# 1. System Verification: Introduction

José Proença

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CISTER – U.Porto, Porto, Portugal

https://fm-dcc.github.io/sv2425


# What are Formal Methods?

# What are formal methods?

Formal methods are techniques to model complex systems using rigorous mathematical models

**Specification**

Define part of the system using a modelling language

**Verification**

Prove properties.
Show correctness.
Find bugs.

**Implementation**

Generate correct code.

All formal models are wrong

All formal models are wrong

... but some of them are usefull!

# Program verification vs. System verification

## Program verification

- software (code)
- $+$ annotations (logic)
- $+$ some user interaction
- $=$ correctness proof

# Program verification vs. System verification

## Program verification

- software (code)
- + annotations (logic)
- + some user interaction
- = correctness proof

## SYSTEM verification

- system specification (model)
- + system requirements (logic)
- + some user interaction
- + fixing parameters/scenarios
- = correctness proof

In this course: we will focus on model-checking

# Contents of the module

# Syllabus

- Introduction to model-checking
- CCS: a simple language for concurrency
  - Syntax
  - Semantics
  - Equivalence
  - mCRL2: modelling
- Dynamic logic
  - Syntax
  - Semantics
  - Relation with equivalence
  - mCRL2: verification
- Timed Automata
  - Syntax
  - Semantics (composition, Zeno)
  - Equivalence
  - UPPAAL: modelling
- Temporal logics (LTL/CTL)
  - Syntax
  - Semantics
  - UPPAAL: verification
- Probabilistic and stochastic systems
  - Going probabilistic
  - UPPAAL: monte-carlo

# Logistics

# Useful information

Relevant class material and announcements will be posted on the website periodically

`https://fm-dcc.github.io/sv2425`

E-mail

- jose.proenca@fc.up.pt

Office hours (please send an email the day before if you wish to meet):

- *José Proença:* Thursday morning

# Assessment

Assessment will consist of

- 60% – an individual test at the end (*época normal*);
- 40% – a group assignment with 2 parts involving the use of the mCRL2 and the Uppaal model checkers; and
- 100% – Final (optional) exam during the extra period (*época de recurso*).

# What is model-checking?

# What is model-checking?

Check Requirements of a Model

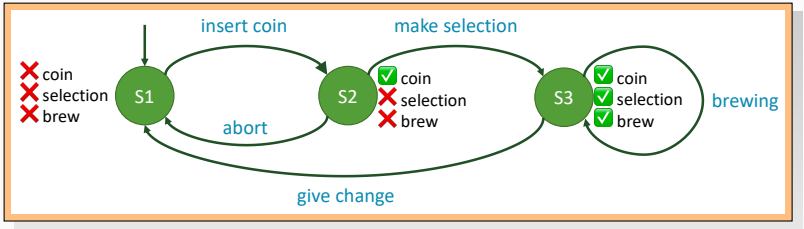
using **Formal Methods**

# Example: coffee machine


$$\mathcal{M}, w \models \phi$$

does the model
$\mathcal{M}$
in state
$w$
satisfies the **requirement**
$\phi$

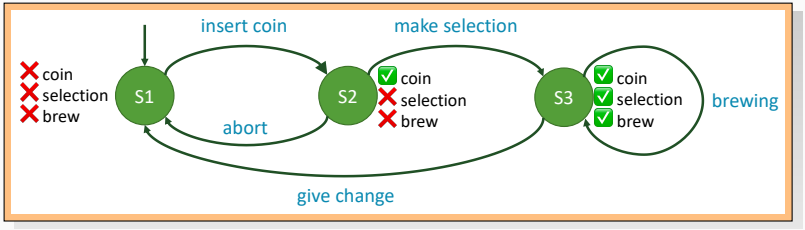
# Example: coffee machine - the MODEL


**Actions** **States** **Propositions**

Just building the model is often a large contribution

# Example: coffee machine - the REQUIREMENTS


$\mathcal{M}, S2 \models \mathit{coin}$

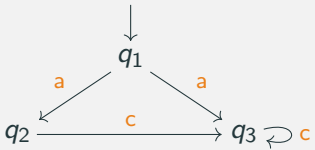
means coin holds in state $S2$

$\mathcal{M}, S1 \models [\mathit{make\ selection}]\ \mathit{selection}$

means selection holds in every state reachable with make selection from $S1$

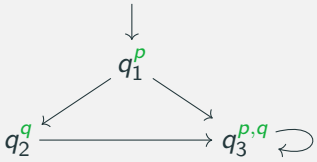
# Actions vs. States

## Focus on events




- desired/forbidden sequences of actions
- Process algebra to generate models
- $\mathcal{M}, q_2 \models [a]\mathit{false}$

## Focus on states




- reachable/forbidden states
- Language/Diagram to generate models
- $\mathcal{M}, q_1 \models p$ , $\mathcal{M}, q_1 \models F\ G\ p$

# Note 1/2: Models and logics are tightly connected

$$\mathcal{M}, q_2 \models [a]\mathit{false}$$

- Models that safisty exactly the same requirements:
  **equivalence** (e.g. bisimulation, trace equivalence)
- Models that satisfy a subset of requirements:
  **inclusion** (e.g. simulation, trace inclusion)
- A model should only capture the necessary to show its requirements.

# Note 2/2: Chose your Model and Logic wisely

$$\mathcal{M}, q_2 \models [a]false$$

- **Real-time:** how long it takes between actions
- **Differential dynamic:** state evolves using differential equations
- **Beliefs:** who knows what
- **Deontic:** obrigatory and permitted actions
- **Fuzzy:** other values instead of truth values
- **Probabilistic:** the odds of something occuring
- *Many tools:* mCRL2, UPPAAL, Spin, NuSMV (NuXMV), TLA+, Maude, Storm, CPN (petri nets)