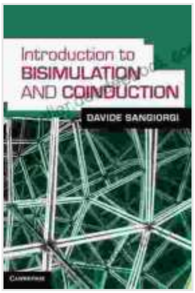
Introduction to Bisimulation and Coinduction



Introduction to Bisimulation and Coinduction

by Davide Sangiorgi

5 out of 5

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Abstract

Bisimulation and coinduction are two powerful formal verification techniques used to prove the equivalence or refinement of systems. This article provides a comprehensive to these methods, covering their fundamental concepts, practical applications, and advanced techniques. We begin by introducing the basic definitions and properties of bisimulation and coinduction. We then discuss their applications in formal verification, including equivalence checking, model checking, program analysis, and concurrency theory. Finally, we explore advanced techniques such as modal bisimulation, probabilistic bisimulation, and infinitary bisimulation, which extend the scope and applicability of these methods.

to Bisimulation

Bisimulation is a relation between two systems that ensures that they exhibit equivalent behavior. Informally, two systems are bisimilar if an observer cannot distinguish between them by observing their external behavior. Formally, bisimulation is defined as a relation R between the states of two systems such that:

1. **Preservation**: For all states s and t in R, if s can transition to state s', then there exists a state t' such that t can transition to t' and $s' \; R \; t'$.
2. **Reflection**: For all states s and t in R, if t can transition to state t', then there exists a state s' such that s can transition to s' and $s' \; R \; t'$.

Bisimulation has several important properties, including:

- **Symmetry**: R is symmetric, i.e., if $s \; R \; t$, then $t \; R \; s$.
- **Transitivity**: R is transitive, i.e., if $s \; R \; t$ and $t \; R \; u$, then $s \; R \; u$.
- **Equivalence**: Two systems are bisimilar if and only if there exists a bisimulation relation between them.

to Coinduction

Coinduction is a technique used to prove the equivalence or refinement of systems that exhibit infinite behavior. Unlike bisimulation, which focuses on matching individual steps of execution, coinduction considers the overall behavior of systems over time. Informally, two systems are coinductive if they evolve in a similar manner, even if their individual steps may differ.

Formally, coinduction is defined as a relation R between the states of two systems such that:

1. **Co-Preservation**: For all states s and t in R, if s can transition to a set of states S, then there exists a set of states T such that t can transition to T and $S \; R \; T$.

2. **Co-Reflection**: For all states s and t in R, if t can transition to a set of states T, then there exists a set of states S such that s can transition to S and $S\ R\ T$.

Coinduction has several important properties, including:

- **Symmetry**: R is symmetric, i.e., if $s\ R\ t$, then $t\ R\ s$.
- **Transitivity**: R is transitive, i.e., if $s\ R\ t$ and $t\ R\ u$, then $s\ R\ u$.
- **Equivalence**: Two systems are coinductive if and only if there exists a coinduction relation between them.

Applications of Bisimulation and Coinduction

Bisimulation and coinduction are widely used in formal verification for a variety of applications,

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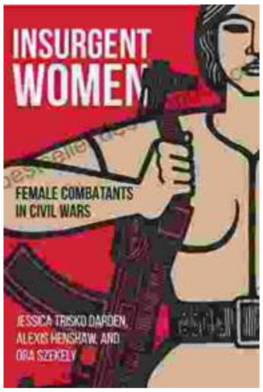

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