Towards Lifelong Learning of Optimal Control for Kinematically Complex Robots
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Outline

- Introduction
- Behavior Library
- Online Behavior Selection
- Proof of Concept
- Conclusion and Outlook
Kinematically-complex robots shall autonomously adapt their control layer to the current context to improve their performance.
Control Architecture

- Supporting activation, parameterization, and different topologies of behaviors
- Robot-independent interface to higher layers
  - Transferability to other systems
  - Handling of variable inputs and outputs
- Supporting complex problems (high number of inputs / outputs and mutual dependencies)
Behavior Library

Behavior Library (Case Bases)

Context Generator

Task

State

Configuration Producer (Case-based Reasoner)

Introduction

Behavior Library

Behavior Selection

Proof of Concept

Conclusion & Outlook
Online Behavior Selection with CBR

CaseLoco1(ConfigurationE, StateX, PerformanceB)
CaseLoco2(ConfigurationF, StateY, PerformanceC)
...

value
weight

SpeedX
SpeedY
TurnRate
Energy Eff.
Power
Stability
MaxHeight
MaxWidth

SlopeX
SlopeY
ObstacleSize
Roughness
SoilType
Load

Case-Based Reasoning

Task
Configuration
Performance
Evaluation

Locomotion Layer
CBR Processing Steps

- Determine the relevance of cases according to the input query and select the best subset of cases
  - Product of the weighted mean square error of both feature vectors
- Generate one solution out of the K Nearest Neighbors
- Adapt to improve outcome
- Criticize solution to avoid past mistakes
- Measure performance
- Update stored performance or store new solution
  - Increases accuracy
  - Increases competence

Derived from [Kolodner1992]
Proof of Concept

- Traversing an obstacle of a height of 20 cm
  - 2 locomotion patterns available
    - Pattern for obstacles (slow, less stable)
    - Pattern for flat plane (stable, energy efficient)
      » Not capable of traversing the obstacle
Integration of externally generated knowledge

- Generation of optimized behaviors for flat plane and 20 cm obstacles
  - Energy per distance as fitness value for CMA-ES parameter optimization
    - Body shifted to front, much longer touchdown phase, reflex sensitivity tuning
  - Storage of these new patterns and their evaluations in behavior library
- Were automatically selected when repeating the experiments

- More energy efficient due to less slippage
Experimente
Conclusion and Outlook

• Introduced context layer which configures control layer autonomously

• Generation of behavior library to store robot configurations and their performance in diverse contexts

• Case-Based Reasoning for behavior selection
  ▪ Robot-independent interface
  ▪ Integration of externally generated knowledge

• Outlook
  ▪ Online performance evaluation
  ▪ Generation of new solutions through case adaptation
  ▪ Experiments in more complex scenarios
References

- **[Manz2013]** Manz, M. Bartsch, S. Kirchner, F. (2013). *MANTIS – A Robot witch Advanced Locomotion and Manipulation Abilities*. Symposium on Advanced Space Technologies in Automation and robotics
Thank you!

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