

# Knowledge, action, and the frame problem

Reasoning about Actions

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# Introduction



# Table of Contents

- ▶ Scherl and Levesque's Approach
  - Introduction
  - Knowledge as a fluent
  - Knowledge effects
- ▶ Example: The Gardening Robot
  - Axiomatization
  - Considerations on theorems
  - Golog
- ▶ The projection problem



# Outline

## Introduction

Situation calculus provides a framework for reasoning about actions.

This work presents an expansion to handle the *knowledge* possessed or acquired by the agent, and allow it to shape the agent's decisions.

- Knowledge is represented by one additional fluent
- Uniform axiomatization with the rest of sitcalc
- Ordinary actions and knowledge-producing ones are strictly separated
- Easy expansion of regression as defined in [Reiter2001]
- Desirable properties are direct consequences of the axiomatization (e.g. knowledge persistence / memory)



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## Introduction

### Opzionale

Un paio di azioni ordinarie e un paio di azioni di conoscenza di esempio, giusto per inquadrare il discorso



## The K fluent

Knowledge as a fluent

$$K(s', s)$$

Defines an accessibility relation between situations.

### (Informal) definition

$K(s', s)$  is true if an agent in situation  $s$  could mistake the current situation for the other  $s'$ , given its current knowledge.



# Knowledge

Knowledge as a fluent

## Definition of knowledge

A fluent is known to be true (false) in a situation  $s$  if and only if it is true (false) in all situations accessible from  $s$ .

Shorthand notation:  $\mathbf{Knows}(\phi, s) \stackrel{\text{def}}{=} \forall s' K(s', s) \rightarrow \phi(s')$



# Knowledge-producing actions

Knowledge as a fluent

Actions that have an effect on the agent's knowledge

## SENSE actions

Learn the truth value of a formula. Example: check if a door is open or closed.

$$\mathbf{Knows}(P, \text{DO}(\text{SENSE}_P, s)) \vee \mathbf{Knows}(\neg P, \text{DO}(\text{SENSE}_P, s))$$

## READ actions

Learn the value of a term. Example: read a number on a sheet of paper.

$$\exists x \mathbf{Knows}(\tau = x, \text{DO}(\text{READ}_\tau, s))$$

*Assumption: ordinary and knowledge-producing actions are strictly separated.*



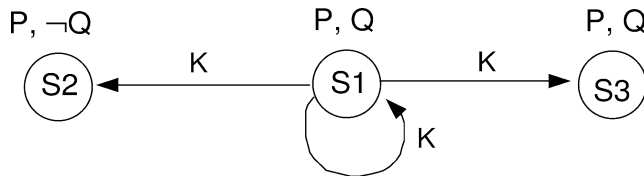


## Towards a successor state axiom for K

Knowledge effects

In order to complete the specification of the K fluent, we need to define its successor state axiom, determining how ordinary actions and knowledge-producing actions affect it.

Consider this case study with three accessible situations. The agent is in S1.



$$\mathbf{Knows}(P, S1) \wedge \neg \mathbf{Knows}(Q, S1)$$



# Ordinary actions

Knowledge effects

Pippo



# Knowledge-producing actions

Knowledge effects

Pippo



# The successor state axiom for K

Knowledge effects

Pippo



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Knowledge effects

Pippo



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## The Problem

- A robot has to manage some plants in a garden.
- The robot can perform an action on one plant at a time and only if it's near the plant.
- A plant can be watered only if it is dry. The plant's humidity can be inspected.
- The robot has a water tank with unlimited capacity.



# Fluents and Actions

Axiomatization

## Fluents

- $Near(x, s) \rightarrow$  Robot is near plant  $x$  in situation  $s$
- $Humidity(x, s) \rightarrow$  Humidity of plant  $x$  in situation  $s$
- $Infested(x, s) \rightarrow$  Plant  $x$  is infested by bugs in situation  $s$
- $Healthy(x, s) \rightarrow$  Plant  $x$  is healthy in situation  $s$

## Actions

- $Treat(x, s) \rightarrow$  Treat plant  $x$  in situation  $s$
- $Water(x, s) \rightarrow$  Water plant  $x$  in situation  $s$
- $GoTo(x) \rightarrow$  Go to plant  $x$





# Successor State Axioms

Axiomatization

In general  $F(x, do(\alpha, s)) \equiv \Phi_F^+(x, a, s) \vee (F(x, s) \wedge \neg \Phi_F^-(x, a, s))$

- $Near(x, do(\alpha, s)) \equiv \alpha = GoTo(x) \vee (Near(x, s) \wedge \neg \exists y. \alpha = GoTo(y))$
- *Healthy?*
- $Humidity(x, do(\alpha, s)) = h \equiv Humidity(x, s) = h$
- $Infested(x, do(\alpha, s)) = h \equiv Infested(x, s) = i$



# Initial State

Axiomatization





# Precondition Axioms

Axiomatization



# Sensing Result Axioms

Axiomatization



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Considerations on theorems



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Golog



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*Thank you for listening!*  
*Any questions?*