TECHNISCHE UNIVERSITÄT DRESDEN

Department of Computer Science, Software Technology Group

A Role-based Language for Collaborative Robot Applications

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17.10.2011

ISoLA SARS 2011, Vienna, Austria

Introduction

- Software Technology Group @ Technische Universität Dresden, Germany
- 14 PhDs + 3 PostDocs

- Expertise in
  - Component-based Software Development
  - (Domain Specific) Language Engineering
  - Software Composition
  - Model-driven Software Development
  - Business Process Modeling, Workflows

- Recently started research in robotic software
  - Project QualiTune (3 PhDs) [www.qualitune.org]
  - Focus on Multi-Quality Self-Optimizing Cyber-Physical Systems

Motivation

- Robots will become affordable for all-day applications:
  - Home entertainment
  - Fabrication
  - …

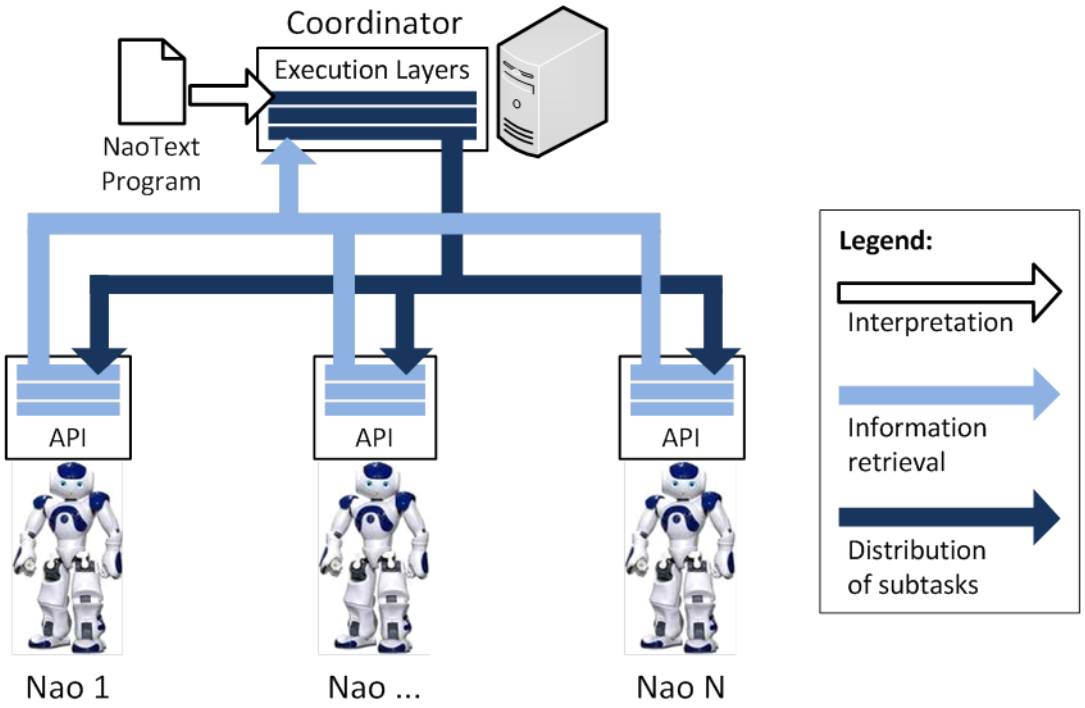
- Many applications will
  - involve *multiple robots*
  - solving *complex tasks*
  - in *collaborative teams.*

- **But** such collaborative tasks are hard to specify.
  - GPLs like C/C++ or Java.
  - DSLs like VPL, Choregraphe or LabView.

    ➔ All lack collaborations as first-class entities.

Motivation

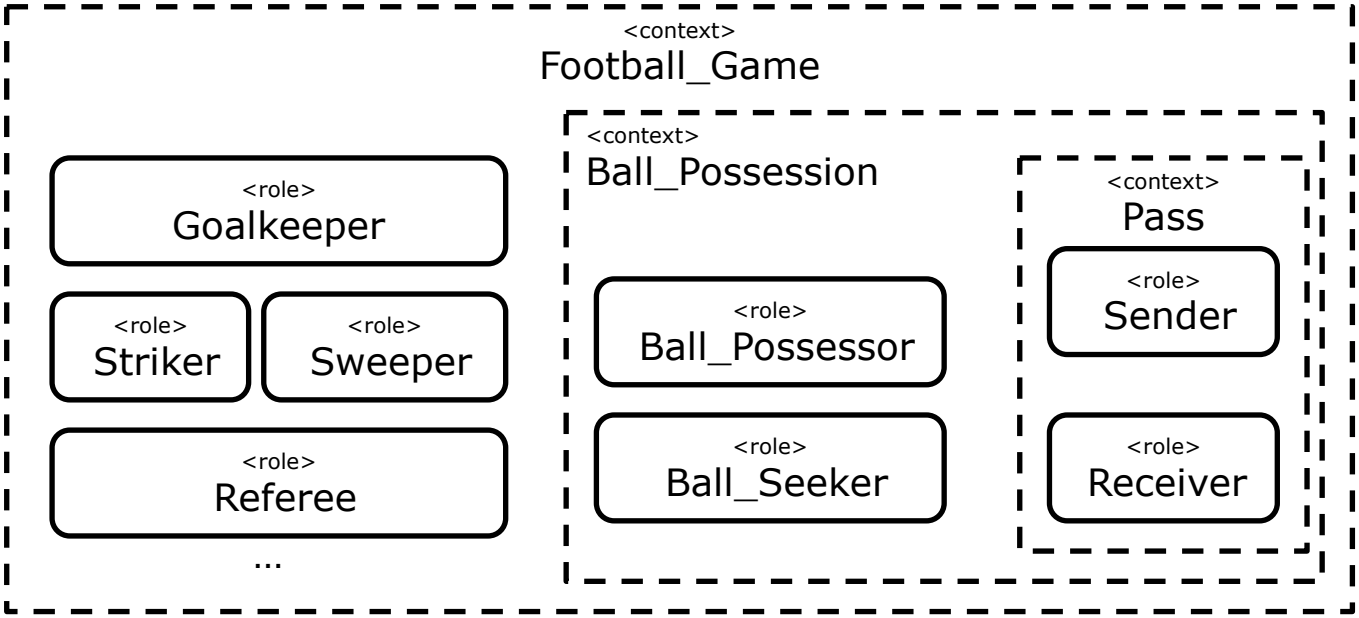
- Requirements for a better language:
  1. Collaborations as first-class entities in programming
  2. Flexible and light-weight communication infrastructure



Communication Architecture

- SOA based on Representational state transfer (REST)

Example



- RoboCup robot soccer as well-known testbed
- A lot of situation-/context-dependent behavior

Example

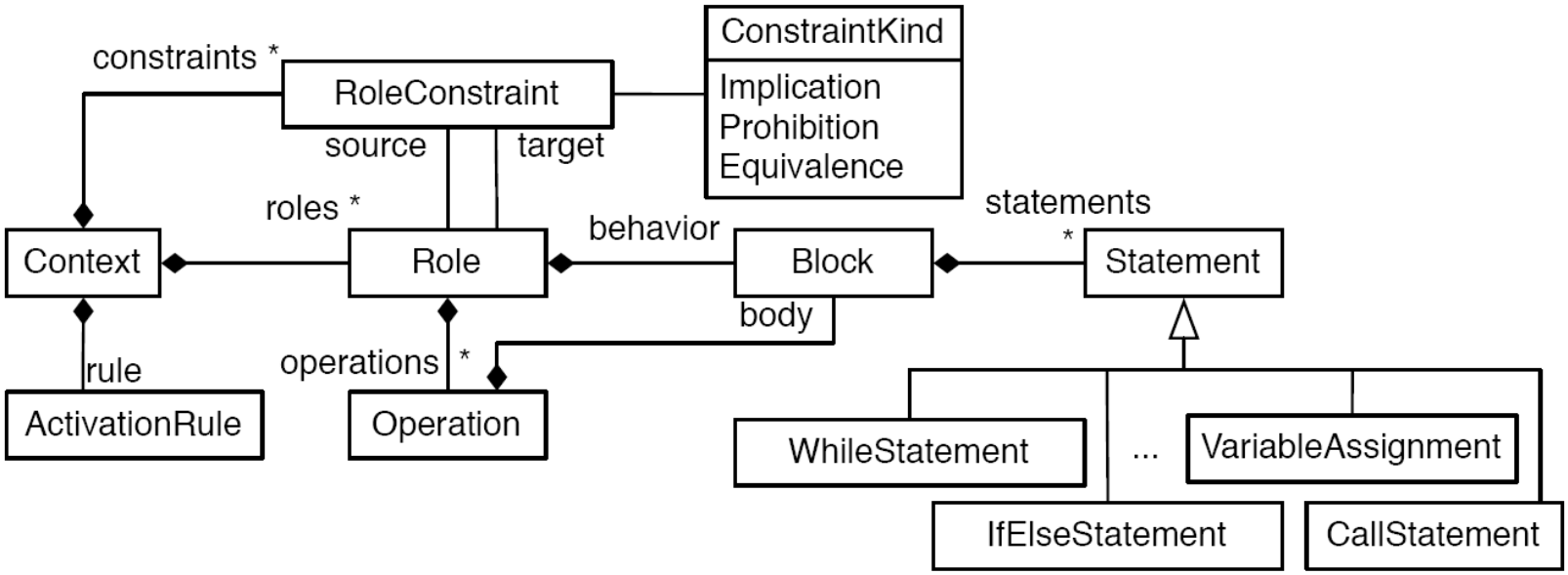
- Scattering and tangling code impairs programmability and maintainability

```
1  if (GOALKEEPER) {
2    if (BALL_POSSESSION) {
3      if(SENDER) { throw_ball: nearest_free_player: this; }
4      else if(RECEIVER) {...}
5    }
6    else {...}
7  }
8  else {
9    if(BALL_POSSESSION) { /* replicated if structure */
10     if(SENDER) { shoot_ball: nearest_free_player: this; }
11     else if(RECEIVER) {...}
12   }
13    else {...}
14   ...
15 }
```

➔ Collaborations as first-class programming constructs!

Excerpt of Metamodel for the role-based NaoText DSL.

- Contexts describe collaborations.



```
1  context Ball_Possession {
2    role BallSeeker { ... }
3    role BallPossessor {...}
4
5    context Pass {
6      Sender prohibits Receiver;
7
8      activate for {
9         BallPossessor p;
10        BallSeeker s;
11     } when {
12        (p.robotInVision: s) and not (p as Striker).isGoalShotPossible;
13     } with bindings {
14        p -> Sender;
15        s -> Receiver;
16     }
17     ... //role definitions on next slide
18   }
```

Role Constraint

Activation Rule

NaoText

```
1  role Sender {
2    attr passRatio: float;
3    behavior {
4      if(ballCatchableByOpponent) {
5        feintShoot;
6        randomWalkWithBall;
7      } else {
8        boolean hit = shootBall;
9        updatePassRatio: hit;
10     }
11   }
12   void updatePassRatio hit:boolean {...}
13 }
14
15 role Receiver {
16   behavior {
17     waitForBallInVision;
18     catchBall;
19   }
20 }
```

Role Attribute

Role Behavior

Role Operation

Related Work

Related work is discussed w.r.t.:

(1) Communication Aspects

(2) Language Aspects

(3) Roles for Collaborative Robot Applications

Communication Aspects

- Many approaches use **CORBA or SOAP**
  - Requires additional communication middleware
- We (and others) use a **REST-ful SOA**
  - No middleware required
- Chen et al. introduced the term **RaaS** – Robot as a Service
  - Showed that robots can be used in the cloud as a SOA unit
- Arumugam et al. developed the **DAvinCi** cloud compute framework for collaborating service robots
- **Google ROS** for peer-to-peer and SOA-like communication

Language Aspects

- DSLs for robot applications have been used by Baer and Reichle (amongst others) in the **Spica MDSD Framework**
  - No first-class collaborations

- **Choregraphe** by Aldebaran is a graphical DSL
  - Does not scale (i.e., large projects are very hard to handle)
  - No first-class collaborations

- **Microsoft's VPL** is a DSL, too
  - Comparable to Choregraphe
  - No first-class collaborations

Roles for Collaborative Robot Applications

- Chaimowicz et al. **showed the applicability of roles** for this kind of applications
  - But, roles are used like states of the robots
  - Robots cannot play multiple roles simultaneously (e.g., Goalkeeper and Sender)
  - They use finite state automatons for each robot
  - → state explosion for multiple, simultaneous roles (state combinations)

- Schultz et al. applied roles for the **ATRON self-reconfigurable robot**
  - Focus on the collaboration of a single robots modules

Current Status

- Communication infrastructure has been implemented
  - http://code.google.com/p/naoservice/
- NaoText is under development
  - Syntax finished
  - Interpreter is currently under development

Future Work

- **Static analyzers** to ensure functional and non-functional properties
- **Test** Framework
- Realization of role-dispatch by **predicate dispatch** using Predicate-C [1]
- Support for **further platforms**

[1] Friedrich Gräter, Sebastian Götz and Julian Stecklina. **Predicate-C - An Efficient and Generic Runtime System for Predicate Dispatch.** To appear in Proceedings of the 6th Workshop on the Implementation, Compilation, Optimization of Object-Oriented Languages, Programs and Systems (ICOOOLPS 2011)

Conclusion

- **REST-ful** SOA as communication architecture

- A DSL with **first-class collaborations** incl. the notion of
  - Contexts,
  - Roles,
  - Role constraints and
  - Activation rules

- These concepts allow for **more concise specifications** of complex, collaborative robot applications
  - Improved programmability
  - Better maintainability

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Thank You!

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17.10.2011