Point-based POMDP Risk Based Inspection of Offshore Wind Substructures

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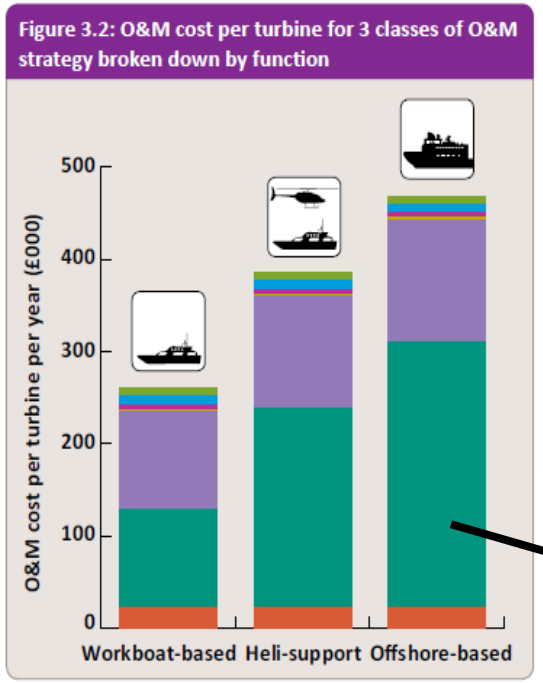
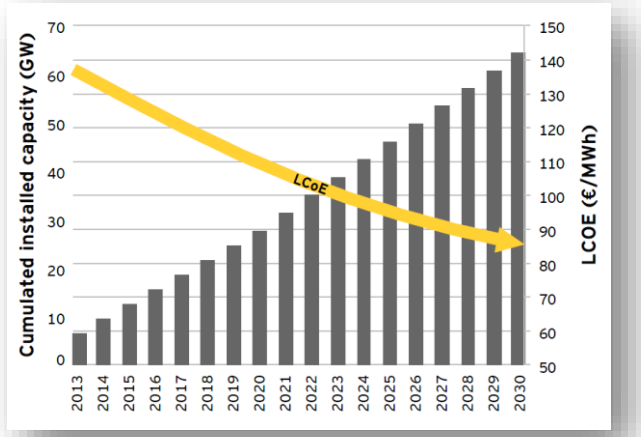
Introduction – Offshore Wind Substructures

Far away from shore

…Complex O&M tasks
Reduce LCOE…



Source: CrownState Report. A Guide to UK Offshore Wind Operations and Maintenance

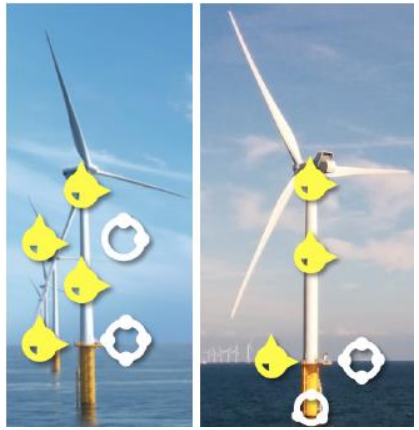


Source: EYReport. Offshore wind in Europe Walking the tightrope to success

Foundation
Maintenance

Information available

….Inspections
Monitoring…



Source: https://www.researchgate.net/figure/Optical-strain-gauges-as-installed-at-a-Belwind-and-b-Northwind

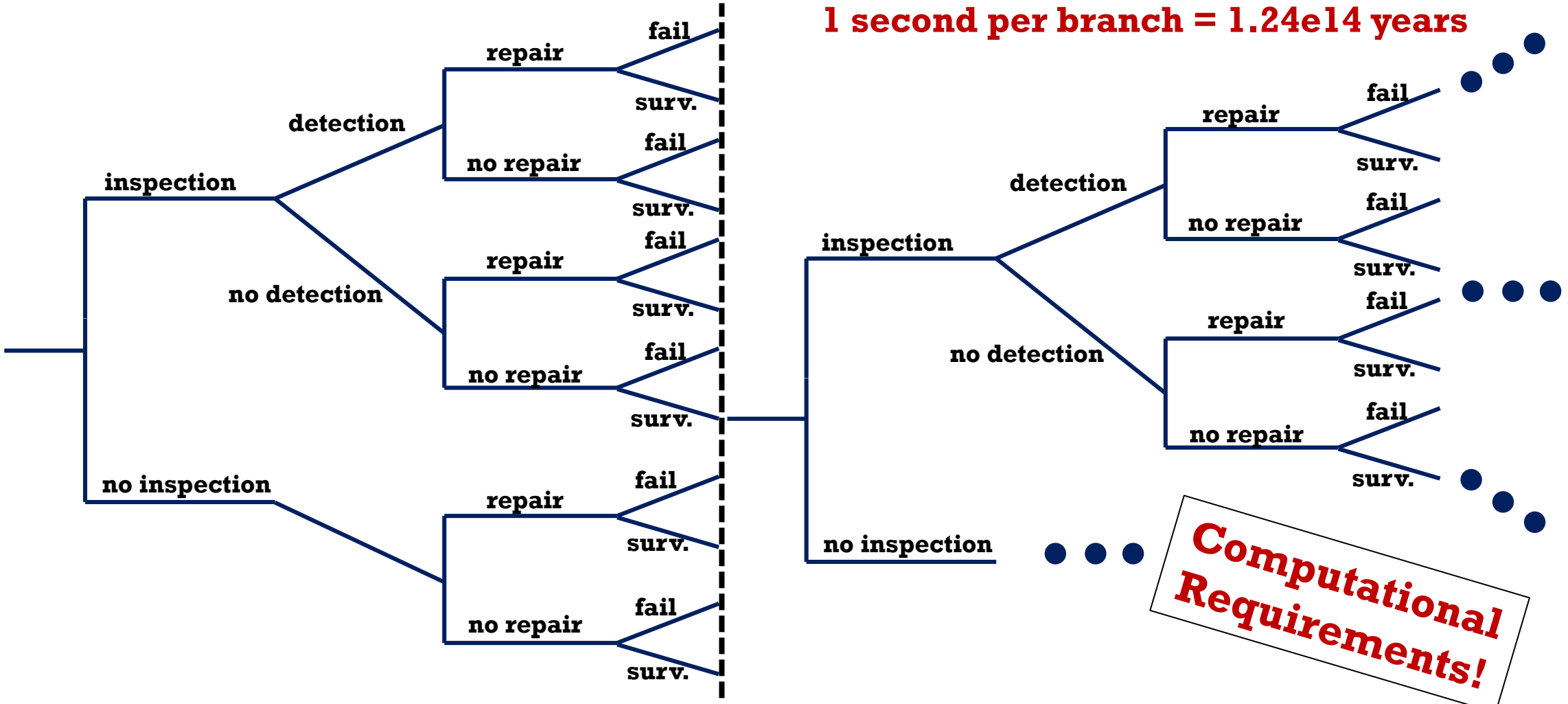
Source: https://www.deltares.nl/en/projects/cutting-maintenance-costs-offshore-wind-farms-using-improved-forecasts

Maintenance Decision Problem

‘Pre-posterior Decision Analysis’…

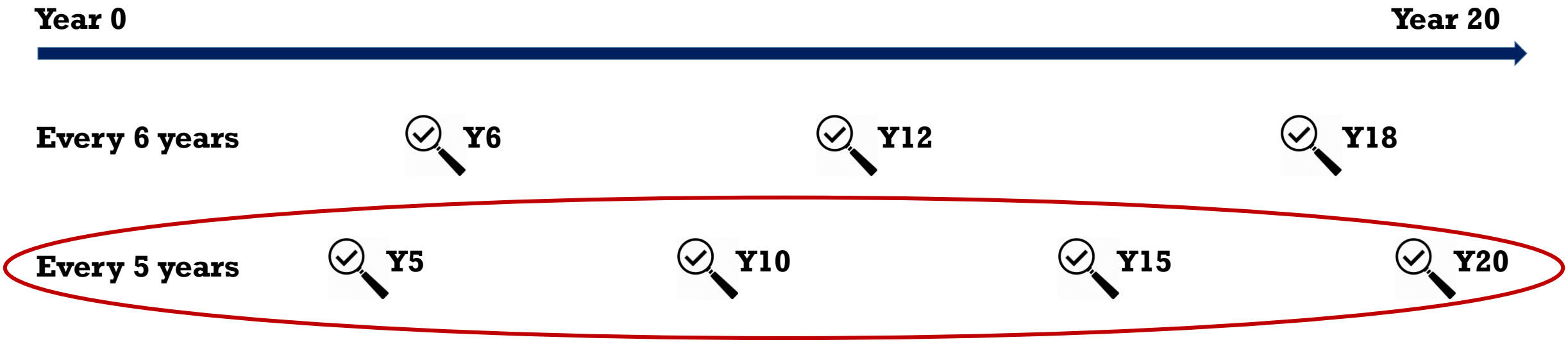
12^{20}=3.8e21 branches

1 second per branch = 1.24e14 years



Decision Problem Simplifications

Heuristic Rule: 'Constant intervals of time'



More simplifications…

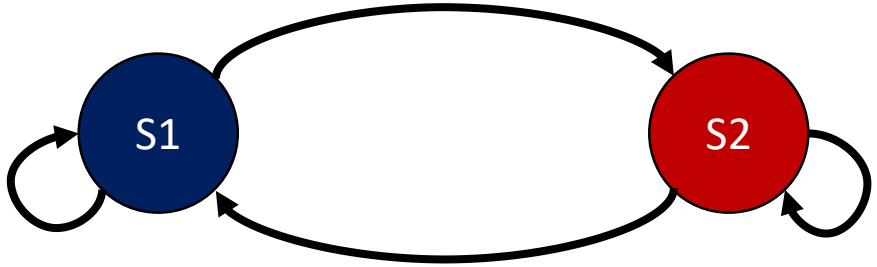
- Perfect inspections
- Repair if detected

MDPs & POMDPs

Decision problem → Dynamic programming

Markov Decision Process (MDP)

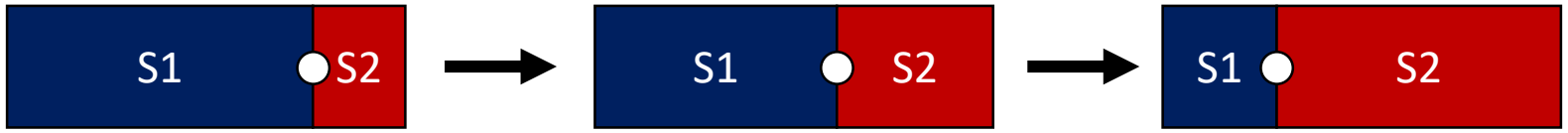
Easy to solve



State / Action: Cost

Partially Observable Markov Decision Process (POMDP)

Solution?



B=[0.9,0.1] **B=[0.7,0.3]** **B=[0.2,0.8]**

Belief State / Action / Observation: Cost

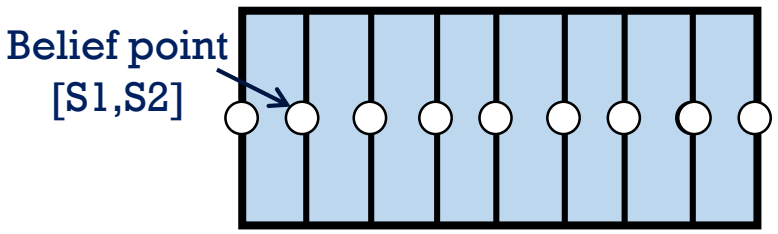
Solving POMDPs

Decision problem:

? Belief State ⟶ Action

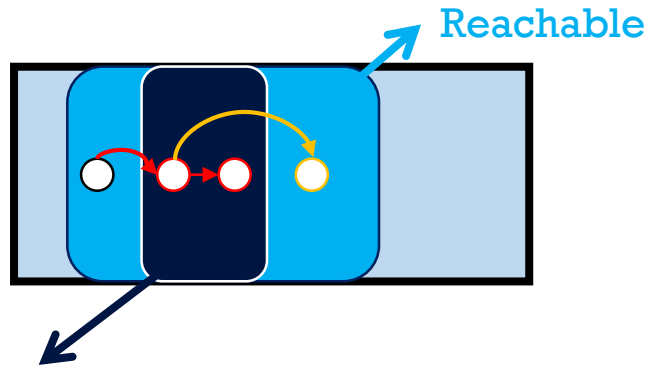
Computational Requirements!

‘Grid-based’ technique



- Finite set of belief points
- Extrapolation/interpolation

‘Point-based’ technique

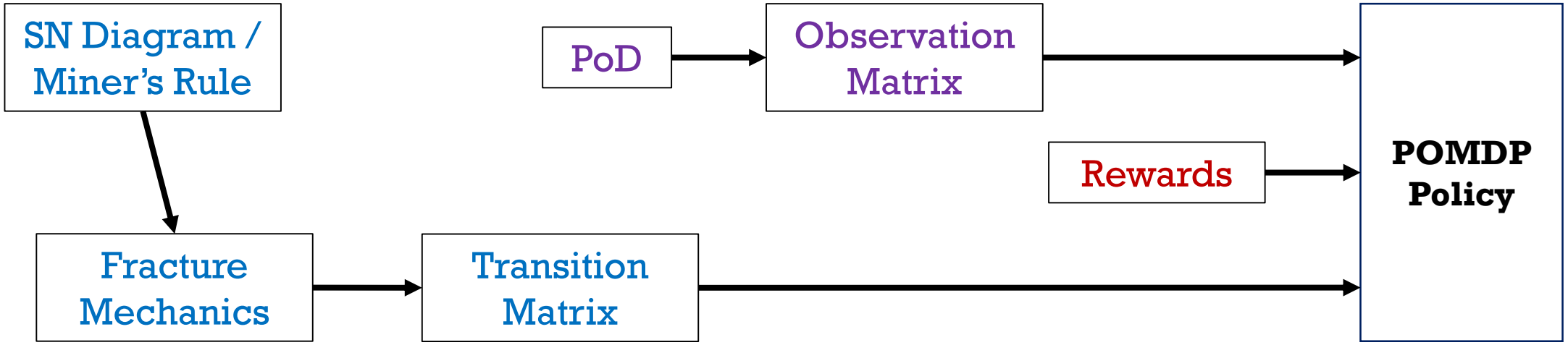


- ‘Optimally’ reachable beliefs
- Large state space (Robotics)

Proposed Methodology

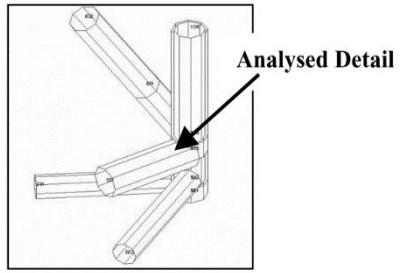
‘Fatigue Deterioration’

Deterioration Model + Inspection Model + Cost Model



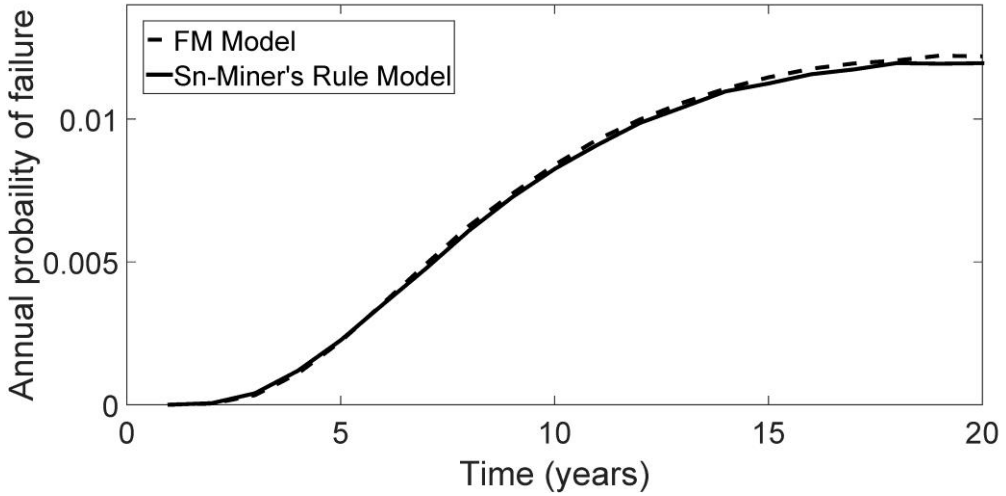
Example: Tubular Joint (1)

‘Probabilistic Fatigue Deterioration’



$$g_{SN(t)} = \Delta - \frac{v_0 t}{\eta}\left[\frac{q^{m_1}}{a_1}\Gamma\left(1+\frac{m_1}{h};\left(\frac{S_1}{q}\right)^h\right)+\frac{q^{m_2}}{a_2}\gamma\left(1+\frac{m_2}{h};\left(\frac{S_1}{q}\right)^h\right)\right]$$

$$g_{FM(t)} = a_c - \left[\left(1-\frac{m}{2}\right)CK^m\pi^{\frac{m}{2}}q^m\Gamma\left(1+\frac{m}{h}\right)\Delta n + a_{t-1}\left(1-\frac{m}{2}\right)\right]^{\frac{2}{2-m}}\text{; given } a_0$$



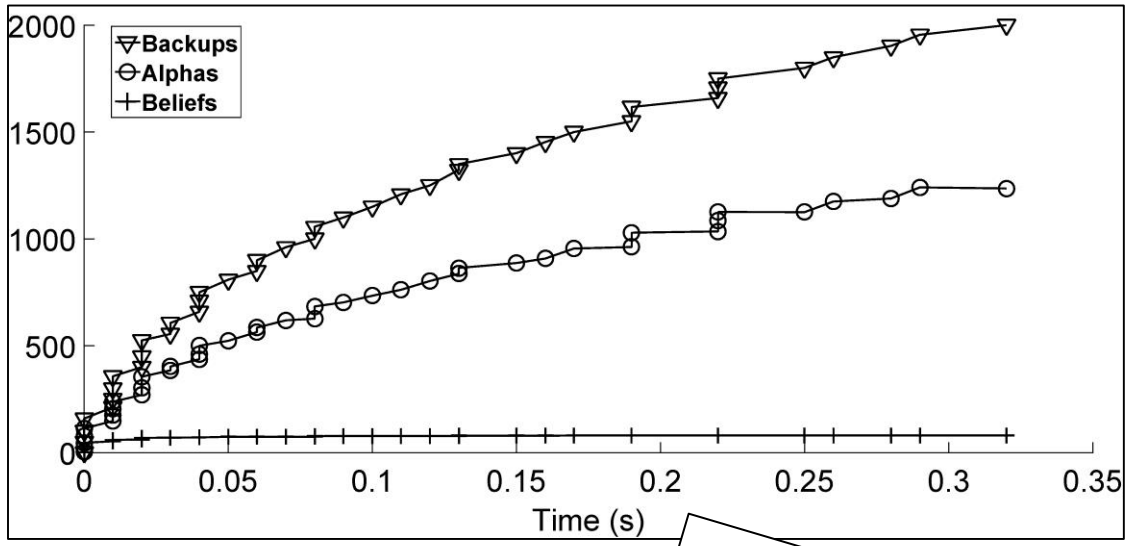
Transition Matrix

60 states

Example: Tubular Joint (2)

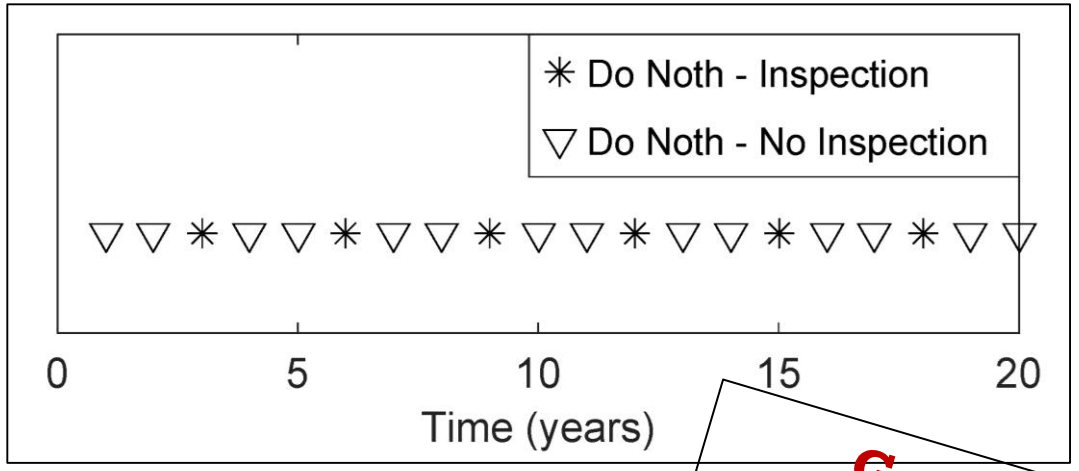
'SARSOP Algorithm': POMDP 60 states

POMDP Simulation



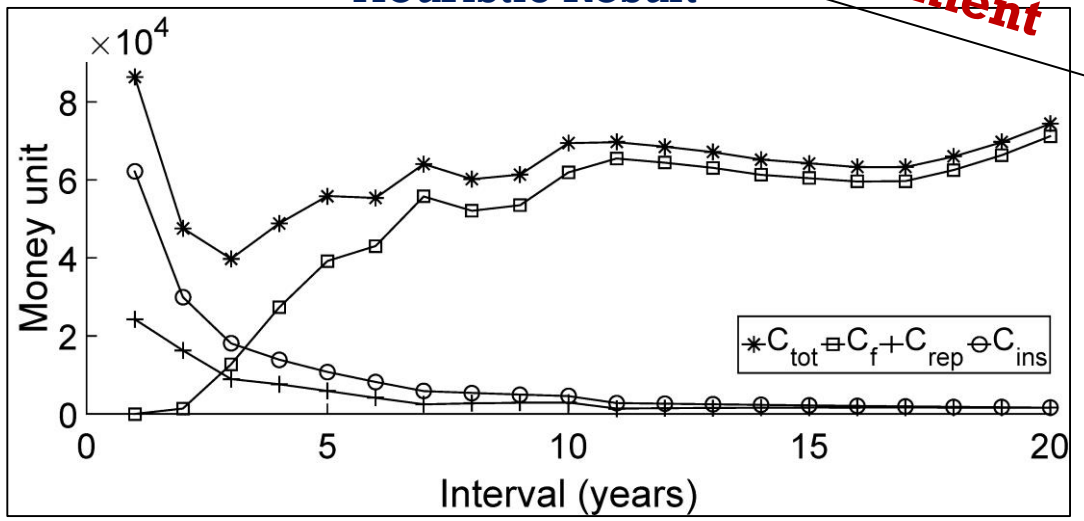
0.32 seconds

POMDP Result



Good Agreement

Heuristic Result



Discussion & Conclusions

- Point-based POMDP - Reasonable CPU Time
- Applied to Offshore Wind Substructures
- Future:
  - System-level
  - Monitoring

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Questions?

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