

# Data-Driven Approach for Modelling the Deterioration and Planning Interventions on Infrastructures (Future Directions)

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Department of Civil, Geological and Mining Engineering (CGM)

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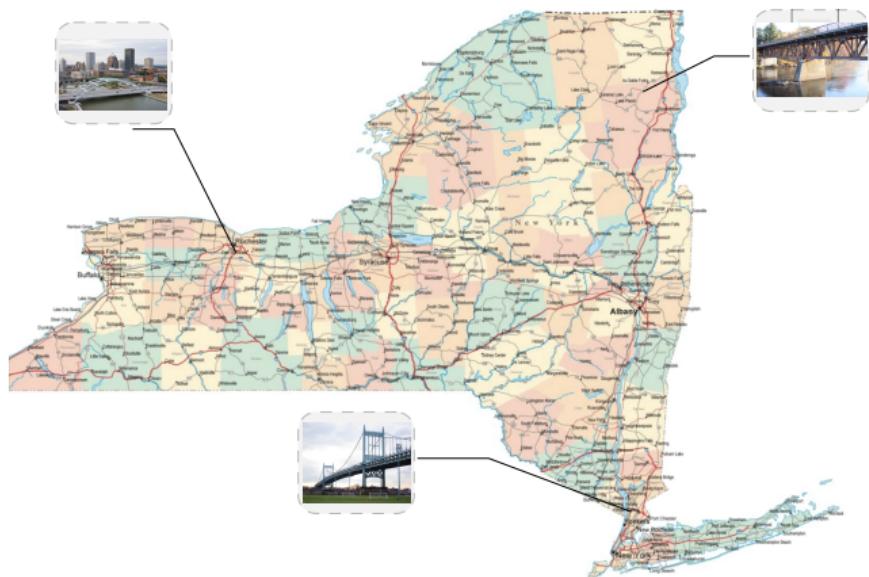
# Context

## Interpretability

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Data → useful measures about safety and serviceability



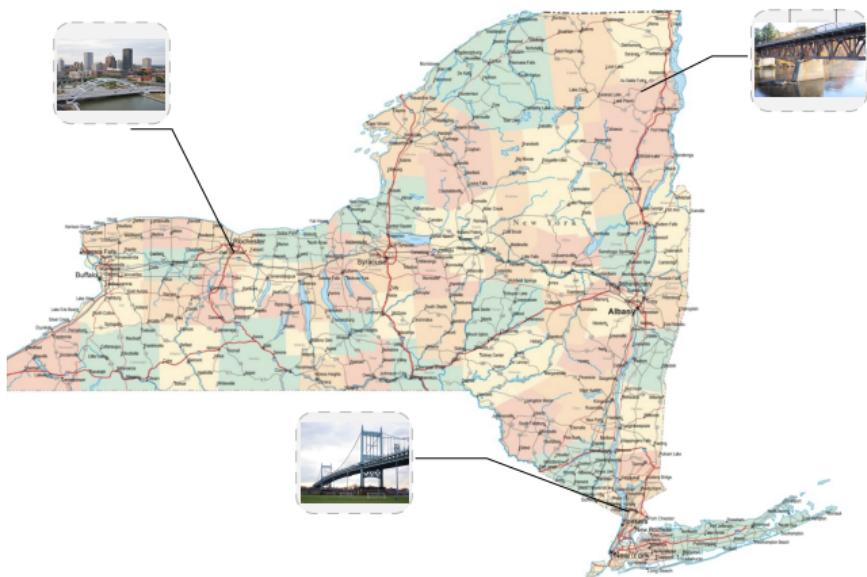
Source: new-york-map

# Context

## Interpretability

Data → useful measures about safety and serviceability

## Decision making



Source: new-york-map

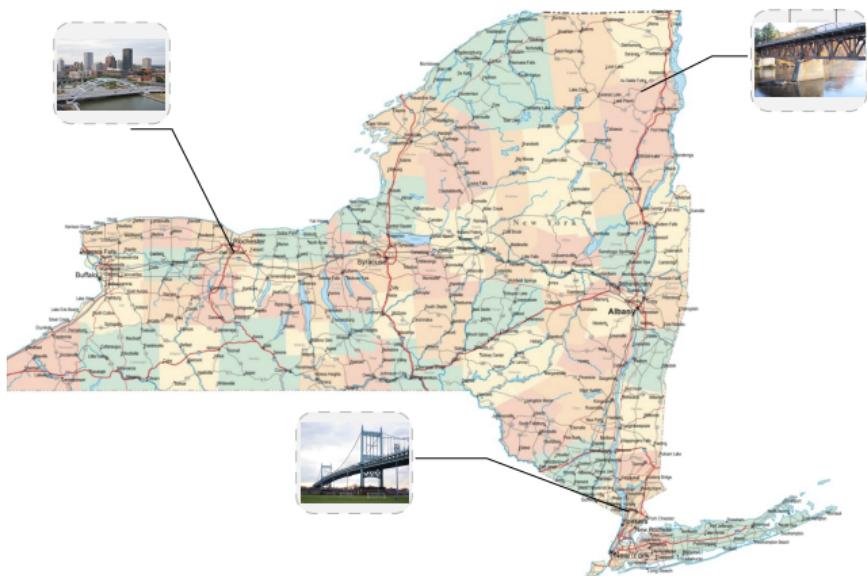
# Context

## Interpretability

Data → useful measures about safety and serviceability

## Decision making

Network-scale systems



Source: new-york-map

# Outline

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## Modelling the Deterioration of Infrastructures

## Adaptive Optimization Methods

## Planning Interventions

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# Modelling the Deterioration of Infrastructures

- ▶ Potential improvements on the deterioration model:

- ▶ Potential improvements on the deterioration model:
  - ▷ Supporting the Deterioration Model with Additional Information.

- ▶ Potential improvements on the deterioration model:
  - ▷ Supporting the Deterioration Model with Additional Information.
  - ▷ Sharing Knowledge Across Infrastructures.

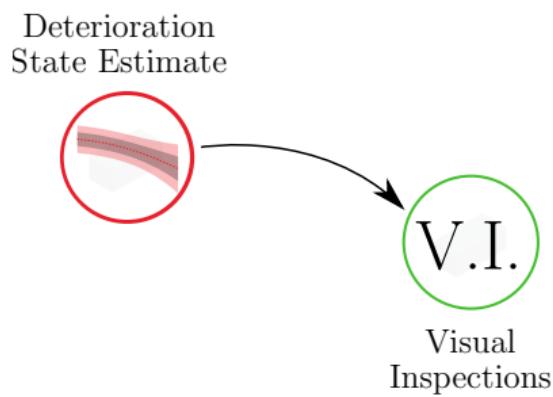
# Supporting the Deterioration Model with Additional Information

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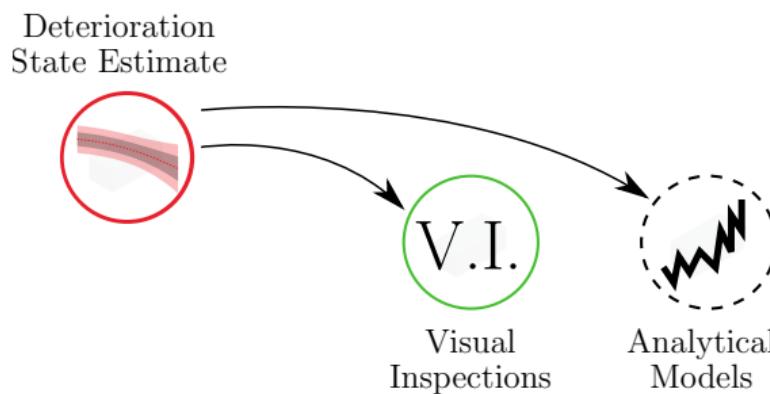
Deterioration  
State Estimate



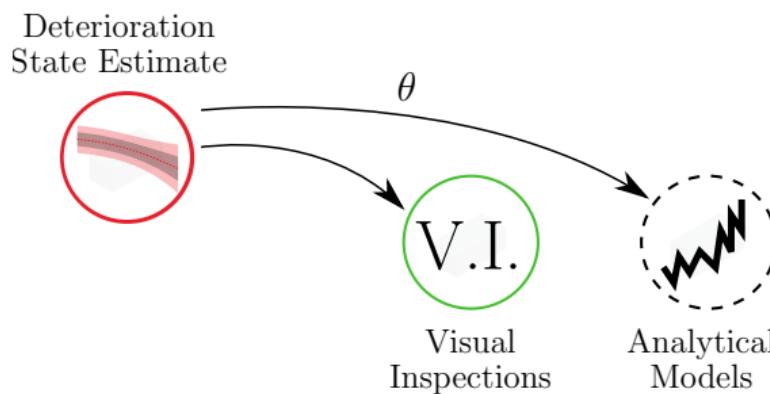
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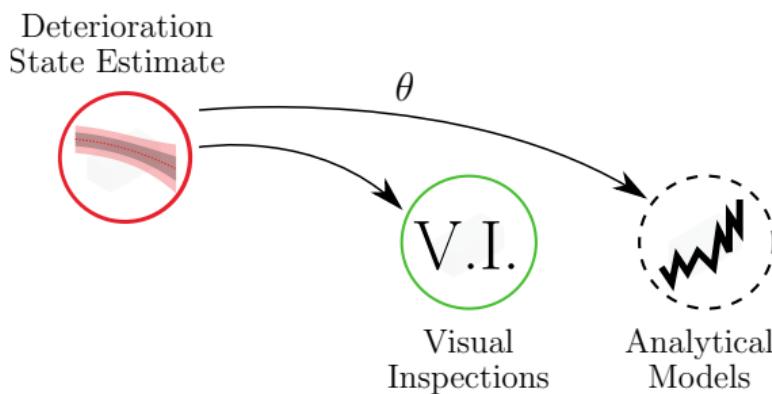
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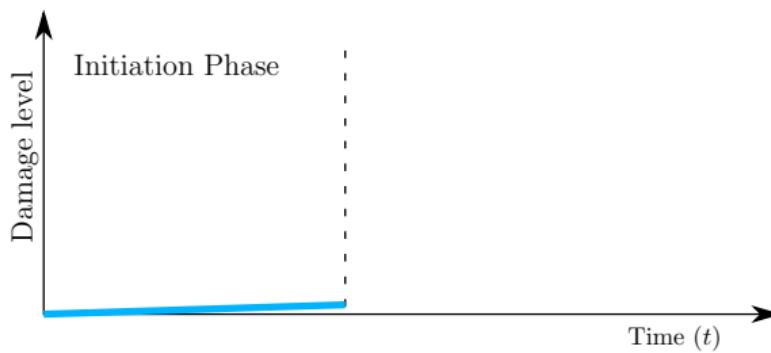
**Example:** analytical models that describe corrosion propagation.

# Modelling Different Phases (Initiation - Propagation)

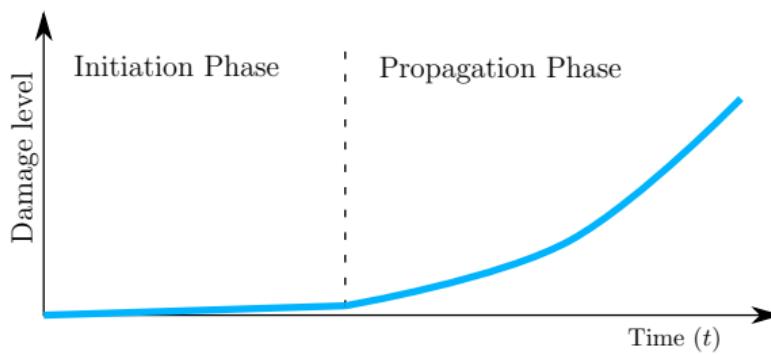
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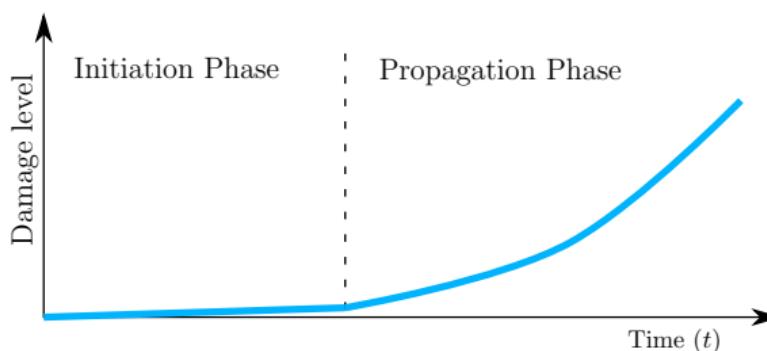
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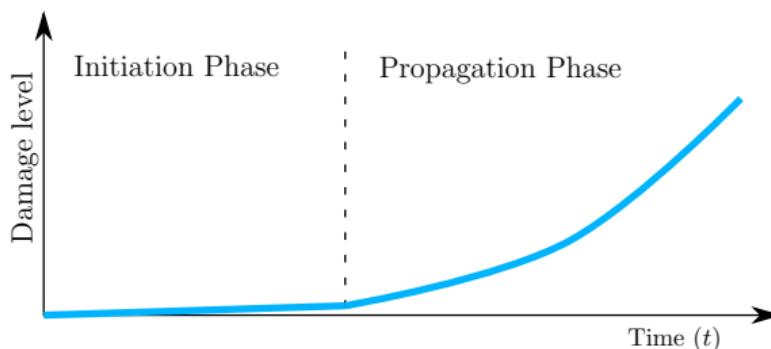
# Modelling Different Phases (Initiation - Propagation)



## Model 1: Initiation

$$\underbrace{\begin{bmatrix} \check{x}_t \\ \check{x}_t \end{bmatrix}}_{\check{x}_t} = \underbrace{\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}}_{\check{A}_t} \underbrace{\begin{bmatrix} \check{x}_{t-1} \\ \check{x}_{t-1} \end{bmatrix}}_{\check{x}_{t-1}} + \underbrace{\begin{bmatrix} \check{w}_t \\ \check{w}_t \end{bmatrix}}_{\check{w}_t}$$

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**Model 1:** Initiation

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**Model 2:** Propagation

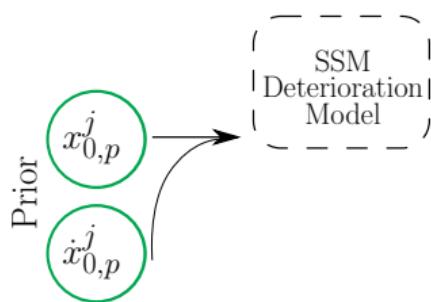
$$\underbrace{\begin{bmatrix} \check{x}_t \\ \dot{x}_t \end{bmatrix}}_{\check{x}_t} = \underbrace{\begin{bmatrix} 1 & \Delta t \\ 0 & 1 \end{bmatrix}}_{\check{A}_t} \underbrace{\begin{bmatrix} \check{x}_{t-1} \\ \dot{x}_{t-1} \end{bmatrix}}_{\check{x}_{t-1}} + \underbrace{\begin{bmatrix} \check{w}_t \\ \dot{w}_t \end{bmatrix}}_{\check{w}_t}$$

# Sharing Knowledge Across Infrastructures

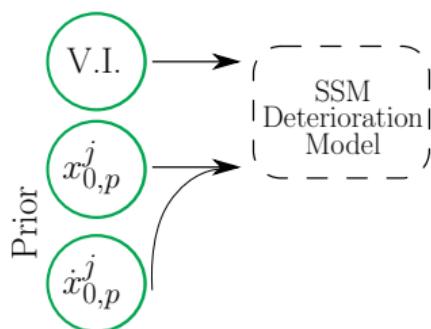
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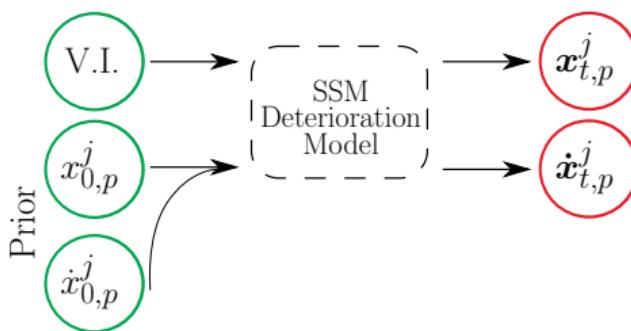
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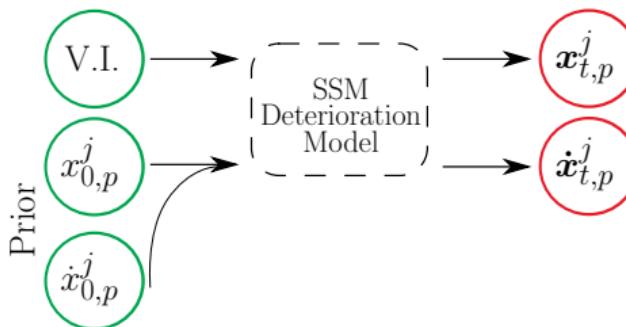
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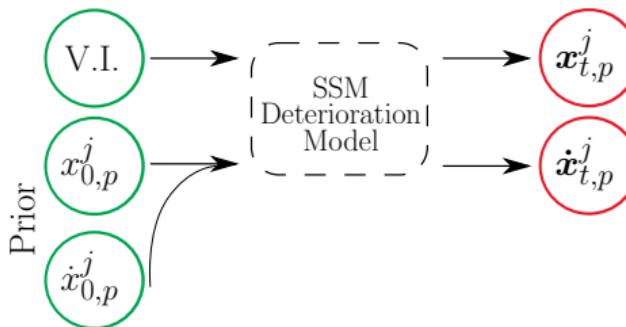
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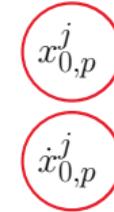
Structural  
Attributes



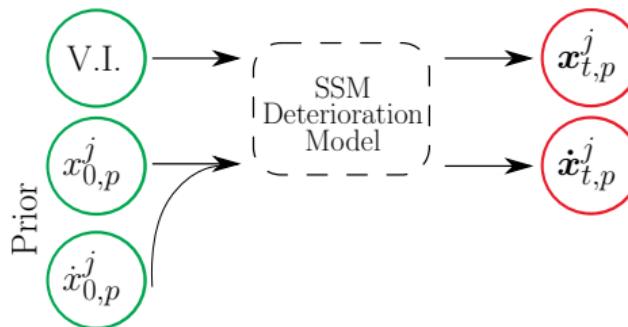
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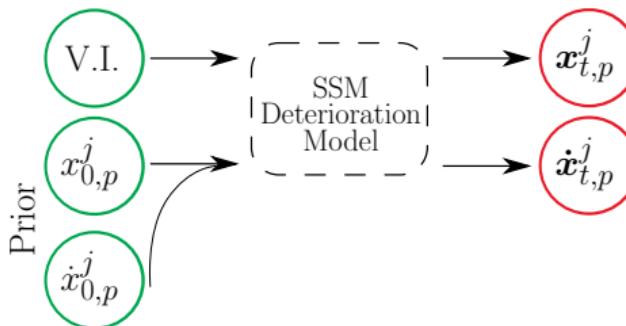
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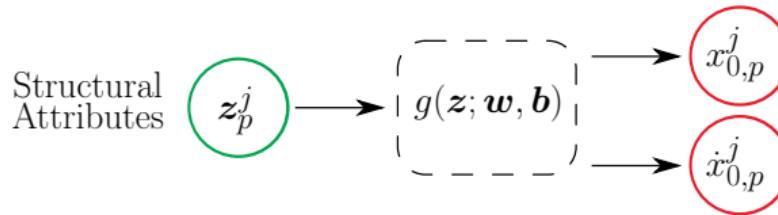
Learn the mapping between the prior and structural attributes,



# Sharing Knowledge Across Infrastructures



Learn the mapping between the prior and structural attributes,



# Adaptive Optimization Methods

# Why are they needed?

- ▶ Expensive blackbox,

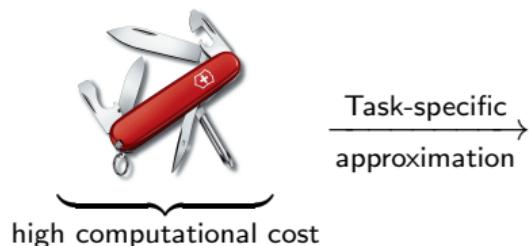
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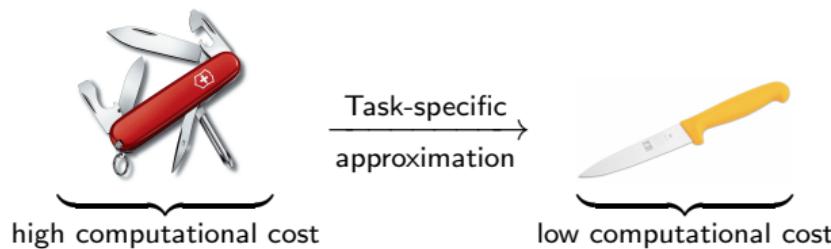
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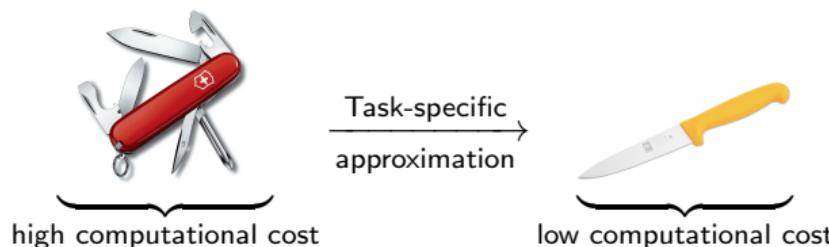
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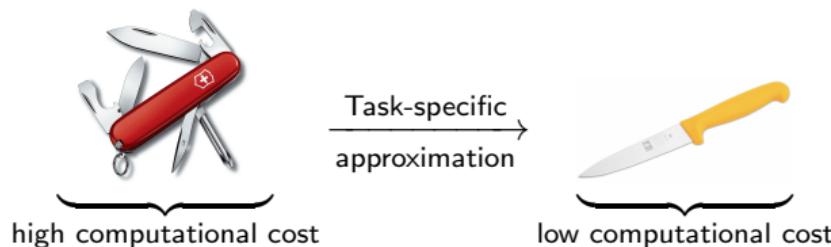
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- ▶ High number of model parameters,
  - ▷ The SSM-KR model (e.g., inspectors' parameters).

# Expensive blackbox

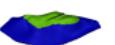
Example: find optimal location  $(x_1, x_2)$  to extract oil from an oil reservoir

Source: Hamida et. al. 2017

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Reservoir model  .

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Example: find optimal location  $(x_1, x_2)$  to extract oil from an oil reservoir

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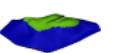
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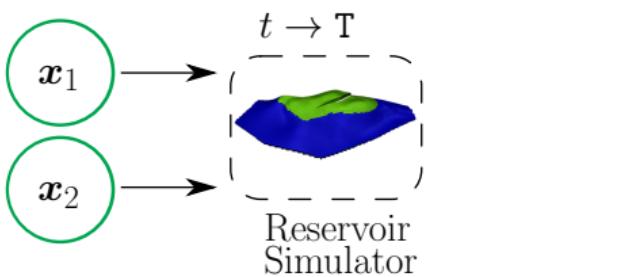
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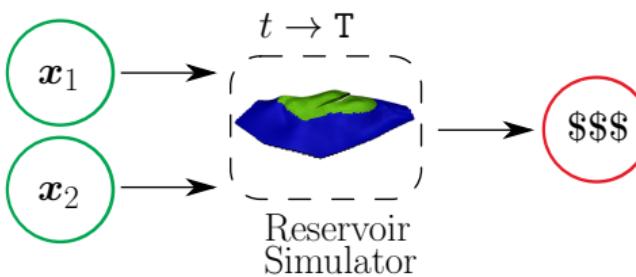


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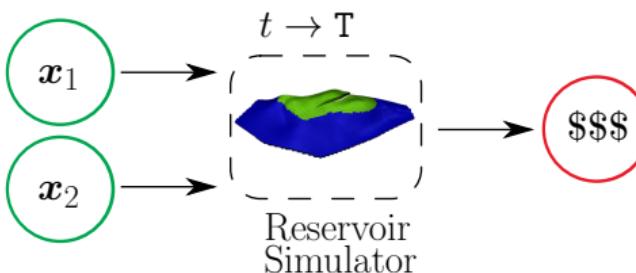
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# Surrogate models

Search for best location by performing simulations from  $t \rightarrow T$ ,

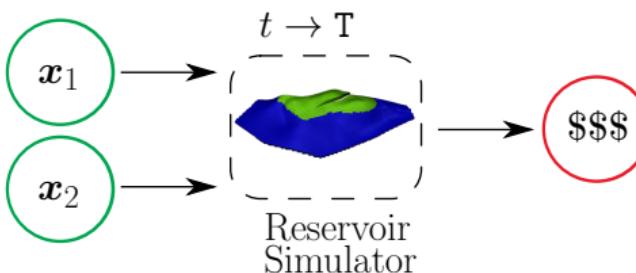
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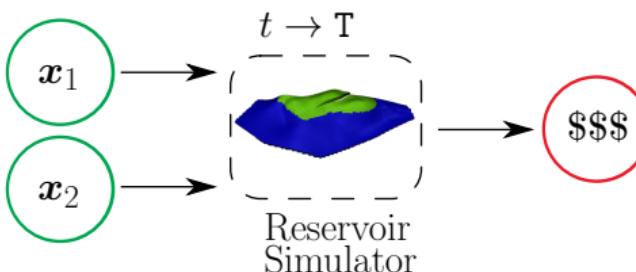
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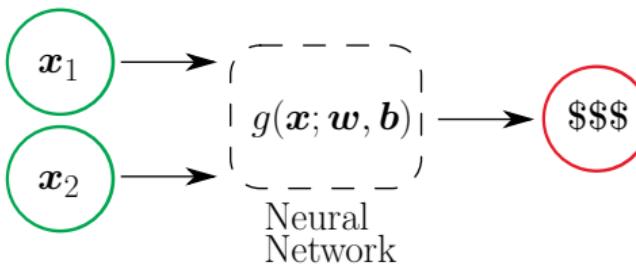
while searching, it is possible also to learn from the input-output combinations,

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  - ▷ Choice of training samples (e.g., learn with the fewest number of samples).
  - ▷ Exploiting the common properties of the best samples.

# High number of model parameters

Source: Blanche et. al. 2022 (In Preparation)

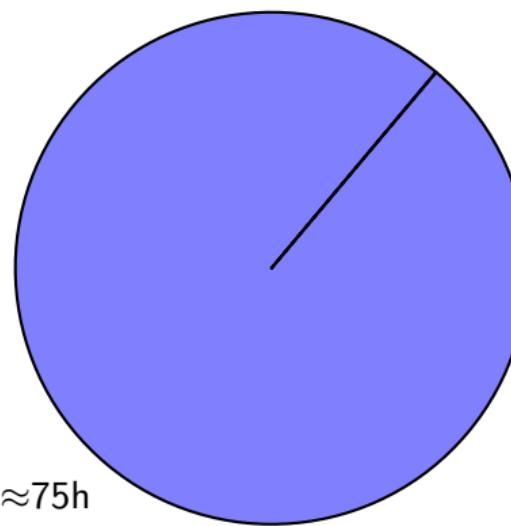
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Analytical inference of inspectors' parameters  $\sigma_V^2(l_i)$ .

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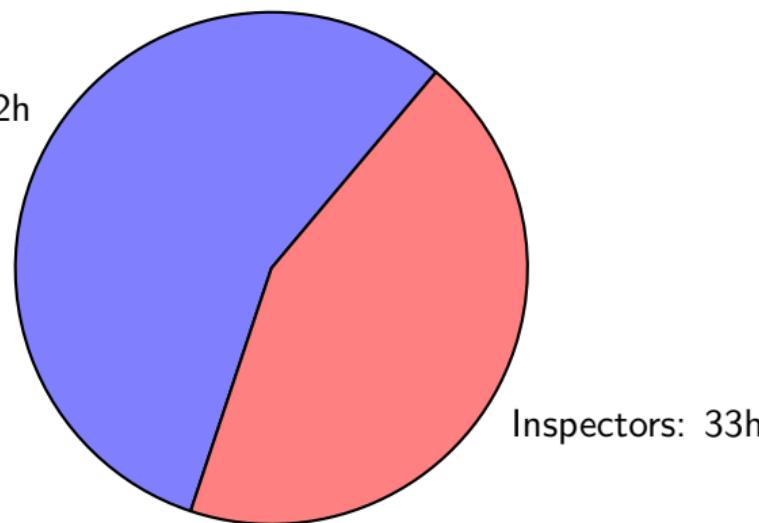
Total estimation time:  $\approx 75\text{h}$

Source: Blanche et. al. 2022 (In Preparation)

# High number of model parameters

Analytical inference of inspectors' parameters  $\sigma_V^2(l_i)$ .

Other parameters: 42h

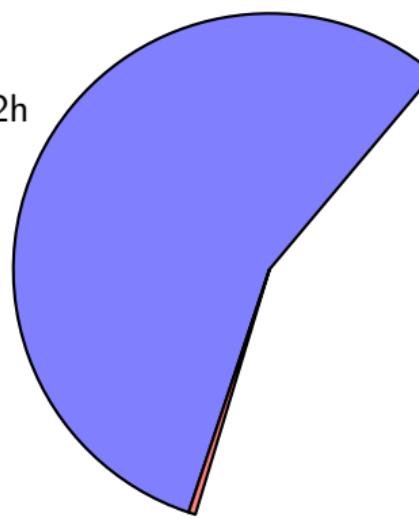


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# High number of model parameters

Analytical inference of inspectors' parameters  $\sigma_V^2(I_i)$ .

Other parameters: 42h



New method: 20min

Source: Blanche et. al. 2022 (In Preparation)

# Planning Interventions

# Context

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**Bad decision (-1)**

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# Context

**Bad decision (-1)**

**Good decision (+1)**

# Context

Source: Vansh Sethi

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- ▷ Agent: Mario (decision maker).

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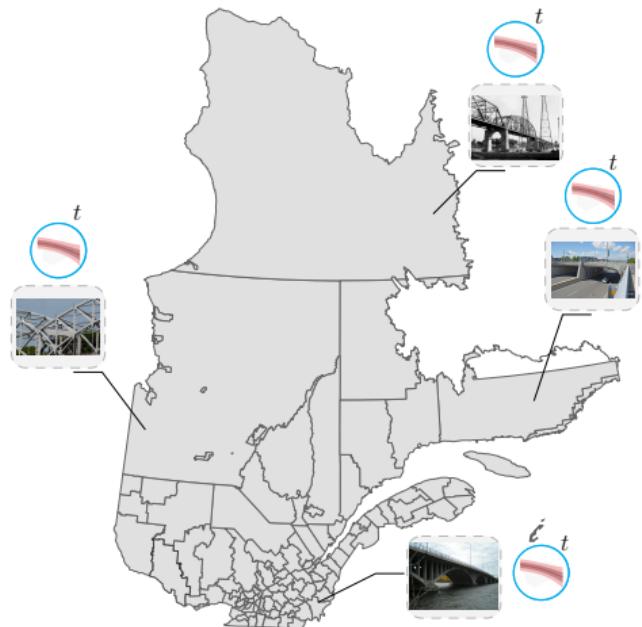
- ▷ Agent: Mario (decision maker).
- ▷ Environnement: video game.
- ▷ Actions: movement.
- ▷ Rewards: win the game.

**The reinforcement learning concepts can be applied for maintenance planning.**

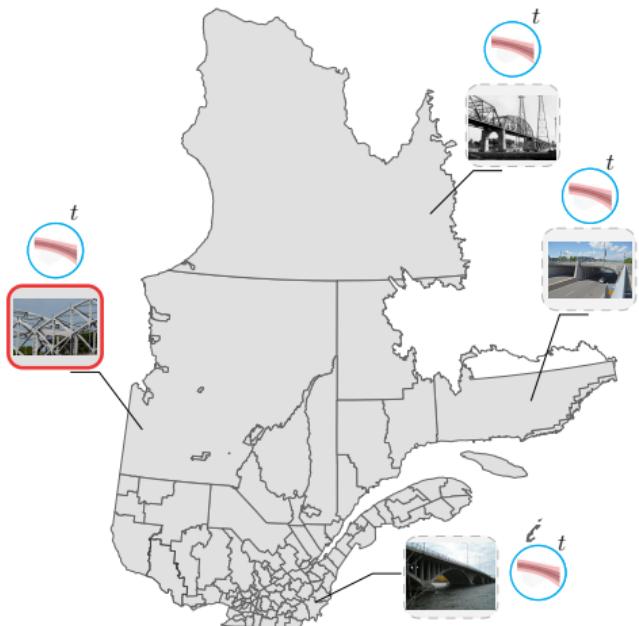
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# Simulation Environment

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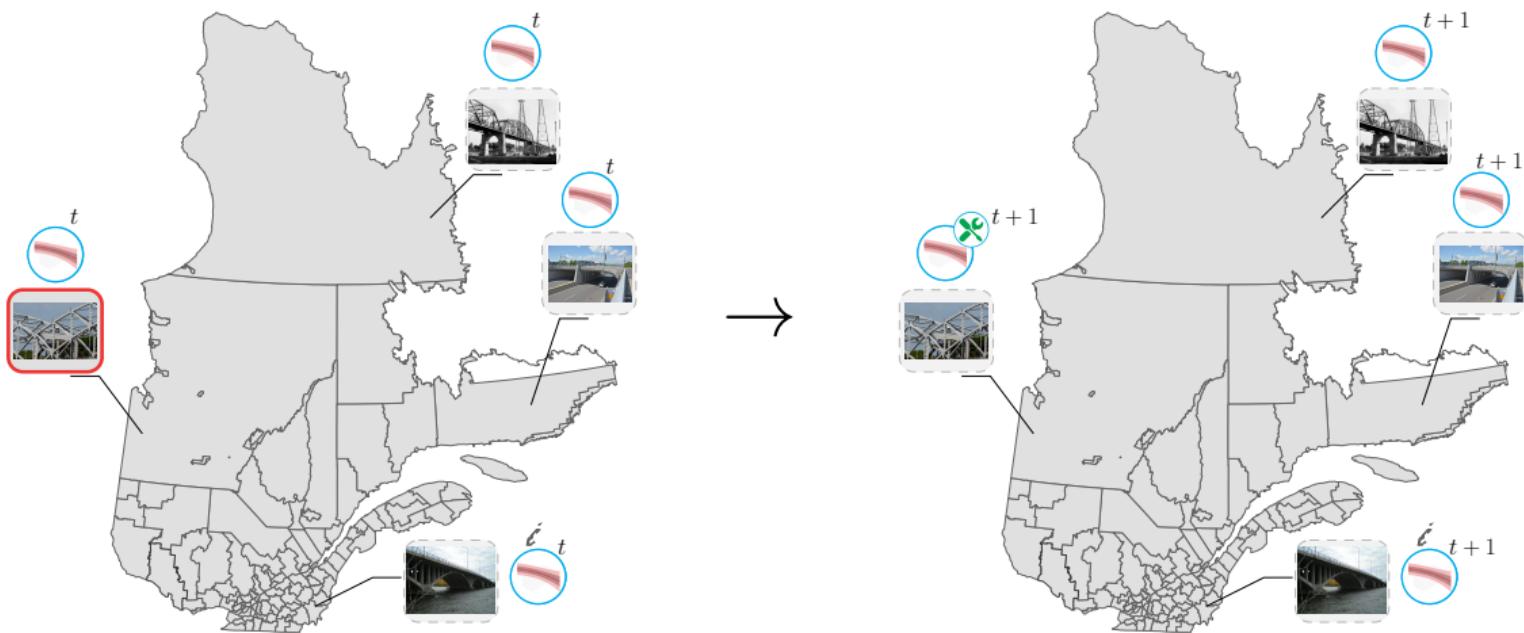


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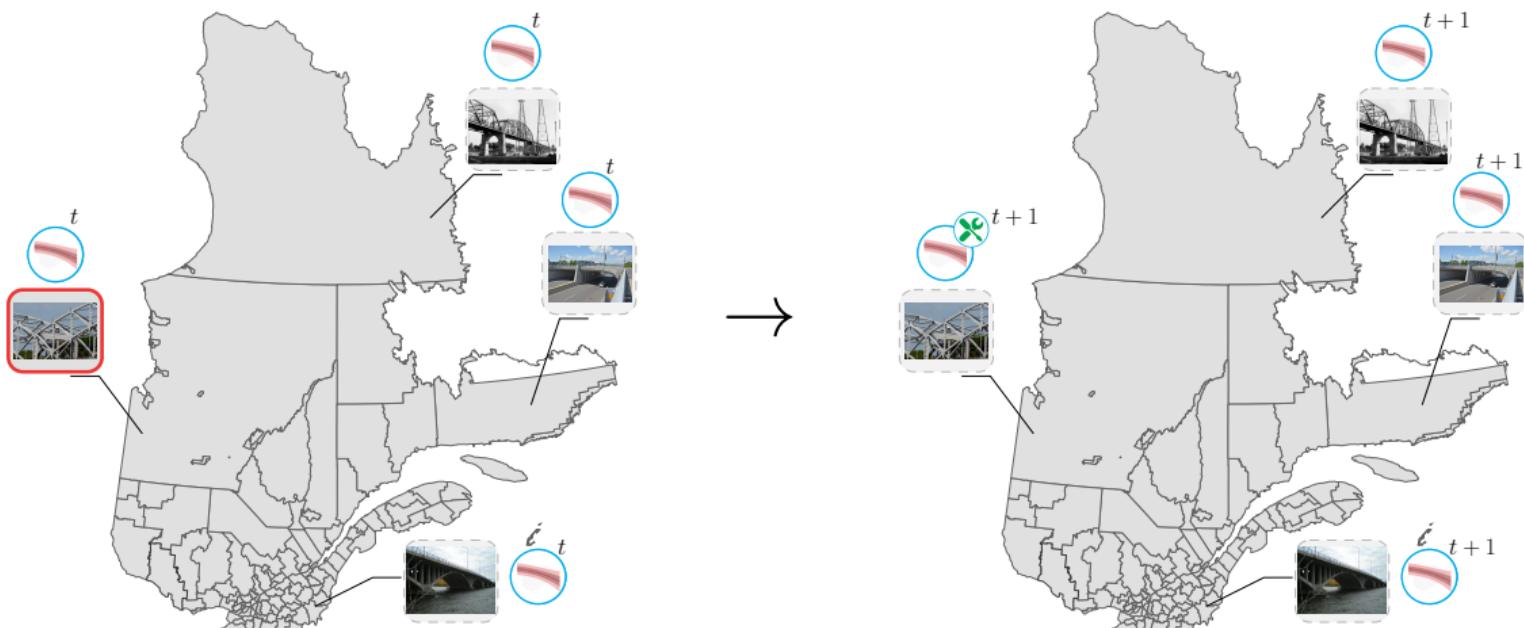


## Simulation Environment for Infrastructures

## Simulation Environment

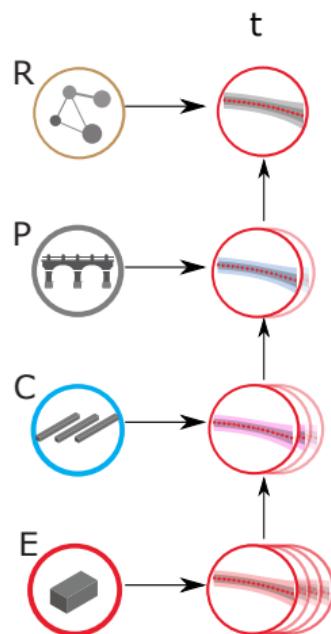


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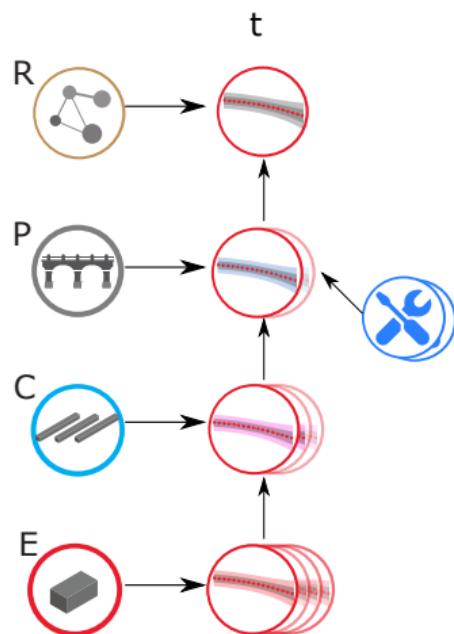


**Provide access to the short & long term effect of an intervention.**

# Maintenance Actions



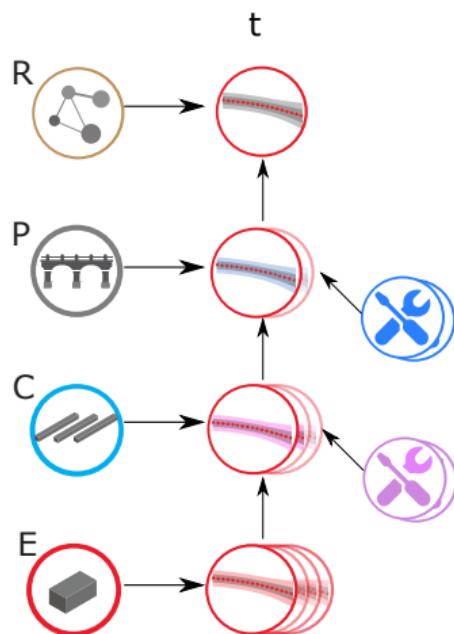
# Maintenance Actions



Hierarchy of decisions:

- ▶ Subset of bridges

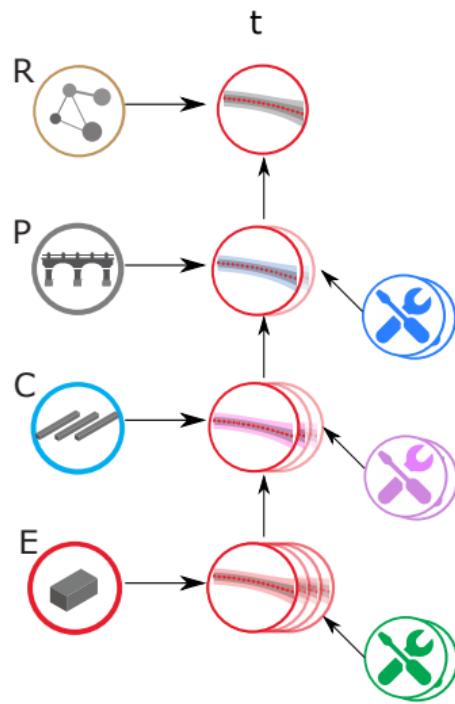
# Maintenance Actions



Hierarchy of decisions:

- ▶ Subset of bridges
- ▶ Subset of structural categories

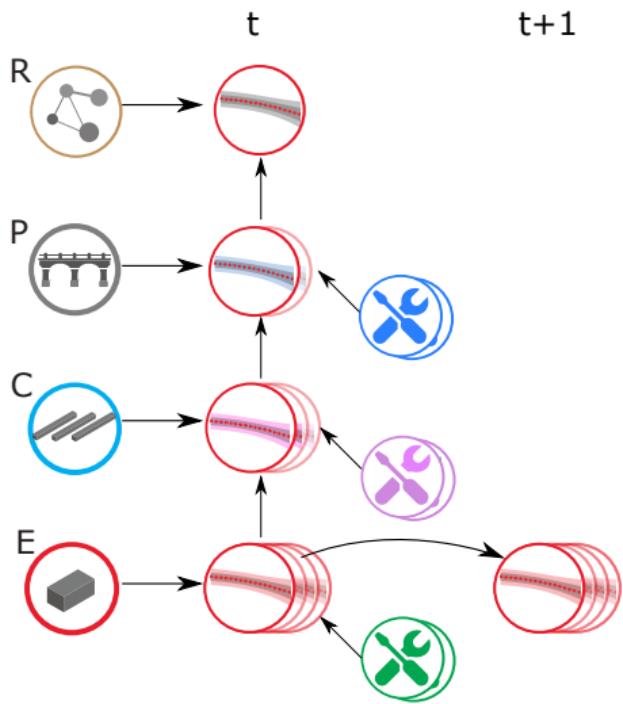
# Maintenance Actions



Hierarchy of decisions:

- ▶ Subset of bridges
- ▶ Subset of structural categories
- ▶ Type of interventions for each element

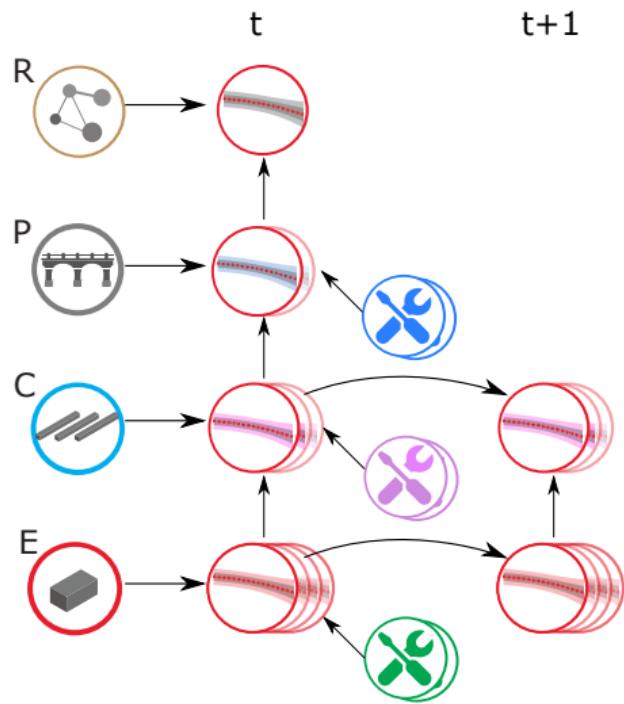
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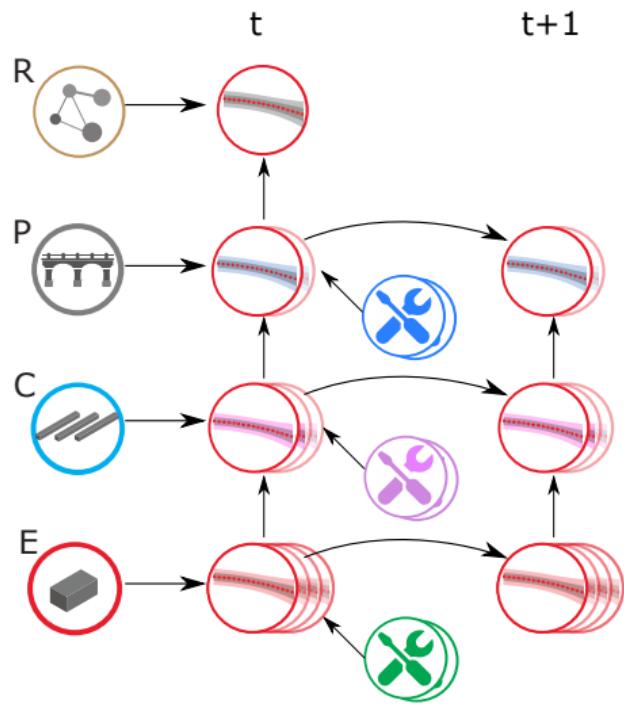
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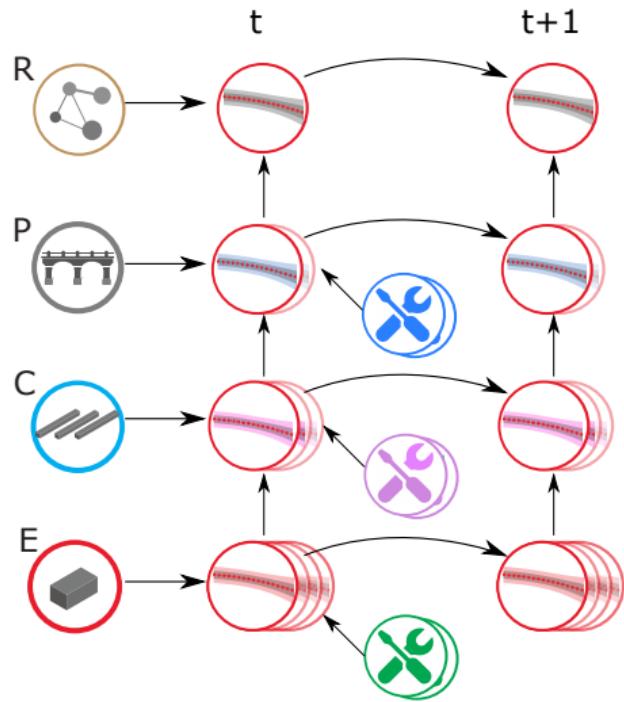
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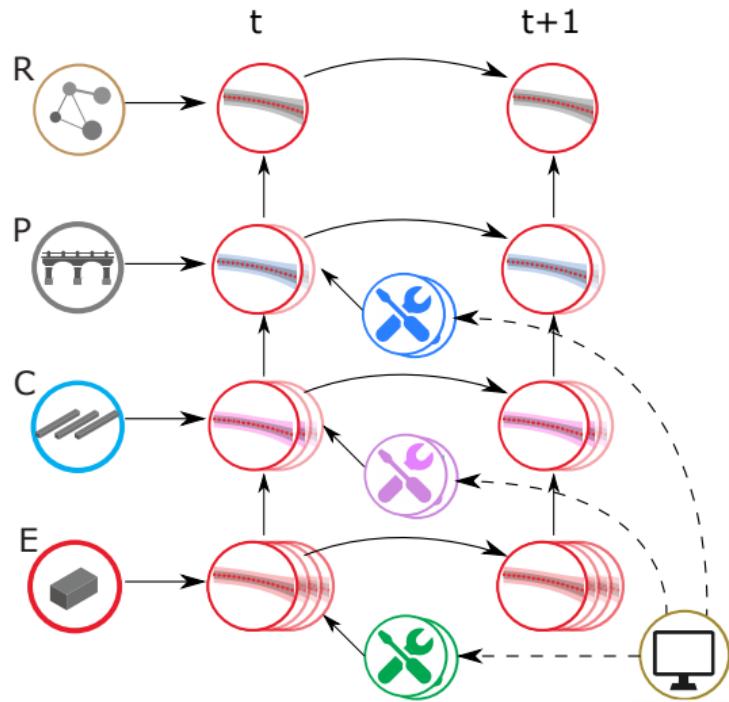
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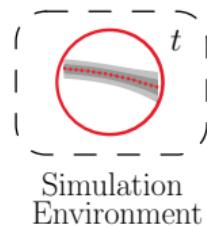
**Objective: develop a framework that ensures applying the necessary actions that are also cost-effective.**

# Preliminary progress

- ▶ Creation of an initial simulation environment:

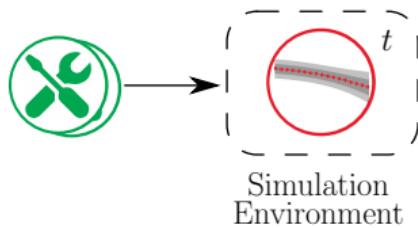
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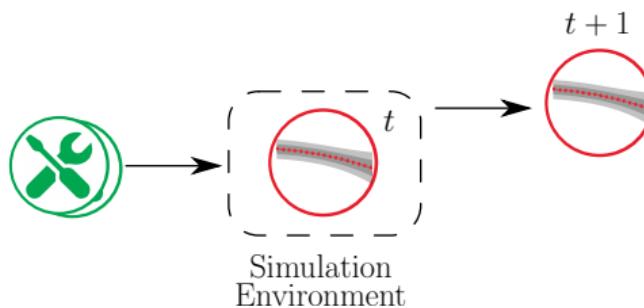
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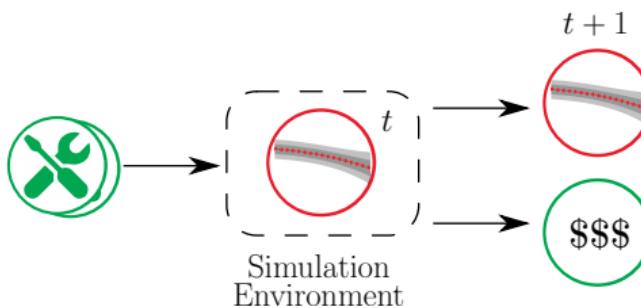
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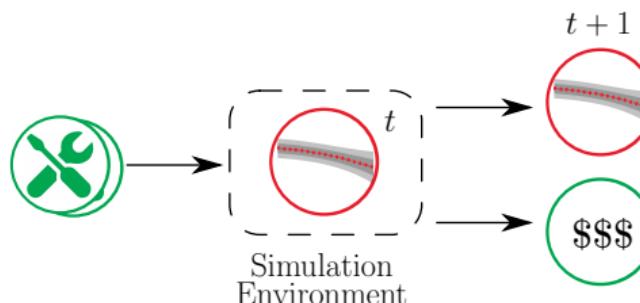
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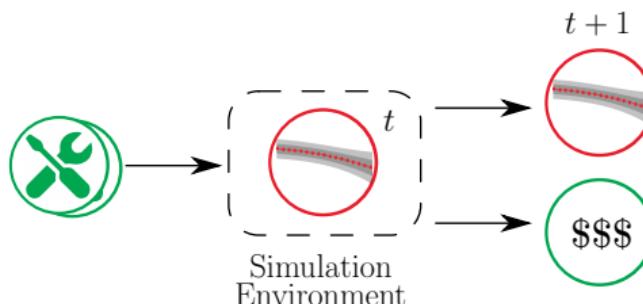
- ▶ Development of an RL agent



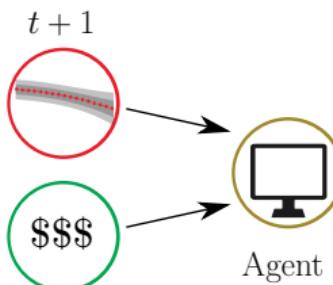
Agent

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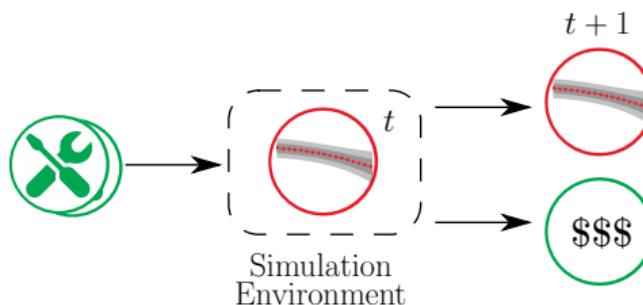


- ▶ Development of an RL agent

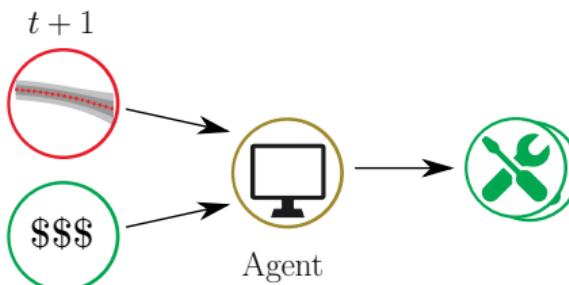


## Preliminary progress

- ▶ Creation of an initial simulation environment:



- ▶ Development of an RL agent



## Potential Contributions

# Potential Contributions

- ▶ Modelling the deterioration of infrastructures:

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  - ▷ Factoring information from analytical deterioration models.

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- ▶ Modelling the deterioration of infrastructures:
  - ▷ Factoring information from analytical deterioration models.
  - ▷ Improve the prior knowledge about structures' condition.

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