Stavros Vassos, University of Athens, Greece stavrosv@di.uoa.gr May 2012

INTRODUCTION TO AI STRIPS PLANNING

.. and Applications to Video-games!

Course overview

- Lecture 1: Game-inspired competitions for AI research, AI decision making for non-player characters in games
- Lecture 2: STRIPS planning, state-space search
- Lecture 3: Planning Domain Definition Language (PDDL), using an award winning planner to solve Sokoban
- Lecture 4: Planning graphs, domain independent heuristics for STRIPS planning
- Lecture 5: Employing STRIPS planning in games: SimpleFPS, iThinkUnity3D, SmartWorkersRTS
- Lecture 6: Planning beyond STRIPS

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SimpleFPS planning benchmark

- Focus on first-person shooter (FPS) games and the non-player characters (NPCs) that act against the human player.
- Focus on goal-oriented action planning (GOAP) for NPC behavior.

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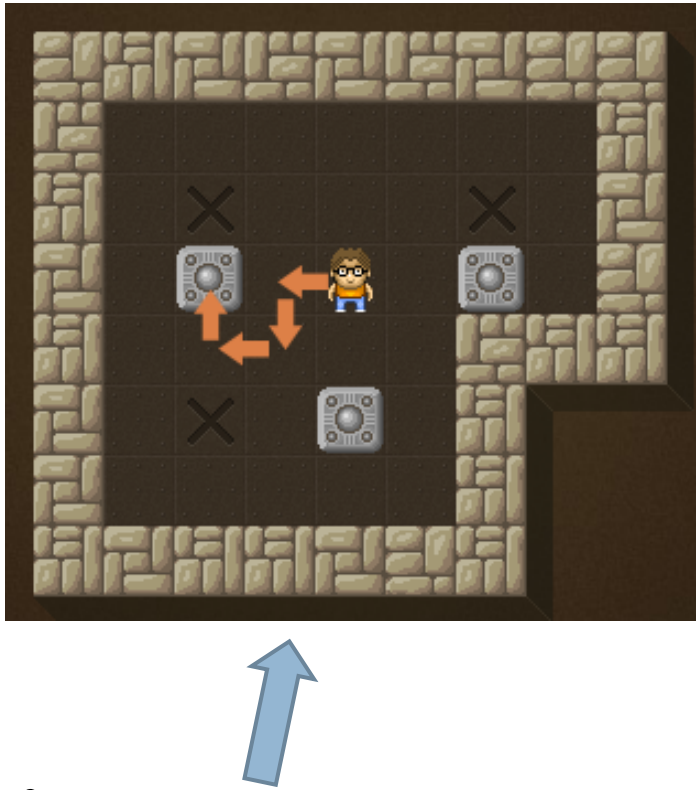
- SimpleFPS is a first step towards **evaluating** how the existing **academic** approaches for **planning** would perform if directly applied **in an FPS setting**.

STRIPS Planning

- Given:
  - Initial State
  - Goal
  - Available actions



- Find:
  - A **sequence of actions** that satisfy the goal
  - E.g.: [**Left, Down, Left, Up, …**]

Planning Domain Description Language

- Language for specifying STRIPS planning problems
- Formal syntax like a programming language

  - Initial State (:init …)
  - Goal (:goal …)
  - Actions

```
(:action name
        :parameters (?from ?to ?dir)
        :preconditions (…)
        :effects (…)
)
```

Planning Domain Description Language

- Language for specifying STRIPS planning problems
- Formal syntax like a programming language
  - Initial State (:init …)
  - Goal (:goal …)
  - Actions (:action name
    :parameters (?from ?to ?dir)
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)
- Literals like Lisp, e.g., bot-at(area1) (bot-at area1)

Planning Domain Description Language

- Language for specifying STRIPS planning problems
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Planning Domain

- Predicates (:predicates …)
- Actions

```
(:action name
        :parameters (?from ?to ?dir)
        :preconditions (…)
        :effects (…)
)
```

Planning Problem

- Objects (:objects …)
- Initial State (:init …)
- Goal (:goal …)

Planning Domain Description Language

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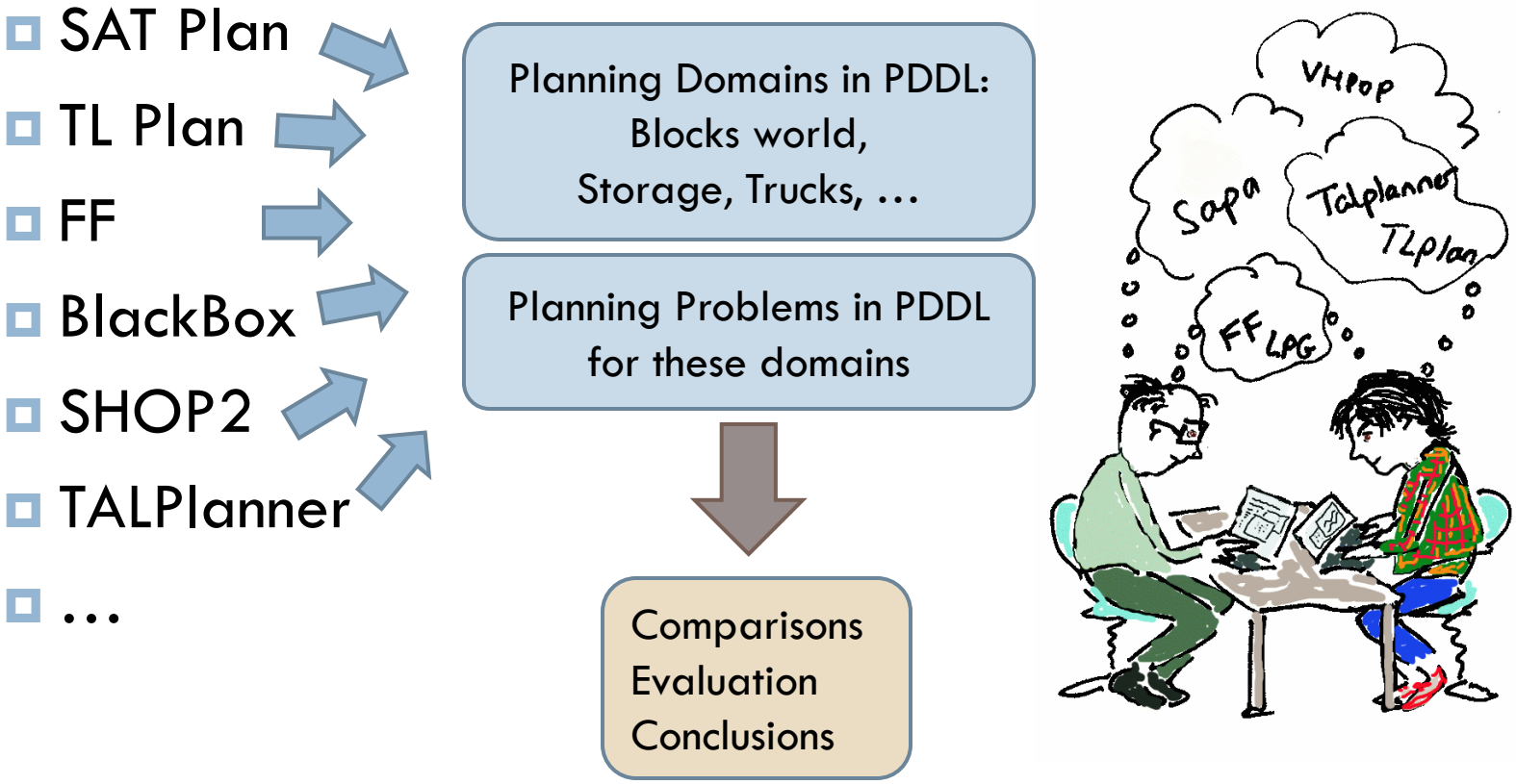

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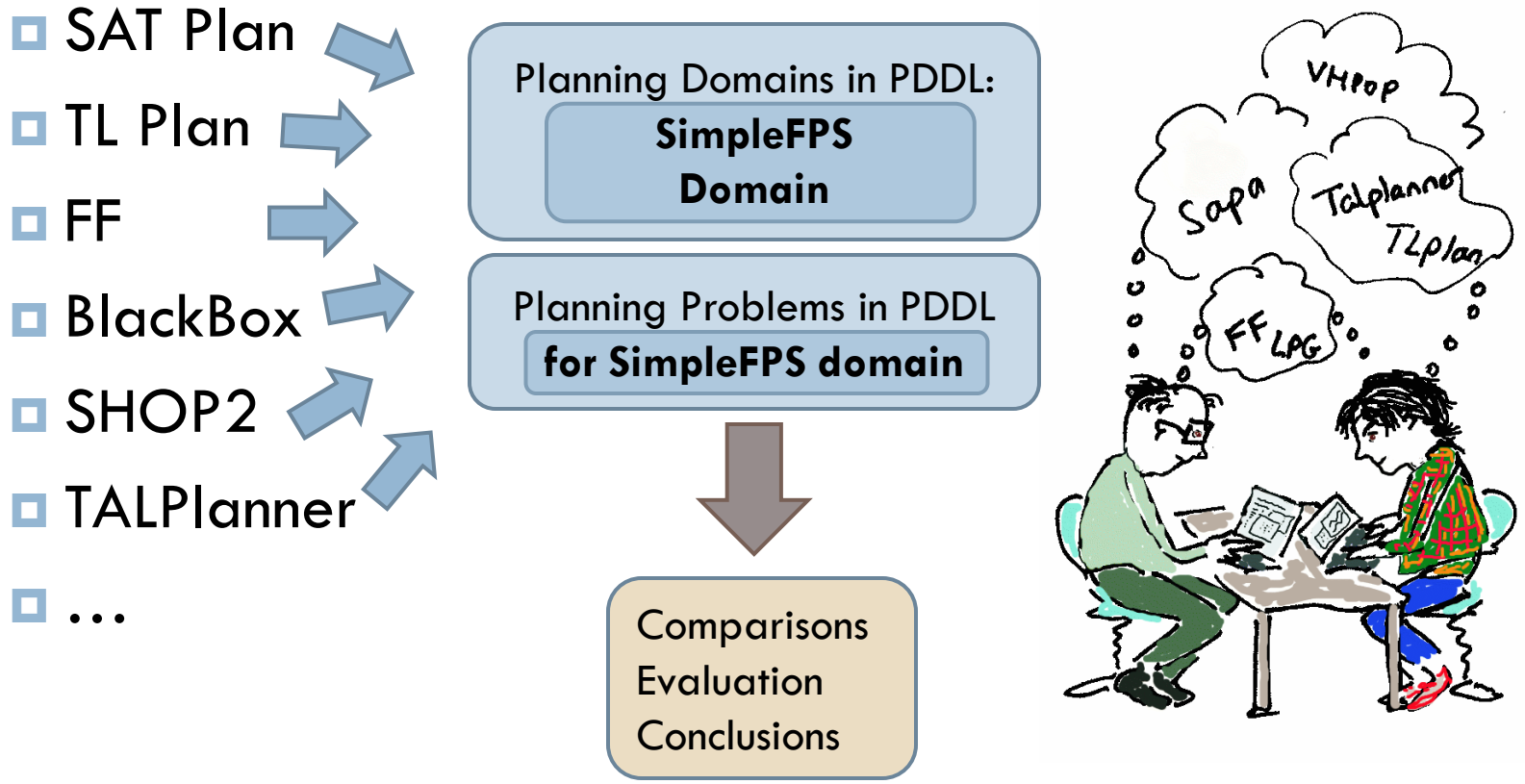


Motivation for SimpleFPS

- Planning in academia: extensively tested
- Planning in FPS video games: not extensively tested
- SimpleFPS: A PDDL domain for evaluating academic planning techniques for NPCs in First-Person Shooters

Motivation for SimpleFPS

- Planning in academia: extensively tested
  - Many PDDL planning domains and problems available
  - Many off-the-shelf PDDL planners available
- Planning in FPS video games: not extensively tested
  - A few success stories but not clear if the same works under different assumptions or what is the best approach
- SimpleFPS: A PDDL domain for evaluating academic planning techniques for NPCs in First-Person Shooters

SimpleFPS planning benchmark

- SimpleFPS_PDDL_Domain.txt

- SimpleFPS_PDDL_ProblemGenerator.c

SimpleFPS planning benchmark

- SimpleFPS_PDDL_Domain.txt:
  - Specifies the **predicates** that can be used to describe the initial state of the game-world and the goal condition for the NPC.
  - Specifies a list of **available actions** that the NPC can perform, along with their **preconditions** and **effects** in terms of the predicates of the domain.

- SimpleFPS_PDDL_ProblemGenerator.c:
  - A tool to generate problem instances, i.e., an **initial state** of the game-world and a **goal** for the NPC.

SimpleFPS planning benchmark

- Summer student project at the University of Athens
  - Michail Papakonstantinou
- AIIDE-2011 workshop paper
  - The SimpleFPS Planning Domain:
    A PDDL Benchmark for Proactive NPCs
- Code/datasets available online
  - http://code.google.com/p/simple-fps-pddl/

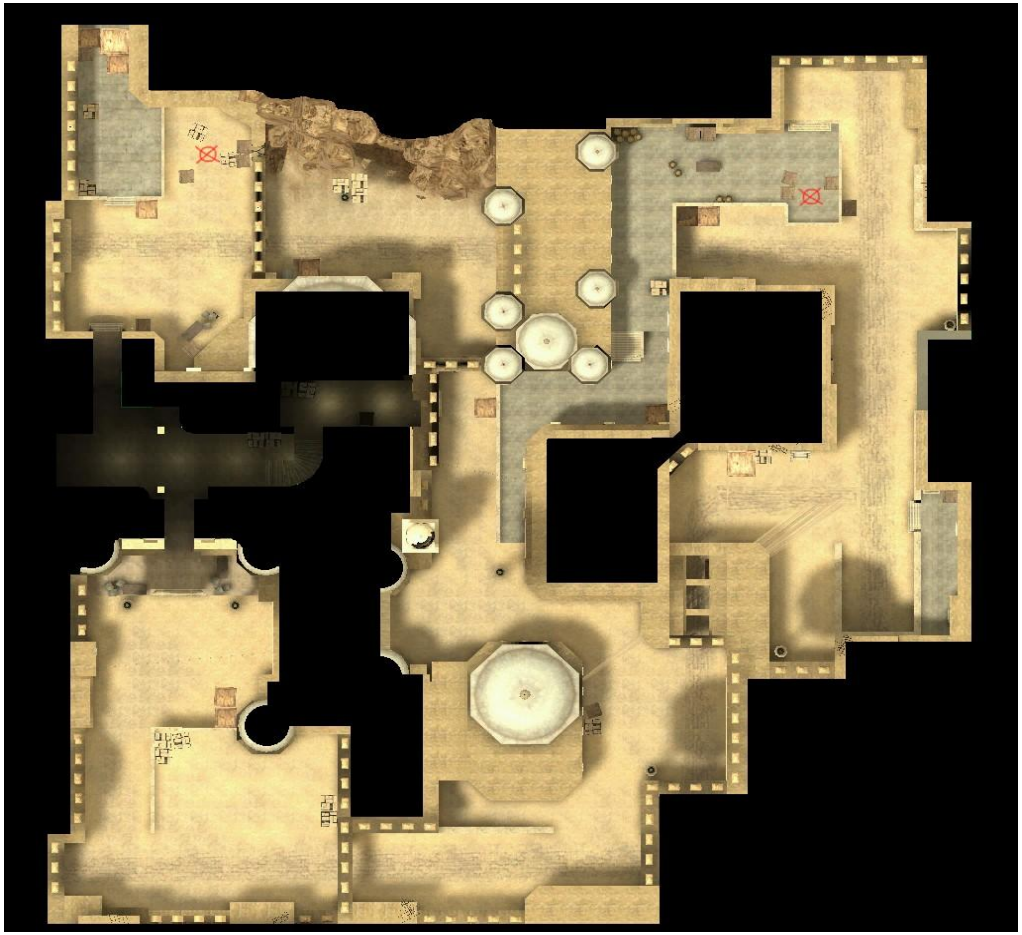
SimpleFPS domain

SimpleFPS domain

- Represent only very simple high-level features:
  - Game-world consists of interconnected **areas**, each of which has a number of **points of interest** (POIs).
  - A few types of **items** located at POIs (weapons, ammo, med-kits, keycards).
  - NPC can perform **basic actions** (move between areas or POIs, pick-up/use items, attack, take cover).

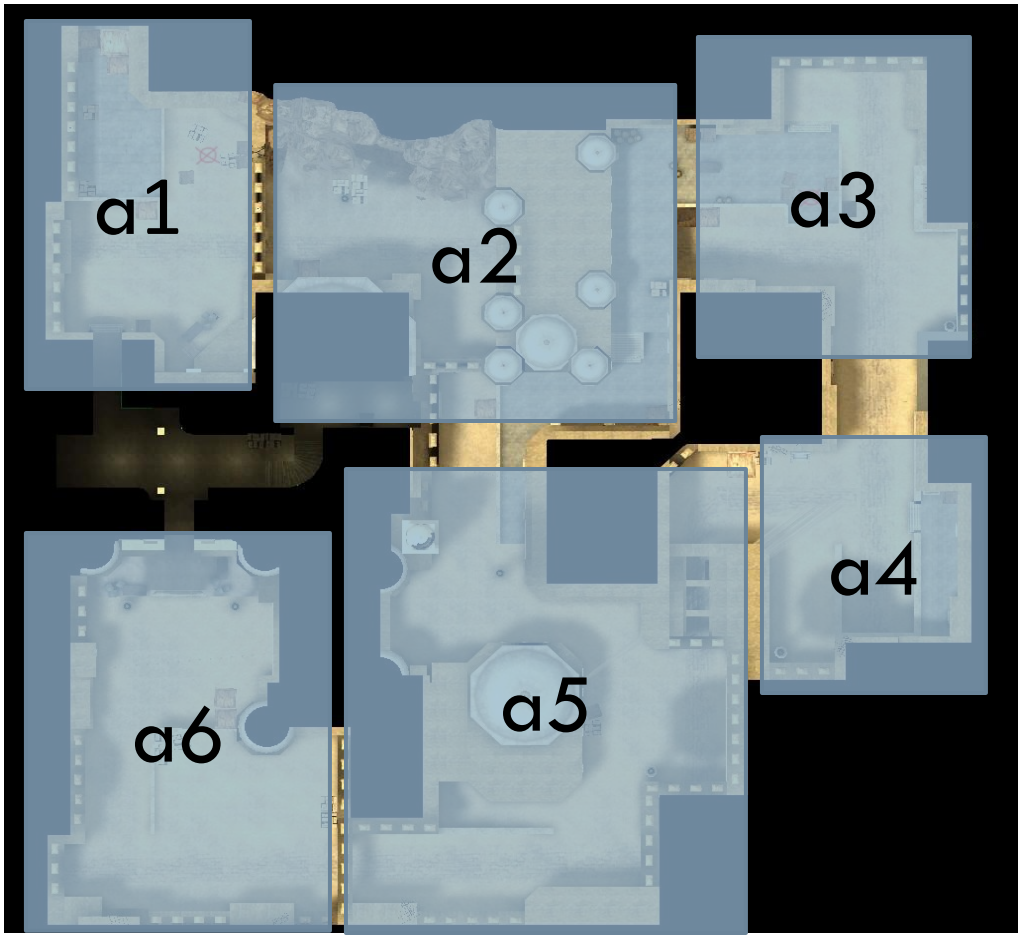
A SimpleFPS problem instance

- (:init …)



A SimpleFPS problem instance

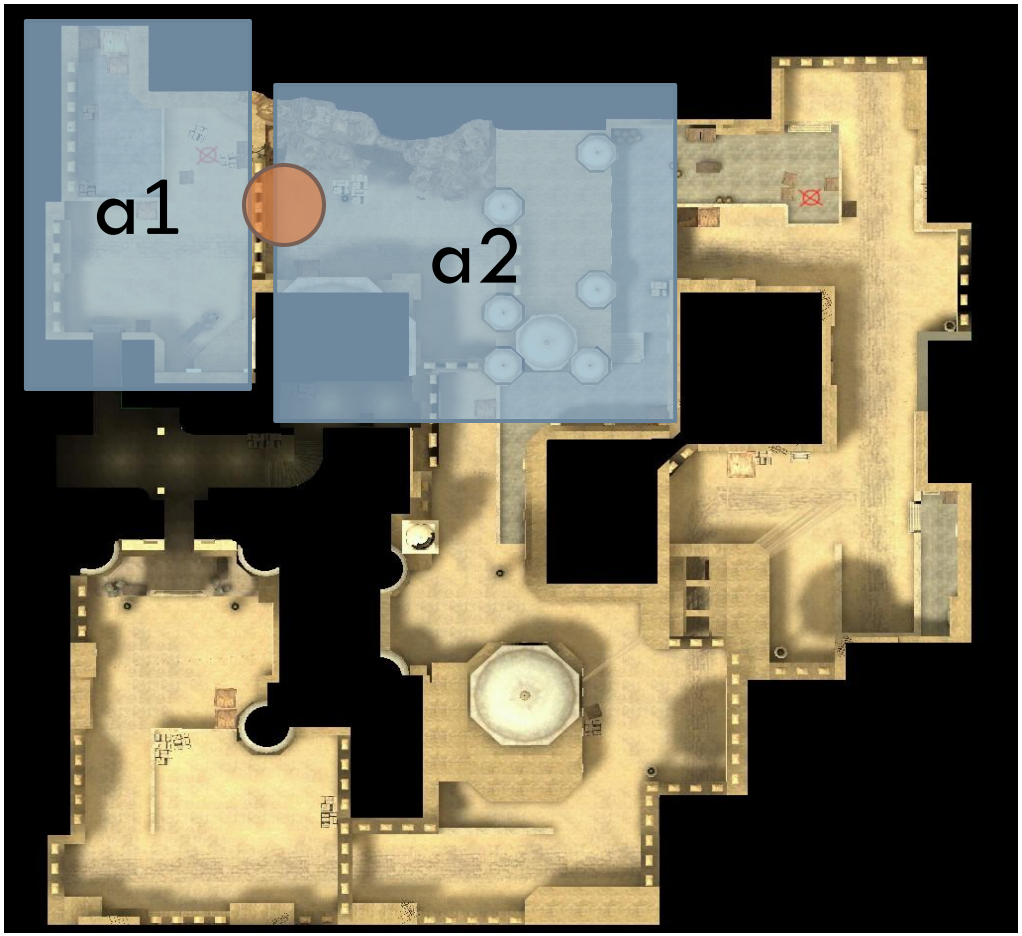
- (:init …)



- 6 areas, some of them connected through doors and corridors:
  - (area a1)
  - (area a2)
  - (area a3)
  - (area a4)
  - (area a5)
  - (area a6)

A SimpleFPS problem instance

- (:init …)

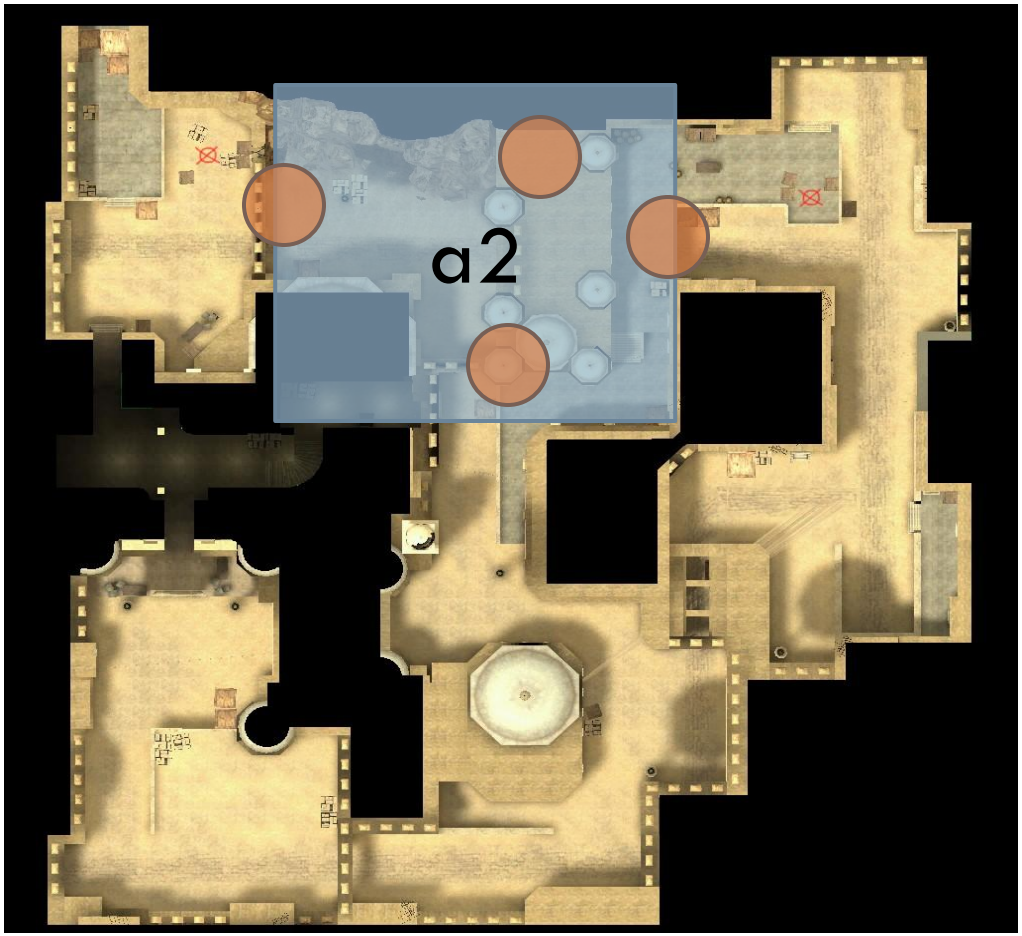


- 6 areas, some of them connected through doors and corridors:

- (poi door1 a1)
- (waypoint door1)
- (connected a1 a2 door1)
- (closed door1)
- (opens door1 keycard1)

A SimpleFPS problem instance

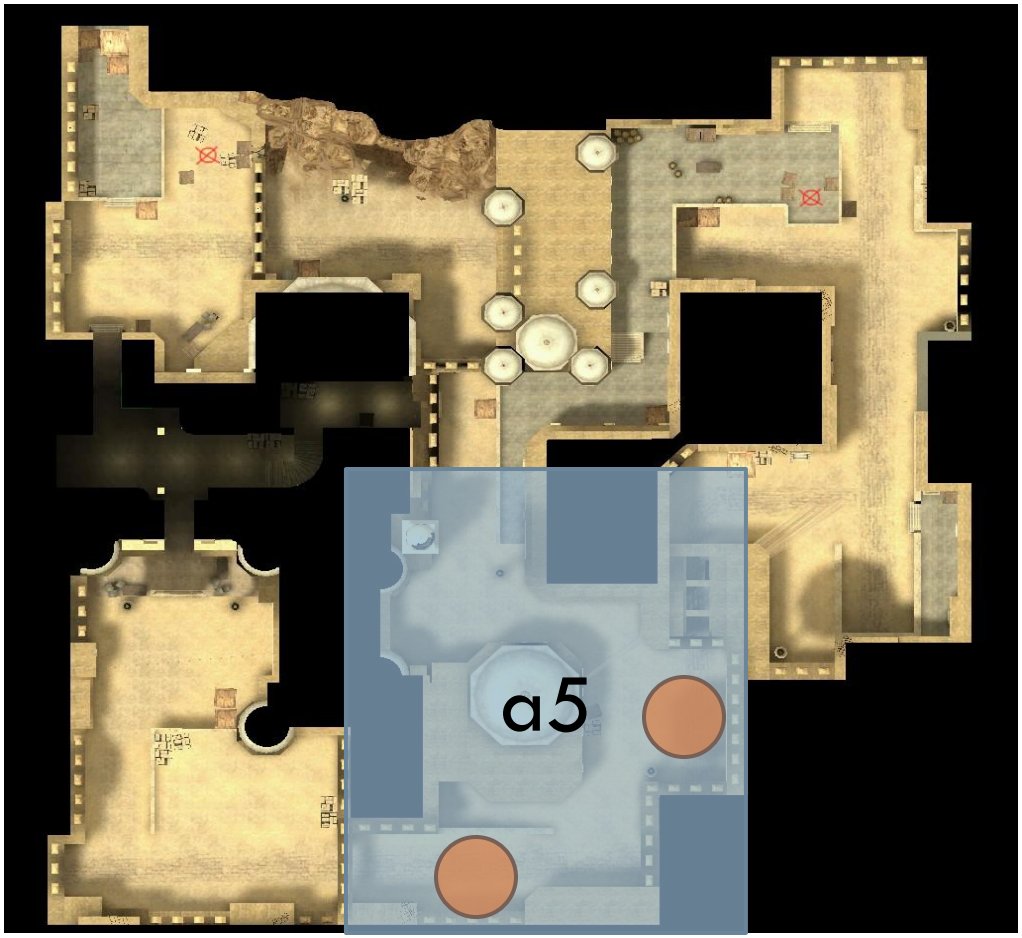
- (:init …)



- For each area a number of POIs are listed along with their properties:
- (poi door1 a2)
- (poi c1 a2)
- (poi c2 a2)
- (connected a2 a1 door1)
- (cover-point c1)
- (cover-point c2)

A SimpleFPS problem instance

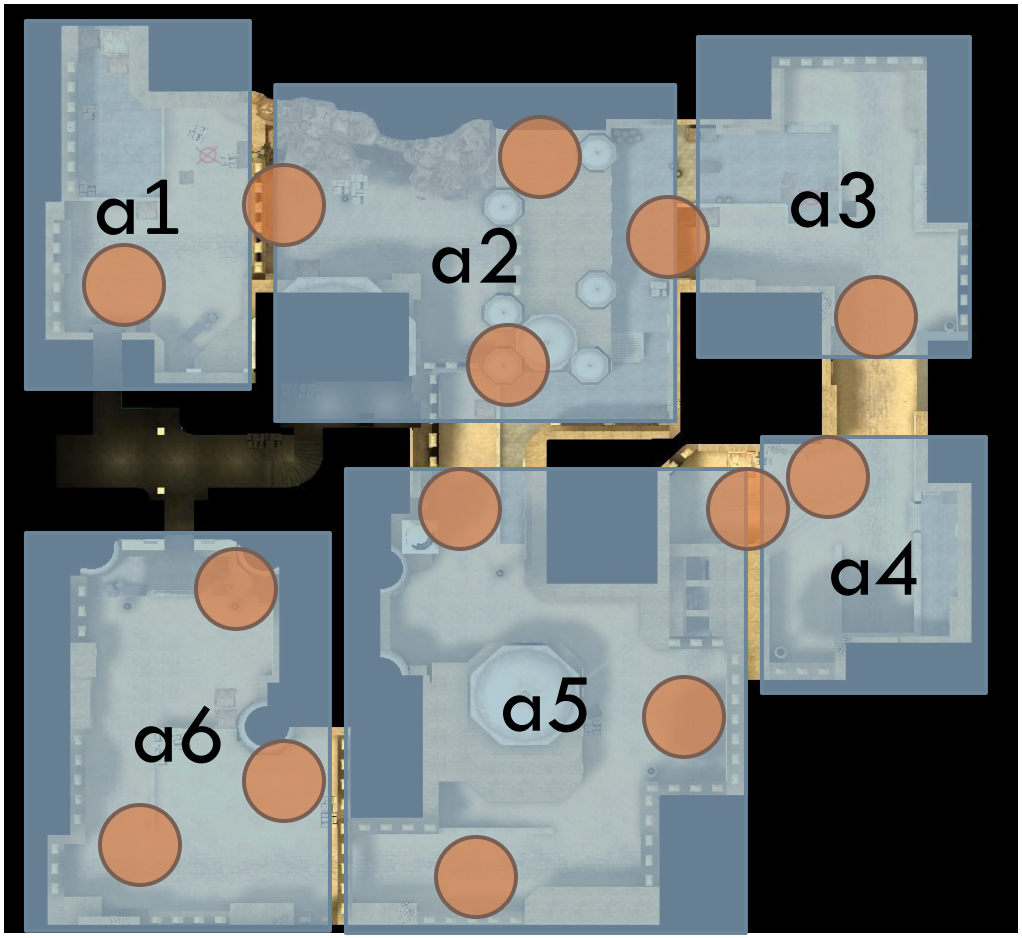
- (:init …)



- For each area a number of POIs are listed along with their properties:
- (poi g1 a5)
- (poi amm1 a5)
- (gun g1)
- (unloaded g1)
- (ammo amm1 g1)

A SimpleFPS problem instance

- (:init …)



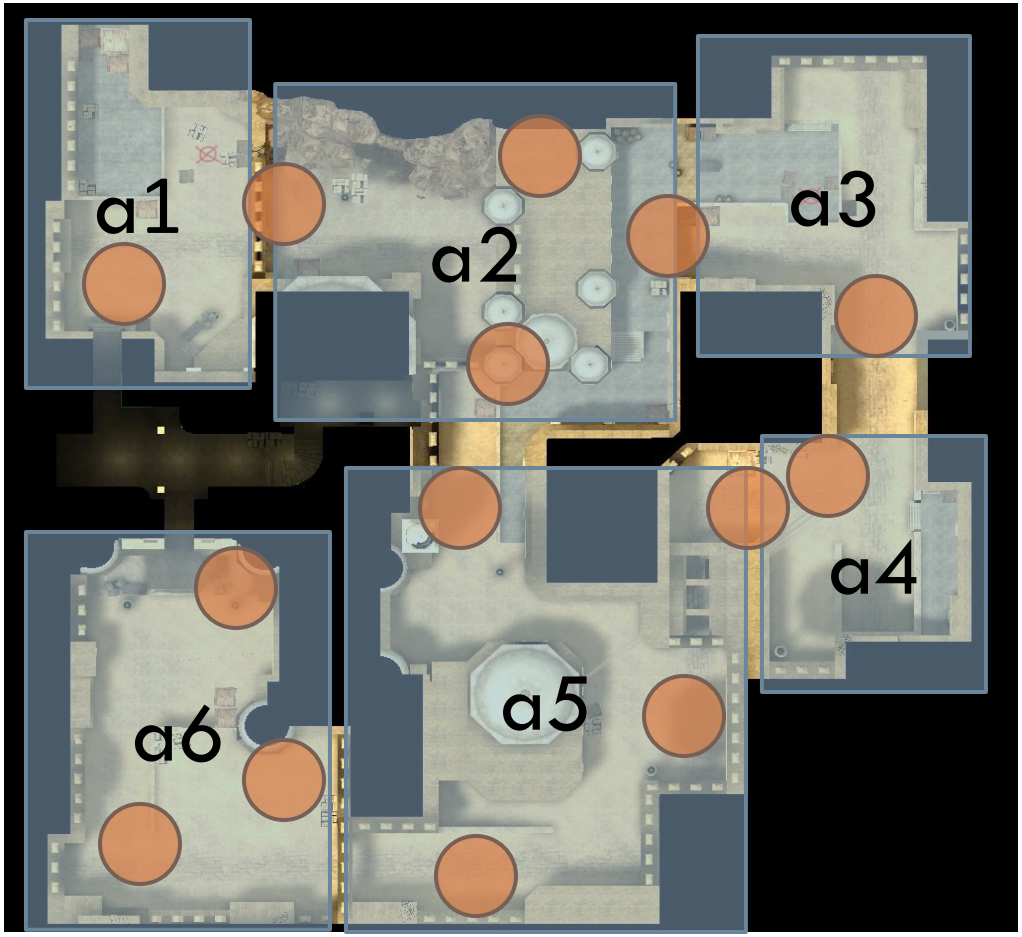
- For each area a number of POIs are listed along with their properties:
  - knife
  - med-kit
  - control-box
  - night-vision-gun
  - …

SimpleFPS domain: predicates

- NPC-related
  - (npc-at ?a)
  - (npc-close-to ?p)
  - (npc-covered)
  - (npc-uncovered)
  - (npc-holding ?o)
  - (npc-injured)
  - (npc-full-health)
  - (npc-aware)
  - (npc-unaware)
- Area-related
  - (area ?a)
  - (conn ?a1 ?a2 ?w)
  - (waypoint ?w)
  - (lighted ?area)
  - (dark ?area)
  - (poi ?p ?a)
  - (control-box ?p)
  - (cover-point ?p)
  - (item ?p)
- Item-related:
  - (med-kit ?m)
  - (knife ?k)
  - (gun ?g)
  - (loaded ?g)
  - (unloaded ?g)
  - (ammo ?i ?g)
  - (night-vision ?g)

SimpleFPS domain: actions

- (: action …)



- Available NPC actions:
  - move-to-area
  - move-to-poi
  - pick-up-item
  - use-item
  - take-cover
  - un-cover

SimpleFPS domain: move-to-point


```
(:action move-to-point
   :parameters (?area ?point)
   :precondition (and
                  (npc-at ?area)
                  (point-of-interest ?point ?area)
   )
   :effect (and
                  (npc-close-to ?point)
   )
)
```

SimpleFPS domain: reload

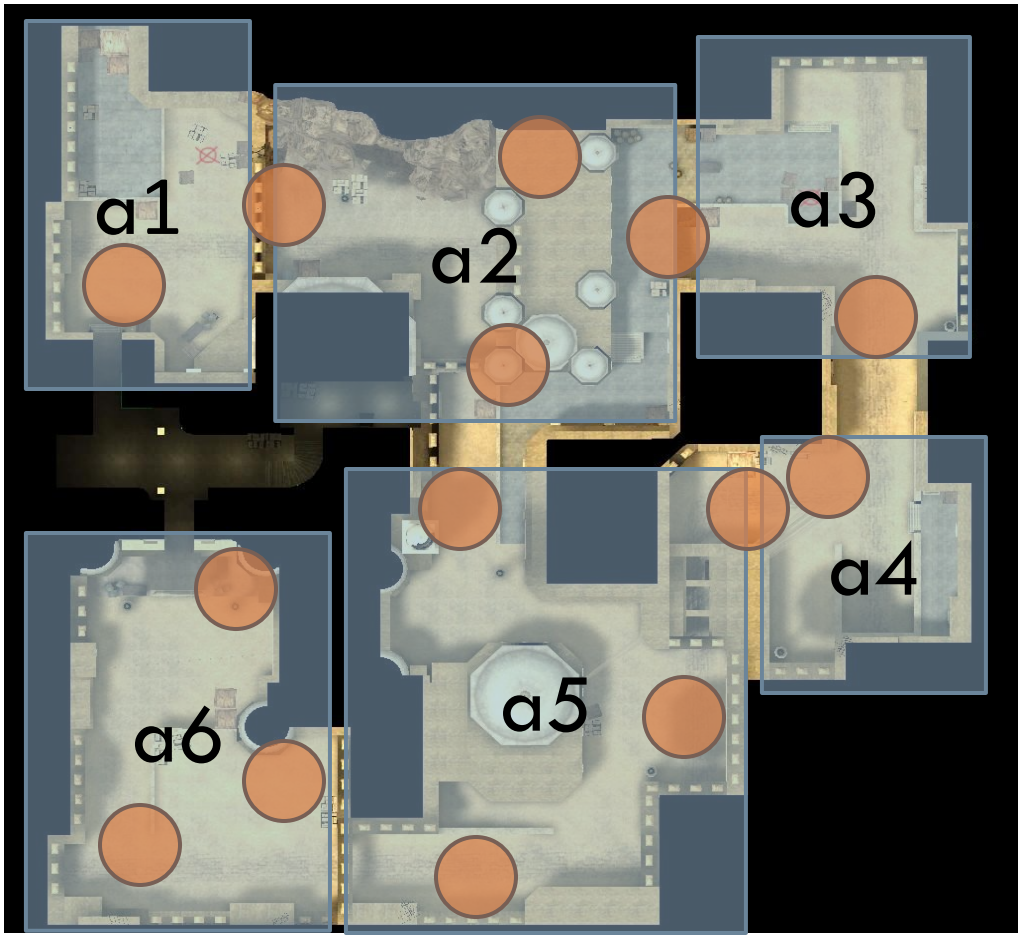

```
(:action reload
   :parameters (?gun ?item)
   :precondition (and
                  (npc-holding ?gun) (gun ?gun) (unloaded ?gun)
                  (npc-holding ?item) (ammo ?item ?gun)
   )
   :effect (and
                  (not (unloaded ?gun))
                  (loaded ?gun)
                  (not (npc-holding ?item))
   )
)
```

The SimpleFPS domain: actions

- Location-related:
  - moving-to-patrol
  - moving-to-take-position
  - move-away-from-point
  - move-to-point
  - move-to-point-from-point
  - make-accessible
  - place-in-inventory
  - turn-on-lights
  - turn-off-lights
- Attack-related:
  - make-contact
  - take-cover
  - uncover
  - use-med-kit
  - reload
  - attack-melee
  - attack-ranged
  - sneak-kill

A SimpleFPS problem instance

- (:goal …)



- NPC goals:
- **g1:** (player-wounded)
- **g2:** (npc-covered)
- **g3:** (npc-full-health)
- **g4:** (and g1 g2 g3)

A SimpleFPS problem instance

- blackbox -o problems\sfps-domain.txt -f problems\sfps-problem1.txt

1. (move-to-point area3 door3-2)
2. (move-to-point area2 control-box2)
3. (turn-on-lights area2 control-box2)
4. (make-contact area2 p)
5. (move-to-point-from-point area2 knife2 control-box2)
6. (place-in-inventory area2 knife2)
7. (move-to-point area2 p)
8. (attack-melee area2 knife2 p)
9. (move-to-point-from-point area2 door2-0 p)
10. (moving-to-take-position area2 area0 door2-0)
11. (move-to-point area0 coverpoint1)
12. (take-cover area0 coverpoint1)

SimpleFPS problem generator

SimpleFPS problem generator

- Takes as input:
  - -a number of areas,
  - -c the probability that two areas are connected
  - -n total number of points of interest
  - -g the goal condition as one of g1, g2, g3, g4
  - -l the number of instances to be generated
- Generates problem instances also using some rules:
  - Card-keys are added for locked doors
  - Ammo is added for guns that are unloaded
  - …

SimpleFPS datasets

- Used the tool to generate 3 datasets:
  - 5 areas
  - 7 areas
  - 10 areas
- For each dataset we generated 10 instances with:
  - 10 items
  - …
  - 100 items
- For each of the 4 goals:
  - g1, g2, g3, g4

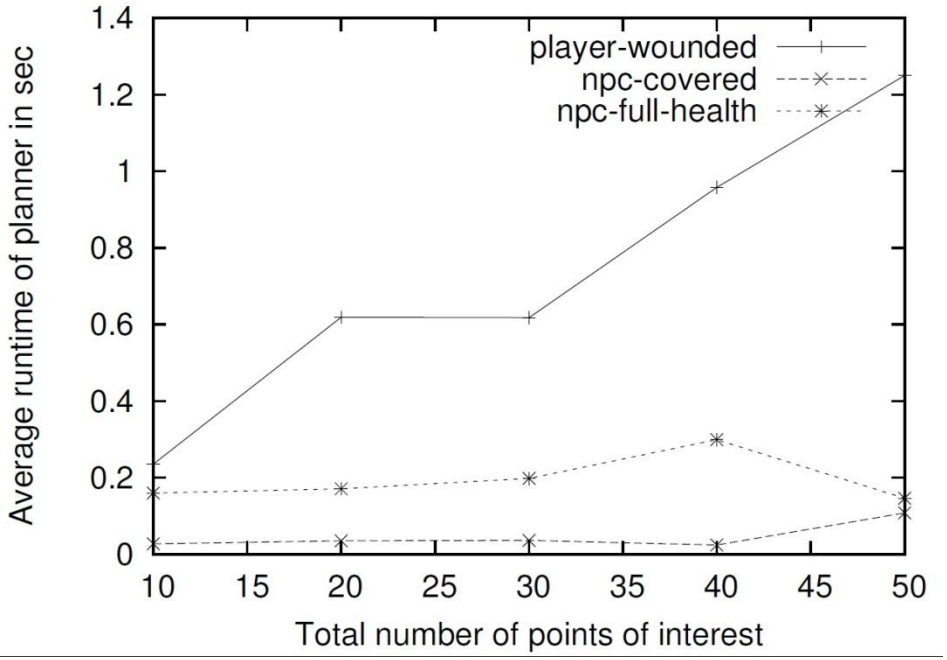
Preliminary results with SimpleFPS

- Used two award-winning planners in these datasets:
  - BlackBox [Kauts, Selman 1999]
  - FastForward [Hoffman 2001]
- Run the planners on an average laptop
  - 1.4 GHz
  - 2 GB RAM

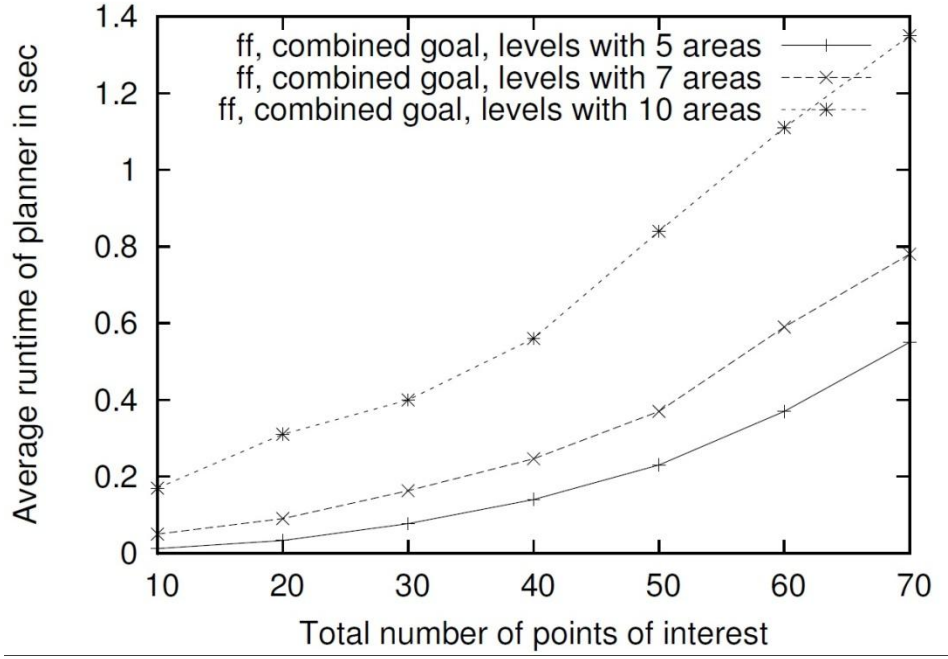
Preliminary results with SimpleFPS

- BlackBox, FastForward
  - Problems planners always return an answer within 1.5sec

BB: up to 5 areas/50 POIs



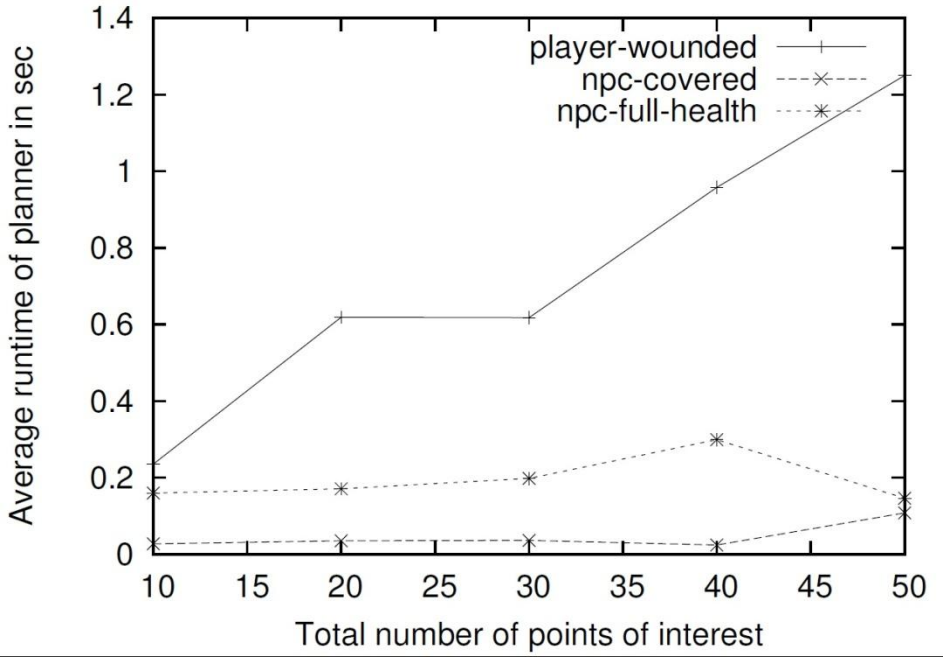
FF: up to 10 areas/70 POIs



Preliminary results with SimpleFPS

Different planning techniques make a lot of difference

BB: up to 5 areas/50 POIs



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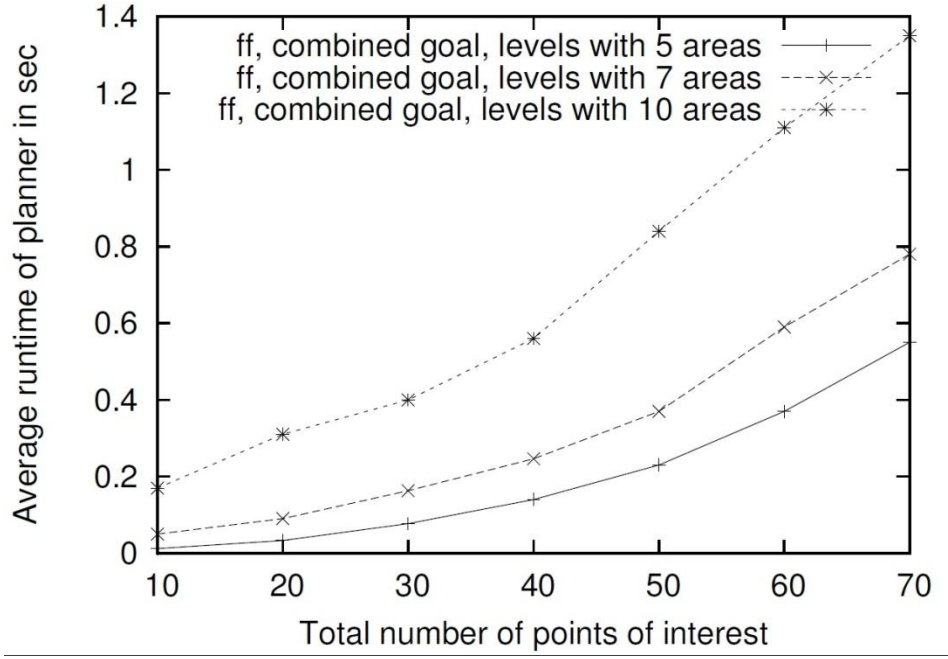
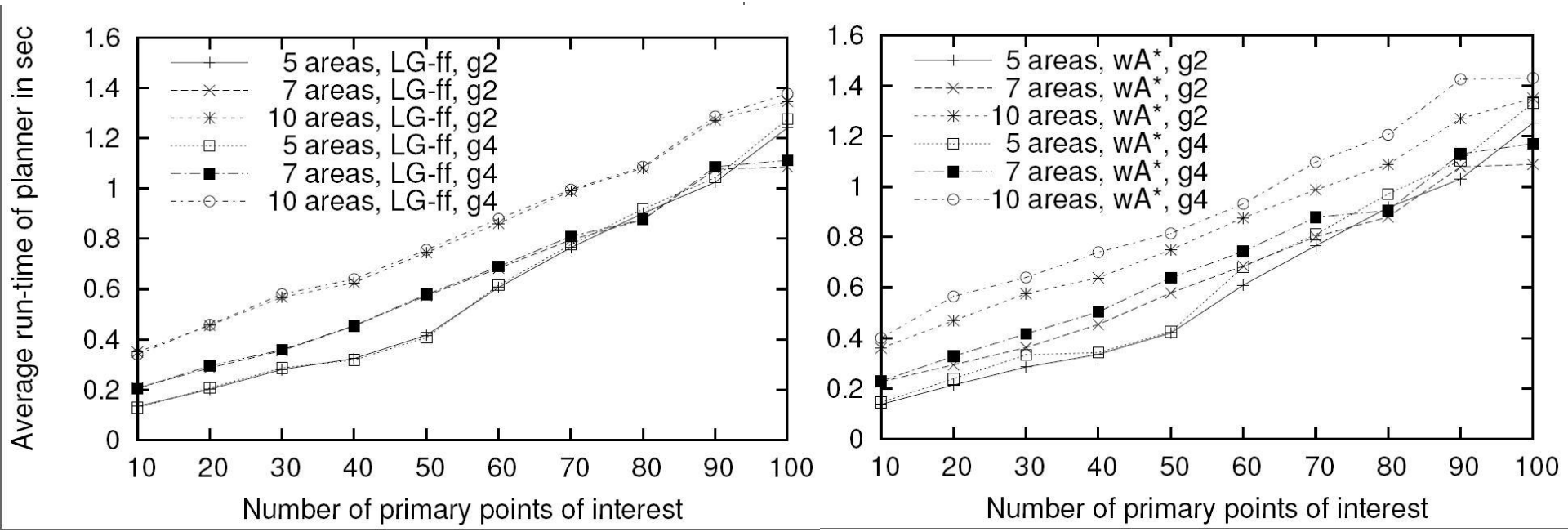


Preliminary results with SimpleFPS

- Investigate further the available heuristics for progression planning using FastDownward as a framework

Thorough results with SimpleFPS

- Left: best-first search with FF heuristic
- Right: weighted A* search with a combination of FF and landmark cut heuristic
- Average (total) run-time of planner



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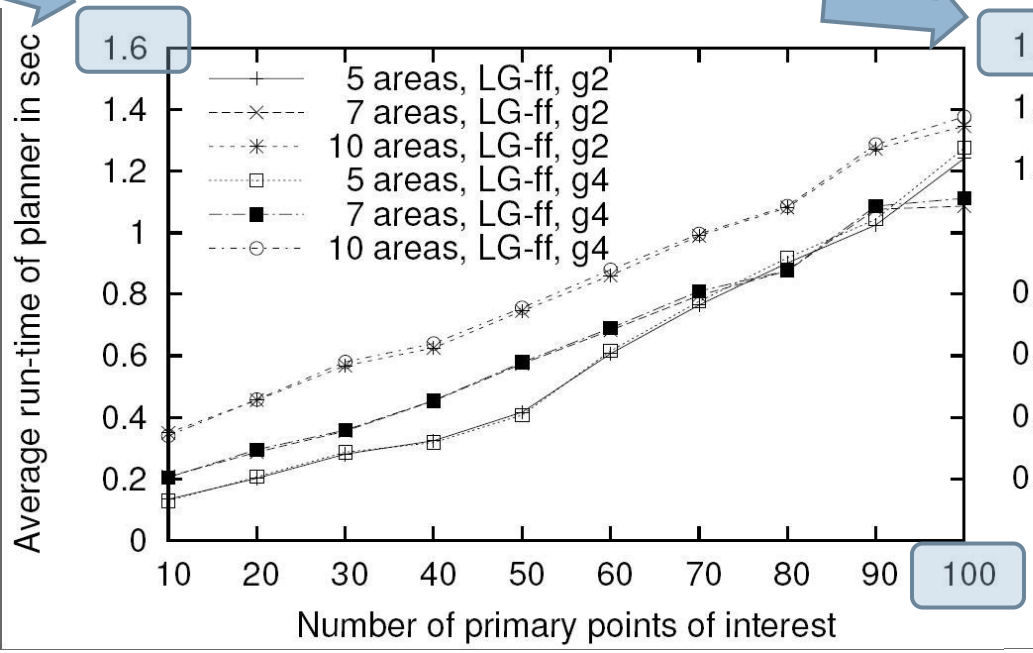

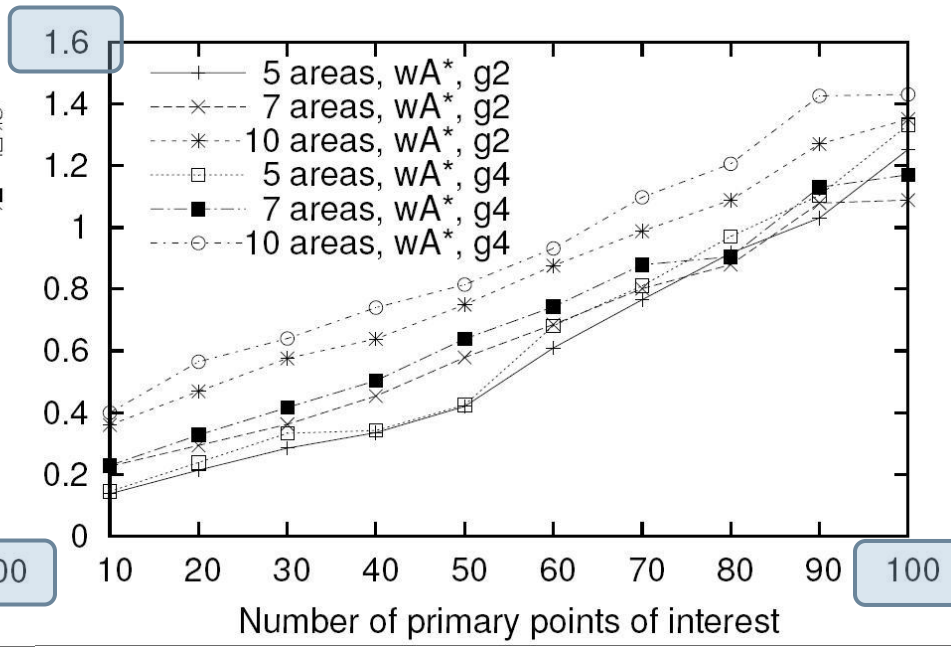

Thorough results with SimpleFPS

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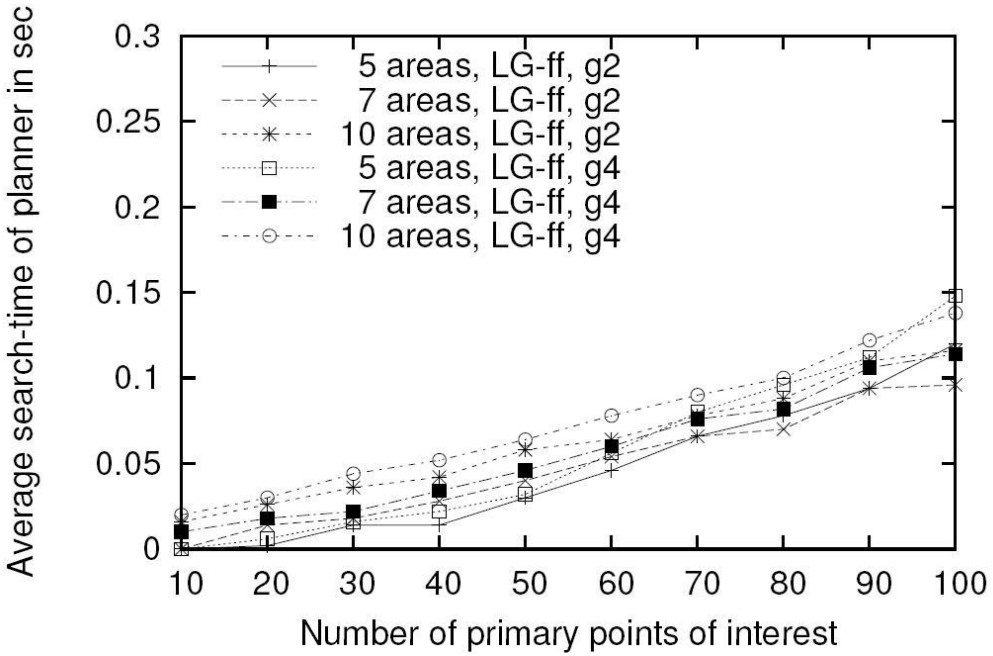
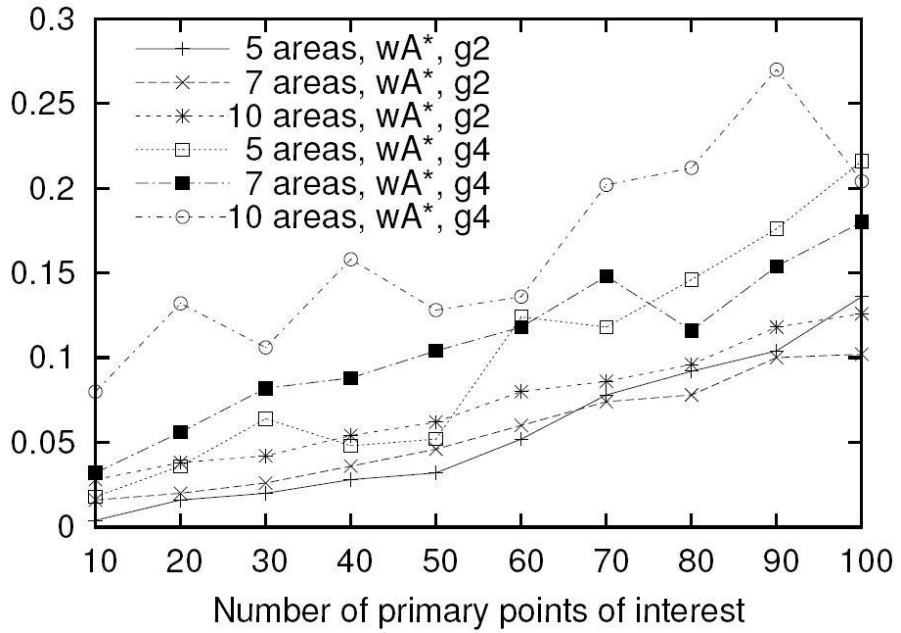
- Average run-time of planner doing search





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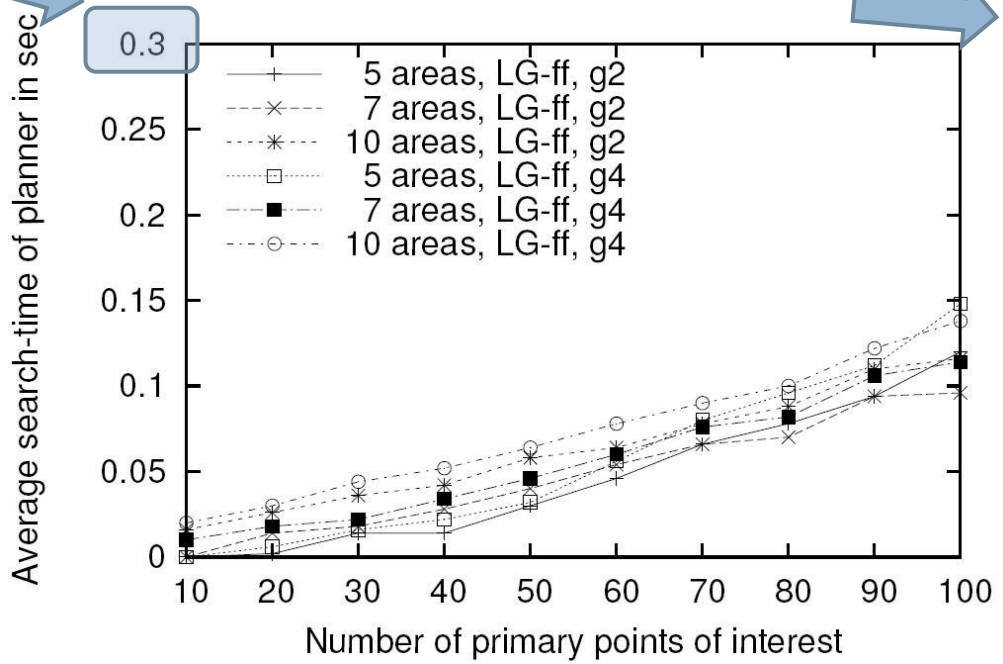

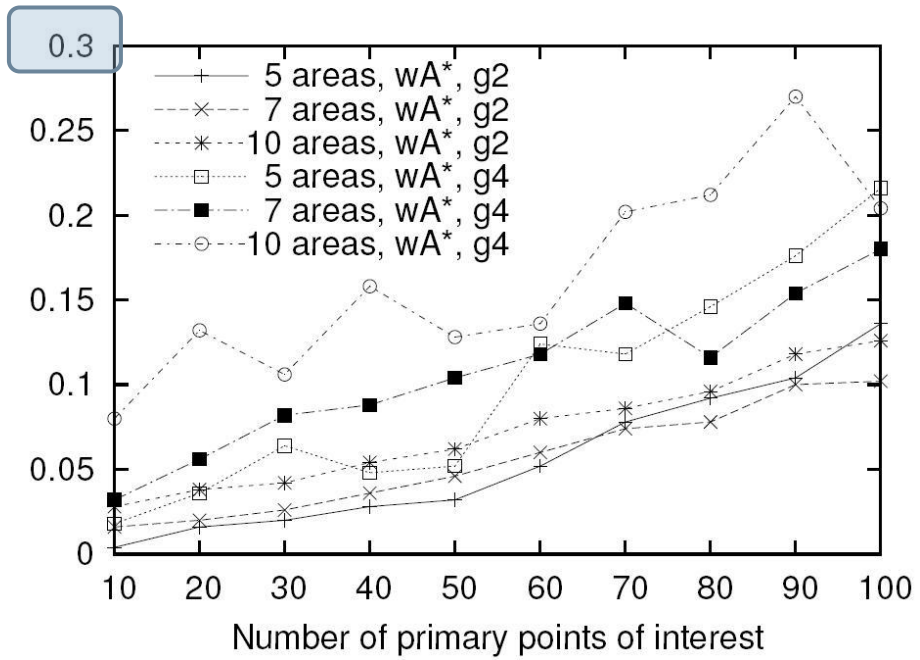

Thorough results with SimpleFPS

- Left: best-first search with FF heuristic
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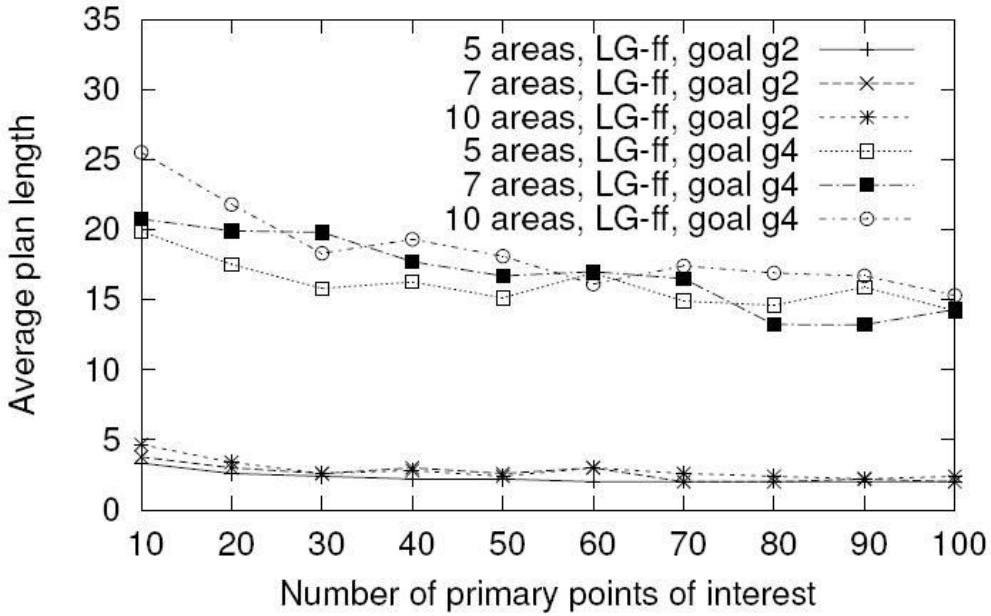
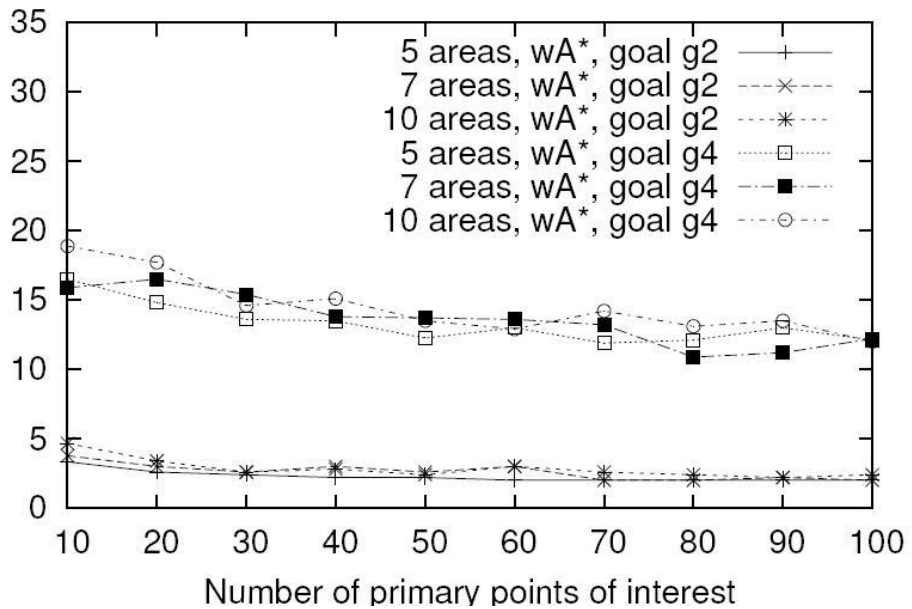
- Average plan length





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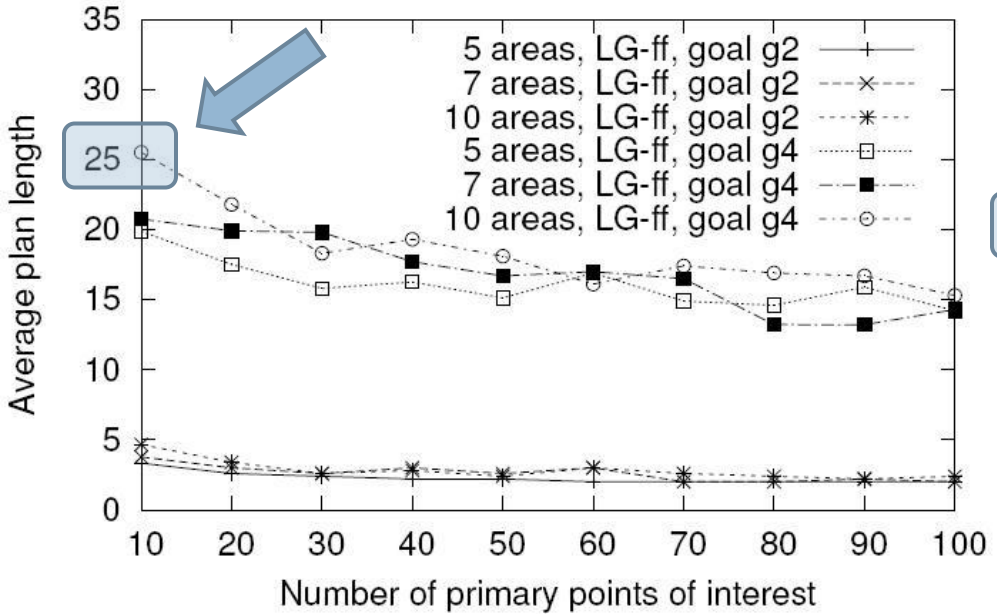

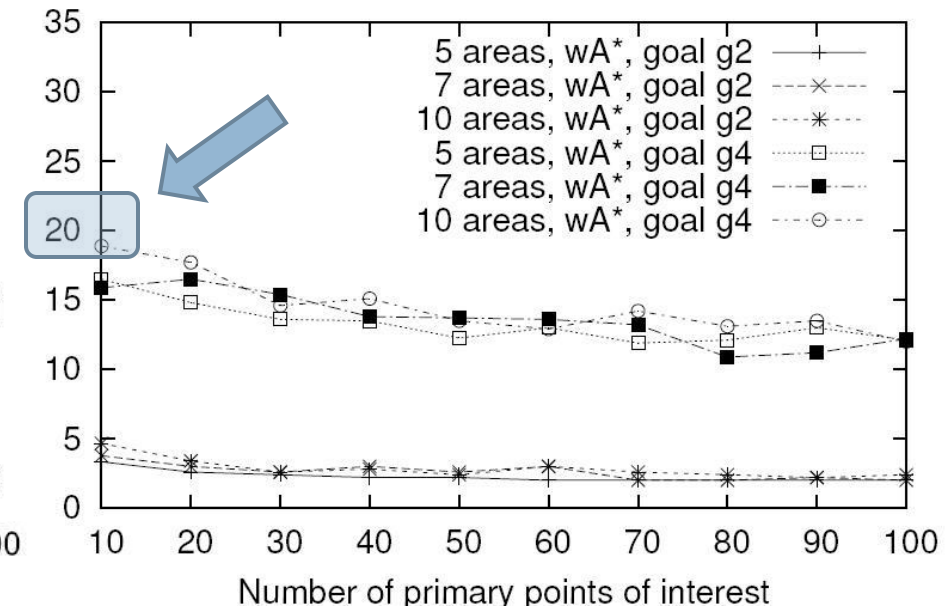

Some conclusions

Some conclusions

- Relatively small-sized problems wrt FPS games:
  - 10 areas/100 POIs
- The planner takes a lot of resources:
  - A lot of **time**: up to 1.4 sec to respond using 100% of the CPU resources of a laptop
  - A lot of **memory**: up to 6.5MB for each problem

Some conclusions

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  - A lot of **time**: up to 1.4 sec to respond using 100% of the CPU resources of a laptop
  - A lot of **memory**: up to 6.5MB for each problem
- **Different assumptions in academia and FPS games**

Some conclusions

- There is a lot of room for improvement
- Take advantage of pre-processing
  - 6.5 MBs is too much for 1 character but how about 100?
  - Maintain the pre-processed state and update instead of re-computing it each time
- Guide the search method
  - The Golog family of languages

Bibliography

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