Decision phase and recommending

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Outline

• Motivation and Challenges
• Key Results
  – Framework for Decision Making
  – Method Filtering
  – Conceptual Architecture
• Future Work
MOTIVATION AND CHALLENGES
Objectives and Tasks

• Objectives
  – To develop software services for assisting enterprise decision making based on decision methods and recommender algorithms.
    • Online decision making service will be triggered by the online predictive analytics service

• Tasks
  – T4.1: Conceptual Architecture for Proactive Recommenders for Enterprise Decision Support (ICCS, M7-M12; May ’14 – Oct ‘14)
    • Examine the specific decision problems within the enterprise that can be leveraged by ProaSense
    • by generalising the use case analysis into a generally applicable framework for decision making
Decision Making in the Context of Proactivity

- Proactivity refers to the ability to avoid or eliminate undesired future events
  - by coupling prediction and decision making technologies.

- **Decide**, within time constraints, how to handle forecasted events and states
  - Aiming to move the system into acceptable/desirable states

Motivating Example

- Sensing abnormal conditions in the equipment
- Online data-driven predictions of a possible future degradation or breakdown
- What action to take to eliminate the breakdown or mitigate its effect?
- When to take the action?
  - Depending on context:
    - Location of the equipment
    - Availability of resources
    - Next planned maintenance
    - Etc...
- Capability to anticipate undesired events can enable proactively resolving problems before they appear
While time to failure is approaching zero, reliability is decreasing.

When time to failure becomes zero, a breakdown of the equipment occurs.

The best time to do maintenance is when the maintenance cost is minimum and reliability starts to decrease significantly.

- **P-F interval**: amount of time that elapses between the point where a potential failure occurs and the point where it deteriorates into a functional failure.
- P-F interval corresponds to the concept of the decision window.
Existing Approaches

- Initial state-of-the-art in D1.1
- Extended state-of-the-art in D4.1
- Examined various approaches
  - Model-based
  - Knowledge based
  - Data driven
  - Combinations
- Most existing works focus on maintenance problems
State of the Art analysis
Methods for Prognostic-based Decision Support

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Limitations of Existing Approaches

- Only generic and conceptual methodologies dealing with proactive decision making have been proposed.

- There is no software framework for online event driven decision making
  - based on the predictions derived from Big Data (both real-time and historical ones) analysis.

- Although there are some theoretical research works, there is a limited number of practical applications.
Main Research Questions

How to support **proactive enterprise decision making** based on dynamic event-driven information?

– How to decide what is the best possible action(s) (e.g. maintenance actions) that can be taken **ahead of the time of forecasted events** in order to eliminate or mitigate their potential negative impact (e.g. breakdown)?
– How to decide what is the best time to take each action (e.g. optimal time of applying the maintenance action)?
– How to consider **contextual elements** on the decision process?

![Diagram](image-url)

**From domain experts:**
- List of actions
- Action cost functions
- Event cost functions

**From Observe/Orient:**
- Predicted event with pdf
- Contextual information

**Decision Module**

**Action – time of action pairs**
KEY RESULTS
Diagnosis concerns the actual monitoring and health assessment of a system as well as the detection of failures.

Prognosis has to do with prediction of the future performance of a system (e.g., probability distributions for future failures) based upon its actual health state.

Reactive actions are considered because there is always the possibility that an undesired event, which has not been predicted, occurs.
Literature Methods for real-time Decision Support

- Statistical Analysis
- Markov Chain
- Neural Network
- Mathematical Programming-Optimization
- Markov Decision Process
- Bayesian Network
- Degradation Modeling
- Rules
- Reinforcement Learning
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A practical approach for selecting the appropriate combinations of methods existing in literature based upon the specific decision problem as well as on the functional and/or non-functional requirements of specific applications.

The criteria used are (in priority order):
- Desired output
- Available input
- Domain Knowledge expressed in utility functions
- Knowledge of the degradation process

More combinations of methods can be incorporated in the future.
Illustration of Method Filtering Approach

Flow based on visionary scenario
- Selection of **optimal maintenance actions** for the equipment
- (e.g. reduction of power usage)
- Availability of historical and online data about the degradation evolution as indicated by sensed parameters (e.g. temp)
- Incorporation of **domain knowledge** in utility functions considering criteria such as cost, time and safety

Potential methods
- BN for data-driven estimation of probability distribution of an undesired event (e.g. specific equipment breakdown).
- MDP for generating recommendations about optimal maintenance actions and optimal time for applying these actions
Requirements for the Online Decision Making Component

• Support event-driven decision making

• Provide timely and reliable recommendations

• Support context-aware decision making

• Support decision-making methods involved in different combinations of methods for predicting and decision making

• Improve recommendations on the basis of feedback
WP4 within the ProaSense Conceptual Architecture

- The Decision Making component will be implemented as an event processing agent of the ProaSense architecture, interacting with the rest of the ProaSense components through the Pub/Sub broker.

- The component will take as input data processed and enhanced by event adapters and WP2/WP3 components – represented in the form of event objects carrying information and variables needed for decision making (e.g. predictions, probability distributions, context data).
Incorporation of a wide range of decision methods is allowed—by implemented them as modules and exposing their functionalities as services.

The context-aware decision management service provides the main functionality—by coupling decision methods with contextual information.

The Rec feedback analyser analyses the feedback about the implementation of the recommended actions—to support the business analyst in the process of refining the recommendation generation process.

FUTURE WORK
Future Work

• Incorporate relevant decision methods in the online decision making service

• Research on how online decision methods can be coupled with predictions and contextual information.

• Research on how to refine future recommendations that may be produced by different decision methods
  – on the basis of feedback with respect to the implementation of the recommended actions in the past.

Tasks

• T4.2: Design and Development of Proactive Context-Aware Recommenders (ICCS, M13-M28; Nov ‘14 – Feb ‘16)

• T4.3: Design and Development of Decision Methods for Enterprise Decision Making (ICCS, M13-M28; Nov ‘14 – Feb ‘16)
THANK YOU FOR YOUR ATTENTION! QUESTIONS?