# Knowledge-Aware

Cyber-Physical Systems

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- Fundamental safety question for ground robot navigation
- When will which control decision avoid obstacles?
- Depends on safety objective, physical capabilities, knowledge

| Pass parking | Avoid/Follow | Head-on | Turn |
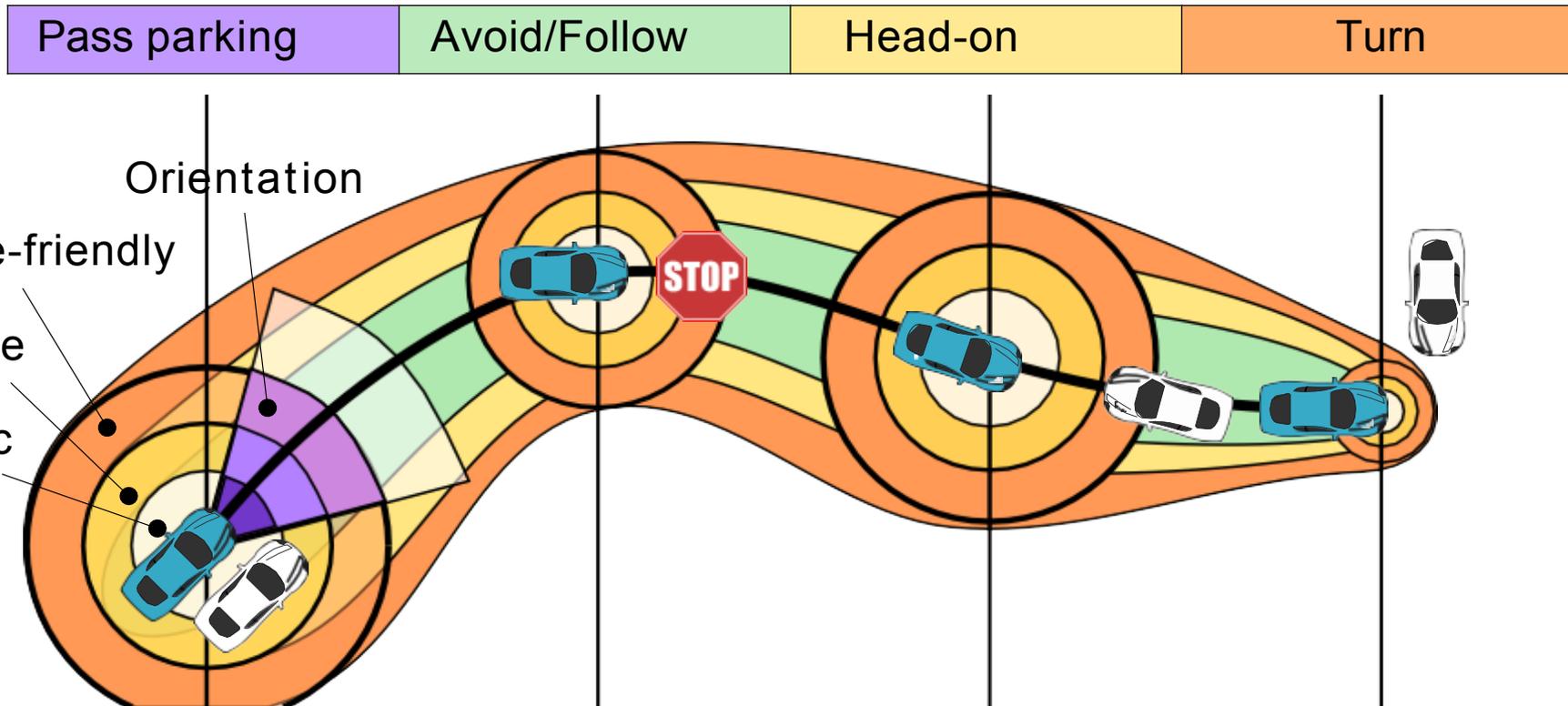
- Identified safe region for each safety notion symbolically
- Proved safety for hybrid systems ground robot model in KeYmaera X

André Platzer.
Logical Foundations of Cyber-Physical Systems
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www.lfcps.org/lfcps/

Logical Foundations of Cyber-Physical Systems

Springer

André Platzer [Carnegie Mellon University]

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Overview

Cyber-physical systems (CPSs) combine cyber capabilities, such as computation or communication, with physical capabilities, such as motion or other physical processes. Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms is challenging due to their tight coupling with physical behavior, while it is vital that these algorithms be correct because we rely on them for safety-critical tasks. This textbook teaches undergraduate students the core principles behind CPSs. It shows them how to develop models and controls; identify safety specifications and critical properties; understand abstraction and system architectures; design by invariant; reason rigorously about CPS models; verify CPS models of appropriate scale; and develop an intuition for operational effects.

Part I – Elementary Cyber-Physical Systems
    Differential Equations and Domains
    Choice and Control
    Safety and Contracts
    Dynamical Systems and Dynamic Axioms
    Truth and Proof
    Control Loops and Invariants
    Events and Responses
    Reactions and Delays
Part II – Differential Equations Analysis
    Differential Equations and Differential Invariants
    Differential Equations and Proofs
    Ghosts and Differential Ghosts
    Differential Invariants and Proof Theory
Part III – Adversarial Cyber-Physical Systems
    Hybrid Systems and Games
    Winning Strategies and Regions
    Winning and Proving Hybrid Games
    Game Proofs and Separations
Part IV – Comprehensive CPS Correctness
    Axioms and Uniform Substitutions
    Verified Models and Verified Runtime Validation
    Virtual Substitution and Real Equations
    Virtual Substitution and Real Arithmetic
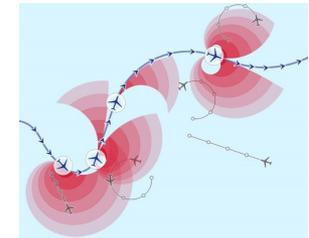
Comments

"This excellent textbook marries design and analysis of cyber-physical systems with a logical and computational way of thinking. The presentation is exemplary for finding the right balance between rigorous mathematical formalization and illustrative case studies rooted in practical problems in system design."
[Rajeev Alur, University of Pennsylvania]

"[The author] has developed major important tools for the design and control of those cyber-physical systems that increasingly shape our lives. This book is a 'must' for computer scientists, engineers, and mathematicians designing cyber-physical systems."
[Anil Nerode, Cornell University]

"This book provides a wonderful introduction to cyber-physical systems, covering fundamental concepts from computer science and control theory from the perspective of formal logic. The theory is brought to life through many didactic examples, illustrations, and exercises. A wealth of background material is provided in the text and in an appendix for each chapter, which makes the book self-contained and accessible to university students of all levels."
[Goran Frehse, Université Grenoble Alpes]

"As computing interfaces increasingly with our physical world, resulting in so-called cyber physical systems, our foundations of computing need to be enriched with suitable physical models. This book strikes a wonderful balance between rigorous foundations for this next era of computing with illustrative examples and applications that drive the developed methods and tools. A must read book for anyone interested in the development of a modern and computational system science for cyber-physical systems."
[George Pappas, University of Pennsylvania]