# Simulation as an experimental design process for emergent systems

**Paul Andrews**[1] Susan Stepney[1] Alan Winfield[2]

[1]Department of Computer Science, University of York
[2]Bristol Robotics Laboratory

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# Overview

- Wish to engineer physically embodied systems (e.g. robotics) with desirable emergent properties
- Unclear how to incorporate emergence into design process
- Propose to co-design emergent systems with a simulation of that system
  - Outline and explore this proposal

# The Problem with Engineering Emergence

- If we knew how to engineer specific emergent properties into systems, we wouldn't be here ...
- Emergent properties not readily deducible
  - We may know the system-wide properties we want
  - Relationship to system components is not obvious
  - Unclear in the general case how to engineer emergence using a conventional design process

# Why Use Simulation?

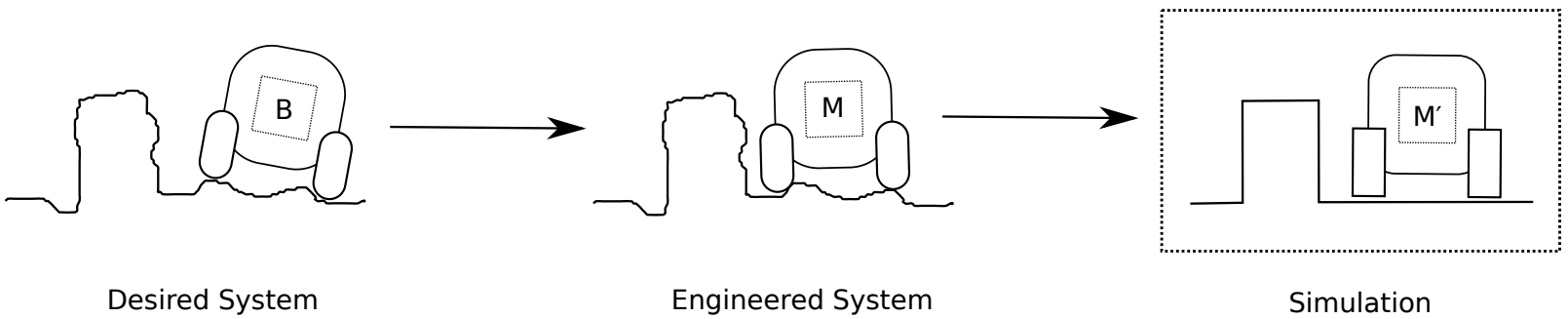
- Simulation is a technique used to aid scientific inquiry
  - Simulations are based on an underlying model
  - Model used to represent system/domain under investigation
  - Simulation explores the model by animating it
- Simulation has many advantages
  - Reduced cost and danger
  - Increased speed and flexibility
  - Overcomes ethical concerns and impossibilities
- Can never replace the richness of the real system where the physics come for free

# A Co-design Proposal

- When engineering emergence, want the advantage of using simulation and the real system
- Co-design emergent engineered system with simulation of that system
  - Simulation as part of the design process
  - Incrementally develop emergent system and simulation in parallel
  - Both explore and develop the emergent property
  - Need to ensure the same emergent property is present in both

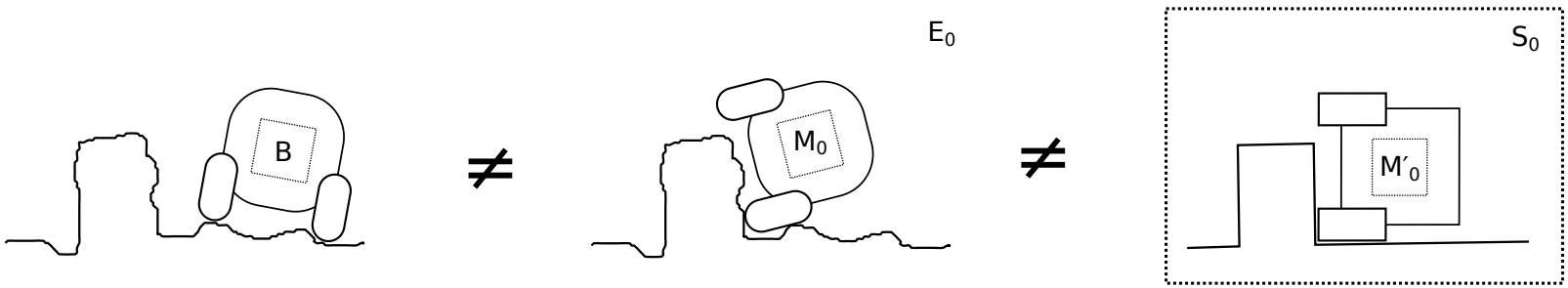
# One Model, Two Implementations

- Consider an example of a robot that we wish to avoid obstacles as an emergent property
- Can view engineered system and simulation as implementing the same model of desired emergent behaviour ($B$)
  - Model implementations ($M$ and $M'$) will differ
  - Aim is to approach $B = M = M'$



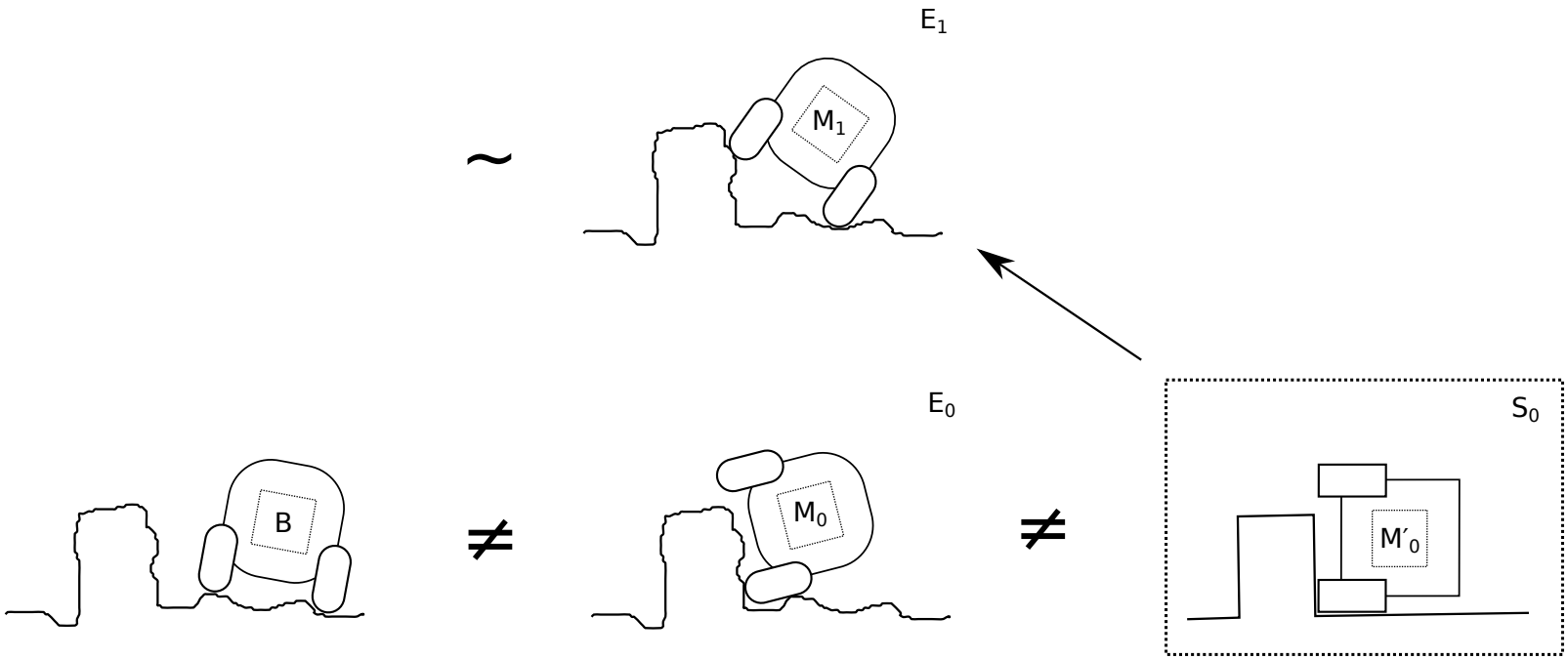
# Co-design Process 1

- We start with a ‘best-guess’ model of the emergent behaviour (in this case obstacle avoidance)
  - Produces a poor implementation and poor simulation of it



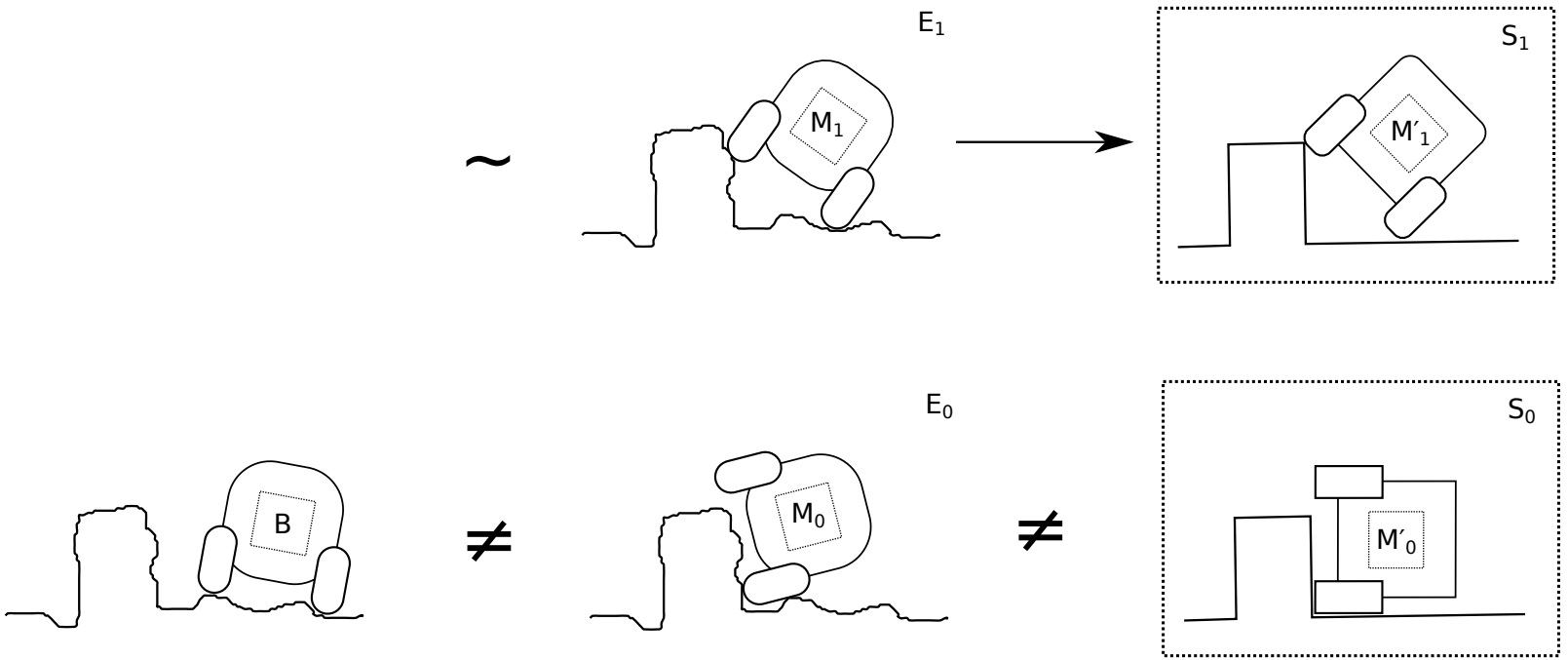
# Co-design Process 2

- Use simulation to explore possible engineered system prototypes



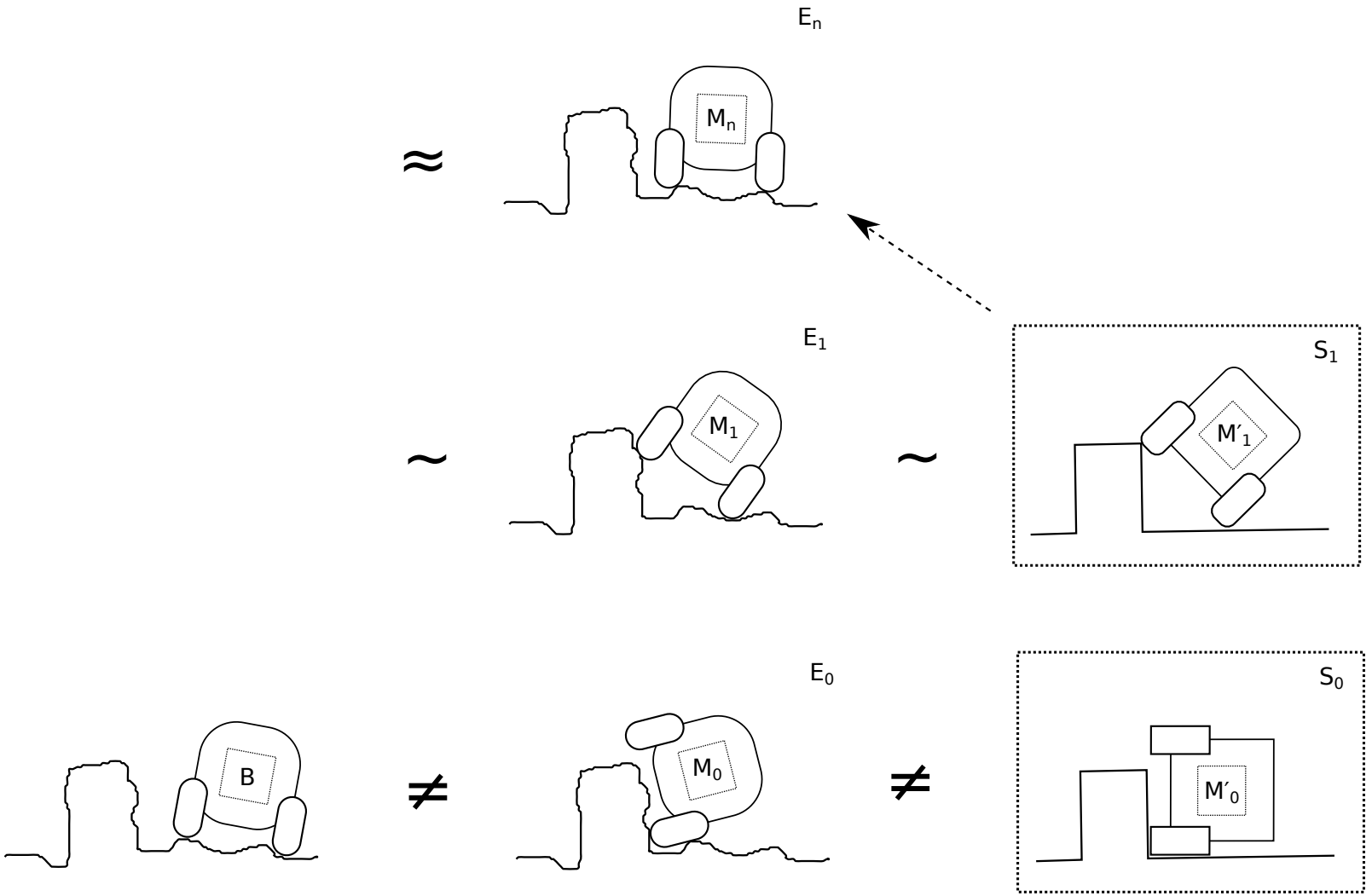
# Co-design Process 3

- Use engineered system to test, validate and update design expressed by simulation



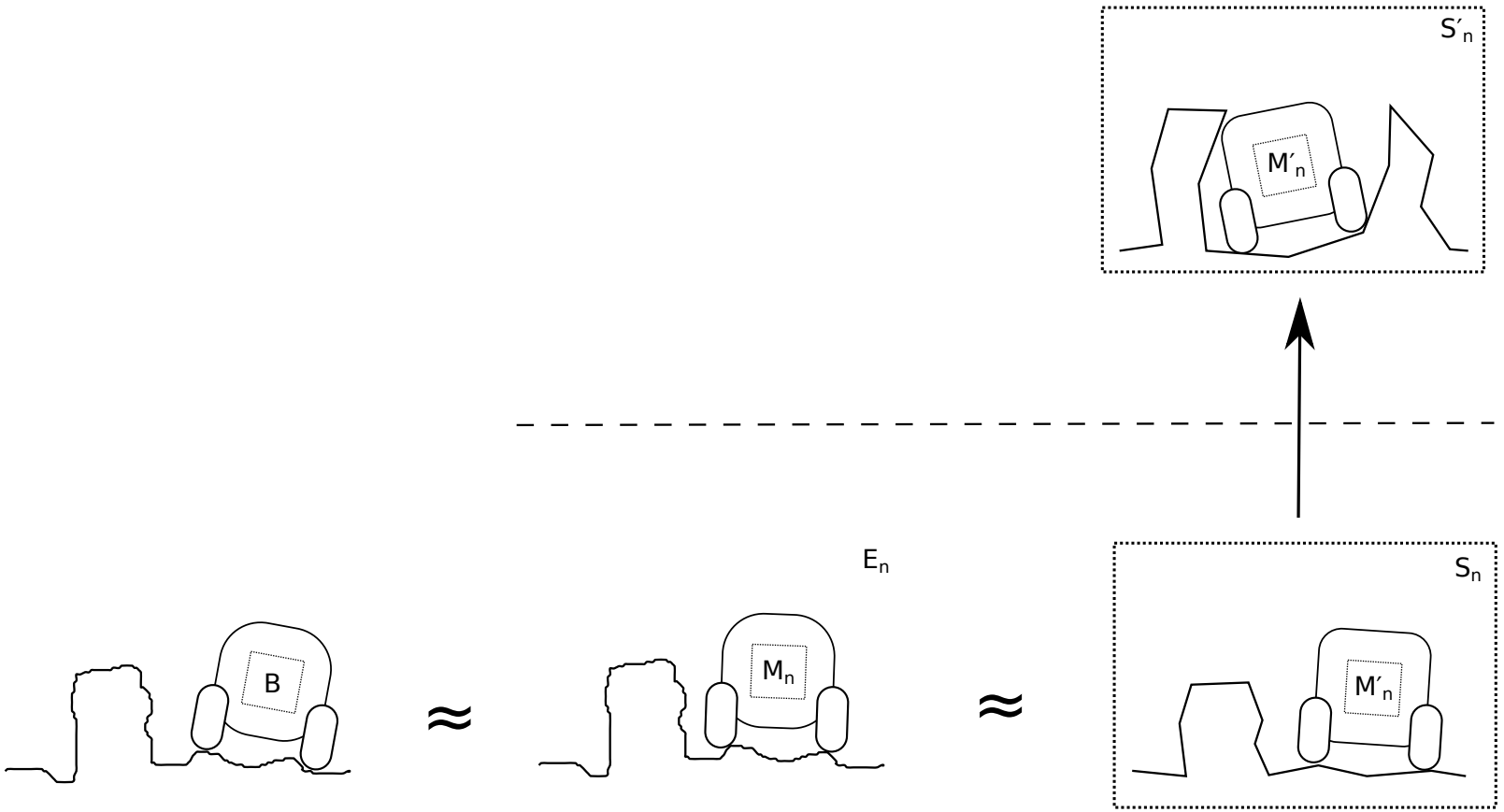
# Co-design Process 4

- Incrementally reach better approximation of desired system



# A Prediction Tool

- Simulation can be used as prediction tool
- Explore how real system might react in different (dangerous/inaccessible) environments



# Advantages of Co-design

- Develop a simulation
  - Drives the design and development of engineered system
  - Helps discover and develop model of emergent behaviour
  - Provides a useful tool designed to the same standard as the engineered system
- Design emergent systems rather than search for them
  - Explicit and traceable relationship between engineered system and simulation
  - Move away from evolutionary approaches that might ‘hide’ this relationship

# Co-design and Emergence

- Co-design of a system with a simulation not limited to emergence, but is highly applicable owing to nature of emergence
  - Non-obvious relationship between behaviour and system components
- Incremental approach lets us converge on possible solution in a controlled way
- Two implemetations of same property helps elucidate and validate the underlying source of emergence

# Thanks For Listening

Any questions?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