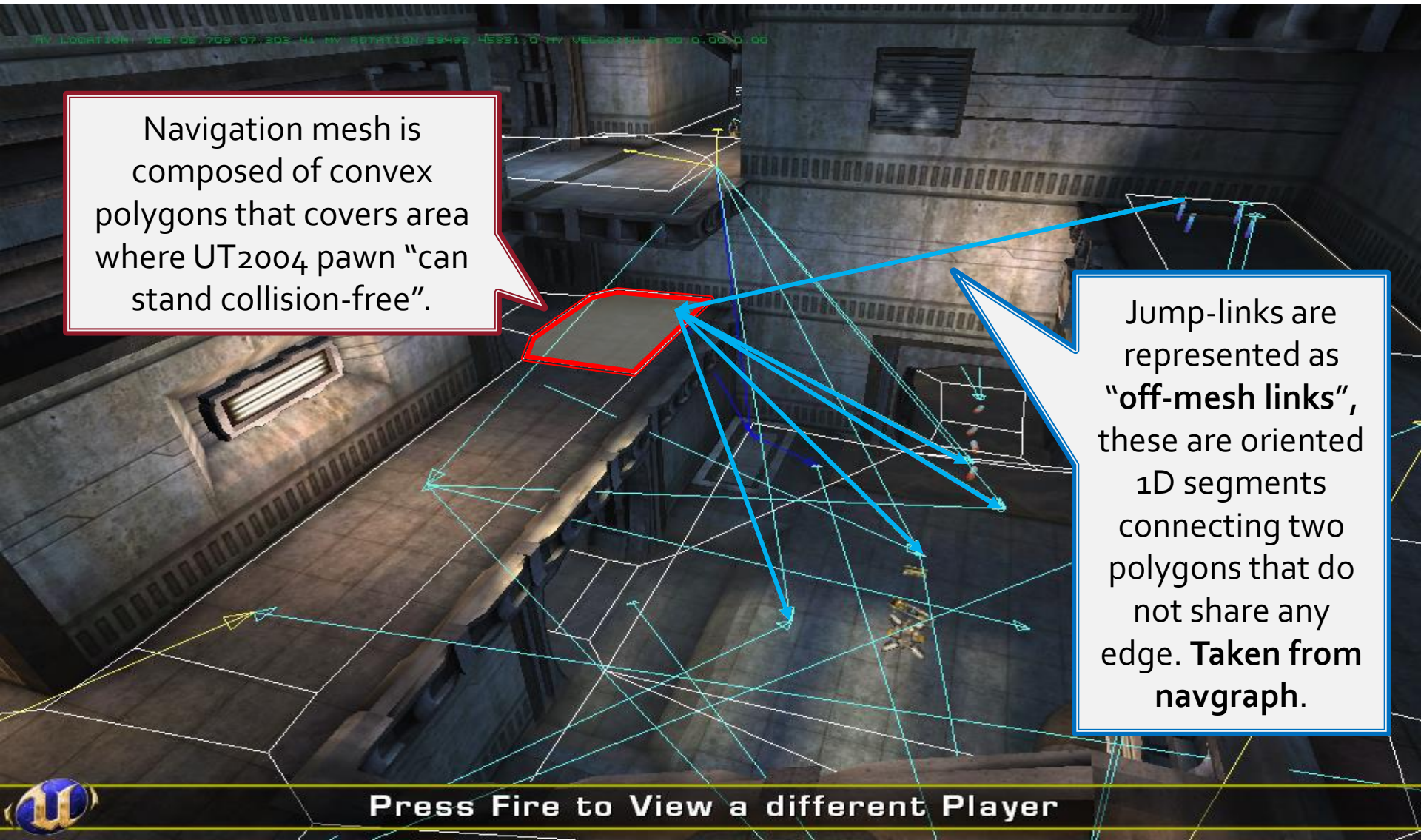

Navigation Mesh

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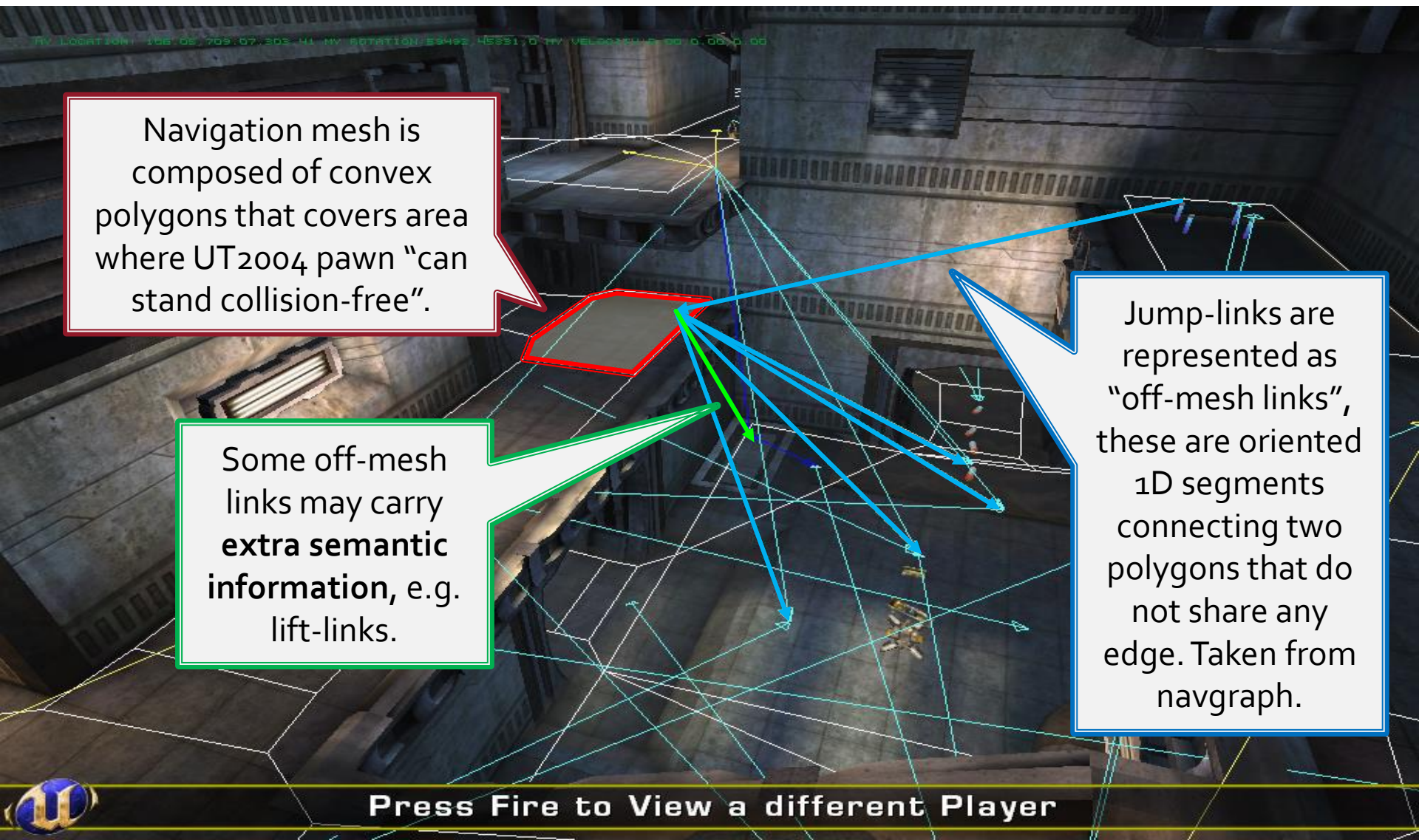


Navigation Mesh
Low-level API

Classes of interest:

`NavMeshModule`:

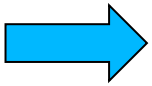
`NavMesh` – „raw“ data vertices, polys, off-mesh points

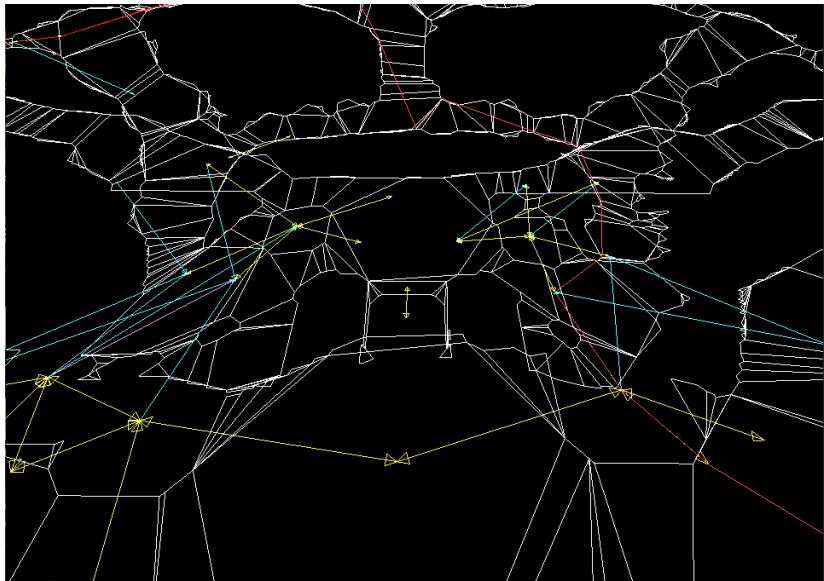
`NavMeshDropGrounder` – find nearest poly

`NavMeshClearanceComputer` – NM “raycast”

Methods of interest:

```
this.navMeshModule
    .getNavMesh()
    .getDropGrounder()
    .getClearenceComputer()
    .getAStarPathPlanner()
```





World Abstraction

`Item, ItemType`

All the small things (details) …

Pogamut World Abstraction

Items overview

Objects - `IWorldObject`

- `Player`
- `Self`
- **`Item`**
- `NavPoint`
- Module for quick sensory readings
  - `this.items`
- Some interesting methods:
  - `items.getItem(UnrealId)`
    - Translation `UnrealId` -> `Item` intsance
  - `items.getItemRespawnTime(Item)`
    - How often is this item respawning
  - `items.isPickable(Item)`
    - Is item pickable given its "spawned" state and my self/inventory state?
  - `items.isPickupSpawned(Item)`
    - Whether the bot thinks the item is spawned within the environment
  - `items.getSpawnedItems()`
    - Map of all items that are believed to be spawned right now

Events - `IWorldEvent`

- `GlobalChat`
- `HearPickup`
- **`ItemPickedUp`**

Pogamut World Abstraction

Items overview

- `Item`
  - More "item spawning location" than item
    - `items.isPickupSpawned(item)`
  - Unique `UnrealId` => Can be used in `Set`, `Map`
  - `ILocated` ~ `getLocation()` ~ X, Y, Z
  - `IViewable` ~ `isVisible()`
  - Usually has corresponding `NavPoint` instance
    - `NavPoint itemNP = item.getNavPoint()`
  - Described by `UT2004ItemType`
    - `item.getType()`

Pogamut World Abstraction

Items overview

- `Item`
  - Not all `Item` instances are "item spawning locations"!
  - `Item.isDropped()`
    - `False` => `Item` describes item spawning location, once picked up, will respawn after some time
    - `True` => `Item` has been dropped by some killed player, once picked up, will never respawn at the same location

Pogamut World Abstraction

Items overview

- `Item.getType()` returns `UT2004ItemType`
  - Enum holding concrete type of the item
  - Part of some `ItemType.Category`
    - Categories are divided based on what items are intended to do
    - `ItemType.Category.HEALTH`
    - `ItemType.Category.ARMOR`
    - `ItemType.Category.SHIELD`
    - `ItemType.Category.WEAPON`
    - `ItemType.Category.AMMO`

"Armor" value a player sees in HUD is a sum of its "armor" and "shield"; different weapons damages/bypasses different "armor types".

Pogamut World Abstraction

Items overview

- `items.getSpawnedItems()`
- Is the item spawned?
  - A crucial question to answer in order to decide what to start navigating to
  - Subject to partial observability of UT2004; if the bot does not see "item spawning point", and it did not pickup the item recently, the bot cannot be sure whether some item is spawned or not
  - The bot can only "believe" that the item is spawned

Pogamut World Abstraction

Items overview

Listening to `ItemPickedUp` event is a bit tricky…

```
@EventListener(eventClass = ItemPickedUp.class)
public void itemPickedUp(ItemPickedUp event) {
   Item item = items.getItem(event.getId());
   …
}
```

Typically, one would think that the callback is raised when you pick some item up ONLY.

However, the problem is that "`ItemPickedUp`" is broadcast also before the bot is spawned into the environment for "initial bot equipment" a bot receives every time it is launched into the environment. Such IDs will not have `Item` instance counterparts!

This is especially problematic for the case when you are spawned into the game for the very first time as you, for instance, have not received `Self` message yet and so, e.g., `this.self` is not properly initialized yet.

Navigation

… and how to decide
where to go?

Navigation

Picking an Item step by step

Navigation means to:

1. Decide where to go
2. Plan the path (list of path points)
3. Follow the path
   - Keep checking that you still want to continue with the navigation.
4. Check that you have truly reached your destination once navigation stops!

Navigation

1. Decide where to go example

```
targetItem =
  DistanceUtils.getNearest(
    items.getSpawnedItems().values(),
    info.getLocation(),
    new DistanceUtils.IGetDistance<Item>() {
      @Override
      public double getDistance(
                        Item object, ILocated target) {
        return
          navMeshModule
            .getAStarPathPlanner()
            .getDistance(target, object);
      }
    });
```

3. Make sure to save the item you're navigating to into your memory.

1. Returns nearest item you think is spawned wrt. your current location.

2. Using path-metric instead of default Euclidean one.

Navigation

2.+3. Plan & Navigate

```
navigation.navigate(targetItem);
if (navigation.isNavigating()) return;
else {
  // item location unreachable from my current
  // position
}
```

- Notice the `else` branch; it might happen that you are trying to start/continue navigation towards unreachable location (depending on your "item selection" routine and your current position)

Navigation

4. Check that you have grabbed the item

```
@EventListener(eventClass = ItemPickedUp.class)
public void itemPickedUp(ItemPickedUp event) {
  if (targetItem != null
      && targetItem.getId() == event.getId())
      itemPicked = true;
}

if (!navigation.isNavigating()) {
  if (itemPicked) {
    // item obtained
  } else {
    if (targetItem “is visible and near”) {
      // move to a location a bit behind the item to grab it
    } else {
      // navigation stuck => you might try to restart it
      // item unreachable => pick different item
    }
  }
}
```

That’s why you need the memory!

Navigation
Cheatsheet

- Deciding where to go
  - `navPoints.getNavPoint()`
  - `DistanceUtils… // Euclidean metric`
  - `fwMap.getNearest(…) // Path-length metric for navigation graph`
  - `navMeshModule.getAStarPathPlanner().getDistance(object, target)`
- Navigation module
  - `this.navigation.navigate(…)`
  - `this.navigation.isNavigating()`
- Stuck listening *(differentiates between "item unreachable" / "stuck")*
  - ```
    this.navigation
            .addStrongNavigationListener(
                    new FlagListener<NavigationState>() { … })
    ```
  - Register this in `beforeFirstLogic()`
- Info about the bot
  - `this.info.getLocation()`
  - `this.info.atLocation(ILocated, epsilon)`
  - `this.info.getNearestNavPoint()`
    ```

Team Communciation

… how to talk to each other?
WhatsApp for bots!

TeamComm Server

Instant messaging for bots

```
public class TeamCommBot extends
    UT2004BotTCController<UT2004Bot>

<dependencies>
    <dependency>
      <groupId>cz.cuni.amis.pogamut.ut2004</groupId>
      <artifactId>ut2004-team-comm</artifactId>
      <version>3.8.1-SNAPSHOT</version>
    </dependency>
</dependencies>
```

Java Example available at:

- svn://artemis.ms.mff.cuni.cz/pogamut/trunk/project/Main/PogamutUT2004Examples/26-TeamCommBot

TeamComm Server

Instant messaging for bots

- TeamComm server is custom solution for sending serializable Java objects (subclasses of `TCMessageData`) between UT2004 bots written in Java
- Requires team-oriented game type to be running (e.g. Team Deathmatch)
- The server understands the game => it makes sure that messages send to the team is not broadcast to members of a different one
- You have to start the TC server manually via:
  - `UT2004TCServer.startTCServer();`
- Once running, you can leave it be (quite stable, handles dis/connection of bots gracefully)

TeamComm Server

Instant messaging for bots

- Module `tcClient`
  - Is connecting to the TeamComm server automatically

```
if (!tcClient.isConnected()) return;
```

  - Provides methods for sending messages to other bots

```
tcClient.sendToTeam(…);
tcClient.sendToTeamOthers(…);
```

- Message is any object that is serializable and extends `TCMessageData`
  - `UnrealId` is serializable
  - `Item`, `Player`, `NavPoint`, … are not!

TeamComm Server

Instant messaging for bots

```
public class TCItemPicked extends TCMessageData {

  private static final long serialVersionUID = 786623423491232L;

  public static final IToken MESSAGE_TYPE =
    Tokens.get("TCItemPicked");

  public UnrealId who;

  public UnrealId what;

  public TCItemPicked(UnrealId who, UnrealId what) {
    super(MESSAGE_TYPE);
    this.who = who;
    this.what = what;
  }

}
```

Java: Each serializable object must has its unique magic number; do not forget to change this when copy-pasting!

TeamComm Server

Instant messaging for bots

```
public class TCItemPicked extends TCMessageData {

  private static final long serialVersionUID = 7866323423491232L;

  public static final IToken MESSAGE_TYPE =
    Tokens.get("TCItemPicked");

  public UnrealId who;

  public UnrealId what;

  public TCItemPicked(UnrealId who, UnrealId what) {
    super(MESSAGE_TYPE);
    this.who = who;
    this.what = what;
  }

}
```

TeamComm: is requiring all messages to define their unique id token; do not forget to change this when copy-pasting!

TeamComm Server

Instant messaging for bots

```
public class TCItemPicked extends TCMessageData {

  private static final long serialVersionUID = 7866323423491232L;

  public static final IToken MESSAGE_TYPE =
    Tokens.get("TCItemPicked");

  public UnrealId who;

  public UnrealId what;

  public TCItemPicked(UnrealId who, UnrealId what) {
    super(MESSAGE_TYPE);
    this.who = who;
    this.what = what;
  }

}
```

TeamComm: is requiring all messages to define their unique id token; pass the token to the super constructor.

TeamComm Server

Instant messaging for bots

```
@EventListener(eventClass=TCMessage.class)
public void allMsg(TCMessage tcMessage) {
    log.info("@EventListener(TCMessage)");
}
```

- Hook for listening to ALL messages TeamComm->Bot
  - Not advised to use for reading, useful for logging while debugging

```
@EventListener(eventClass=TCItemPicked.class)
public void tcItemPicked(TCItemPicked event) {
    log.info("@EventListener(TCItemPicked)");
}
```

- Hook for listening to `TCItemPicked` custom messages
  - Advised way, create separate message handler for every specific message
  - `TCItemPicked` message is user-defined, you may create as many of such a classes as you need

Homework 03

ItemPicker Squad

Revisiting the reasoning

Homework 03
Gotta COLLECT 'em all!

- So now you know how to share information between bots
- How to pick all the items as fast as possible?
  1. One bot will solve the optimization problem and commands the others
     - While you can try to do it … it's resource-demanding => this is not how you would implement in fast-paced games like FPSs; simulation is non-deterministic => pointless to try to plan too much into future
  2. Distributed solution
     - Let it be solved emergently during the simulation itself
     - Each bot is having some information and trying to do the best for itself while cooperating with others
     - You can do a lookahead:
       - Level 0 = be sure not to try to pick something someone else is pursuing
       - Level 1 = be able to interrupt someone else, if you are closer to item other is pursuing
       - Level 2 = assume the common goal and pick the item so the sum of all "current and next run" are the lowest
       - Level 3 = dtto but "current next 2 runs"; usually pointless because of CPU time and simulation non-determinism

Homework 03

Submissions

Submissions will happen through Gdrive again.

Once you finish your homework, ZIP UP your project folder COMPLETELY (except the `target` folder) and upload the ZIP file to shared shared GDrive folder into the `03-ItemPicker` directory.

Questions?

I sense a soul in search of answers…

ASK AT DISCORD!

https://discord.gg/c49DHBJ