MAIN DILEMMAS IN ANTICIPATORY TROUBLESHOOTING (DX-17)

Meir Kalech, Roni Stern, Netanel Hasidi

Software and Information Systems Engineering
PROBLEM OUTLINE

- Leasing Companies have many cars.
- Leasing Companies aim to minimize maintenance cost for 3 years.

Graph showing:
- Expected Cost vs. Remaining Time
- Maintenance Cost vs. Time

Key points:
- Minimize maintenance cost for 3 years
- Comparison of expected costs over time
- Graph indicating financial benefits of leasing

Graph elements:
- Time axis ranging from 0 to 3 years
- Maintenance Cost axis ranging from 0 to 4.5
- Expected Cost decreasing over time
- Remaining Time increasing over time
FIX OR REPLACE DILEMMA

Fix

Refurbished

Cheap

Replace

New

Costly

Depends on

Faulty

Previous DX and IJCAI

DX-17: A novel MDP approach
REPLACE HEALTHY DILEMMA

Ignore

Long term cost

Overhead

No overhead

Replace

Short term cost

Depends on
ANTICIPATORY TROUBLESHOOTING

Diagnosis
Root cause

Prognosis
Future failures

System Failure!

Troubleshooting

Anticipatory Troubleshooting

Minimize Long Term Costs
CAR NETWORK EXAMPLE (NORSYS)

Diagnosis
- Root cause

Prognosis
- Future failures
Survival Functions

Maps components age to survival probability

\[ S(C_i, \lambda, \text{time}) = e^{(-\lambda \cdot \text{time})} \]
Evaluate the cost of Fix & Replace until time $T$.

Expected Replace Cost

$$C_{\text{Replace}} + C_{\text{Replace}} \cdot (1 - S(\text{Rep}))$$

Expected Fix Cost

$$C_{\text{Fix}} + C_{\text{Replace}} \cdot (1 - S(\text{Fix}))$$
WHY ONLY A ONE-STEP LOOKAHEAD?

"Planning is the art and practice of thinking before acting."

[Patrick Haslum]

Input

- Set of possible states
- Initial state
- Goal state(s)
- Set of actions
- Reward/cost

Output: a plan that maximizes reward
WHY ONLY A ONE-STEP LOOKAHEAD?

"Planning is the art and practice of thinking before acting."

[Patrick Haslum]

Input
- Set of possible states
- Initial state
- Goal state(s)
- Set of actions
- Reward/cost
- Transition function \( Tr(s',a,s) \)
  \[ = \text{Prob. of reaching } s' \text{ when doing } a \text{ at state } s \]

Output: a plan that max. the expected reward

Components:
- Component's state (age, new/fixed)
- Time to deadline

Fix/replace
- Repair costs
- Who will fail next?
  (see the curves)
**MDP (MARKOV DECISION PROCESS):**

**AN EXAMPLE OF MDP TREE SEARCH (CONSIDER SINGLE FAULT):**

- Problem: How far we can see? (tree depth)

- By the survival curve

![Diagram showing Markov Decision Process example]

- Fault Ti
- Ti+1
  - Fix
  - Pr(Yes)
  - Replace
  - Pr(No)
- Ti+2
- Fault Ti+1
- Ti+1
  - Pr(Yes)
  - Pr(No)
- Ti+2

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Ben-Gurion University of the Negev
EXPERIMENTAL REAL WORLD DOMAINS

• ELECTRICAL POWER SYSTEM:
  • 26 NODES, 6 HEALTH NODES

• CAR DIAGNOSIS SYSTEM:
  • 18 NODES, 7 HEALTH NODES
SURVIVAL CURVE USED FOR THE EXPERIMENTS

\[ s(t) = \exp\left(-\left(\lambda \cdot t\right)^b\right) \]
RESULTS

Ratio = 0.7

( MDP) better then ( always Replace || always Fix || Hybrid)
RESULTS

( MDP) better then ( always Replace || always Fix || Hybrid)
REPLACE HEALTHY COMPONENTS

• OLD COMPONENTS ARE LIKELY TO BREAK

• REPAIR SOONER RATHER THAN LATER
  • REPAIR NOW MAY INCUR LOWER REPAIR COSTS

Current repair costs

Future repair costs
MDP (MARKOV DECISION PROCESS):

AN EXAMPLE OF TREE SEARCH (CONSIDER SINGLE FAULT):

Health Ti

Ti+1

Ignore

Pr(Yes)

Fault Ti+1

Pr(No)

Fix

Replace

Health Ti+2

Ti+1

Pr(Yes)

Fault Ti+1

Pr(No)

Replace

Replace

Ti+2
RESULTS

Considering health components outperforms all others.

Ratio between fix and repair

Total cost

Always-Fix
Always-Replace
HealthReplaceLK_5
Look-Ahead-Tree_8
CONCLUSION

• ANTICIPATORY TROUBLESHOOTING
  • COMBINE DIAGNOSIS AND PROGNOSIS

• FIX-REPLACE DILEMMA:
  • OPTIMAL DECISION - MDP

• REPLACE HEALTHY COMPONENTS DILEMMA
  • OPTIMAL DECISION - MDP
Questions?

Prognosis
• Future failures

Diagnosis
• Root Cause

Diagnosis Engine
Planner
Tester

New Research Field

Anticipatory Troubleshooting