Decision Support in Structural Health Monitoring

Reinhard Stumptner

Institute for Application Oriented Knowledge Processing (FAW)

Johannes Kepler University, Linz, Austria

FAW

Content

- Johannes Kepler University
- Structural Health Monitoring
- IRIS
- Knowledge Discovery in Measurement Analysis
- Case-based Decision Support
- Integration of Decision Support Systems

Johannes Kepler University

- General figures
  - 3 Faculties:
    - Faculty of Engineering and Natural Sciences
    - Faculty of Social Sciences and Economics
    - Faculty of Law
- 120 full professors, ~700 scientific staff
- ~15 000 students (10% foreign students)

Structural Health Monitoring

5 steps of damage state identification process

- Existence. Is there damage in the system?
- Location. Where is the damage in the system?
- Type. What kind of damage is present?
- Extent. How severe is the damage?
- Prognosis. How much useful life remains?

Ch. R. Farrar, K. Worden:
An introduction to structural health monitoring,
Phil. Trans. R. Soc. A , Vol 365, 303–315, Royal Society Publishing, 2007

Structural Health Monitoring

Challenges

- How does a local damage influence the global response of a structure (vibration, stiffness, …)?
- Almost no data of damaged structures is available
- Defining sensor properties and finding suitable sensors and installations
- Convincing structural system owners that the SHM technology provides an economic benefit

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Structural Health Monitoring

Problems

- Human interpretation of measurement data (e.g. of bridges, lamp posts, etc.) is very complex and time-consuming
- Huge amount of measurement data
- Only experts can interpret these data
- Subjectivity and different levels of experience

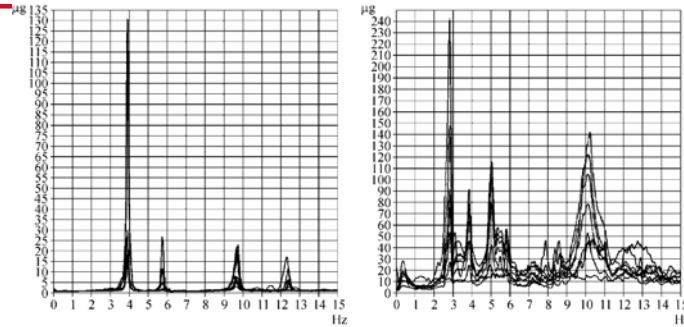
Structural Health Monitoring

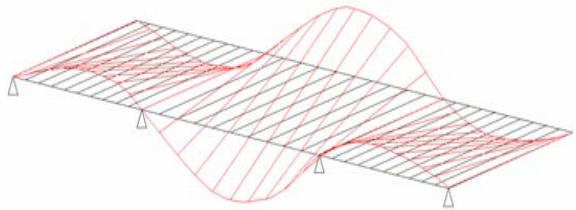
- Objectives (of IT groups)
  - Decision Support System to support the interpretation of measurement data
  - Reduce the workload of experts
  - Support the analytic process (data management, filtering, evaluation, visualization)
  - The system should learn continuously
- Activities of FAW
  - Co-operation with Vienna Consulting Engineers (VCE) in the area of Bridge Monitoring
  - EU-projects: SAFEPIPES, IRIS

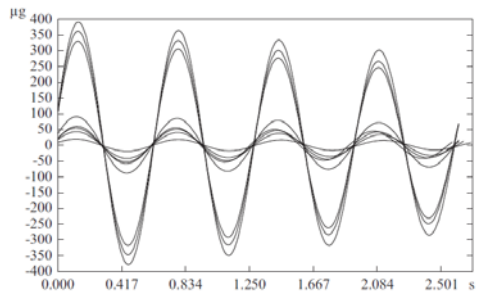
Structural Health Monitoring

Our Partner's (VCE) approach

- Eigenfrequencies
  - The essential parameters in SHM
  - No trivial task to find calculate it from a very noisy signal
  - External influences (wind, rain, temperature, traffic, …)
- Mode-Shapes (Mode of Vibration)
  - Mode in which a structure is oscillating
  - For each eigenfrequency a mode-shape exists
- Damping







IRIS

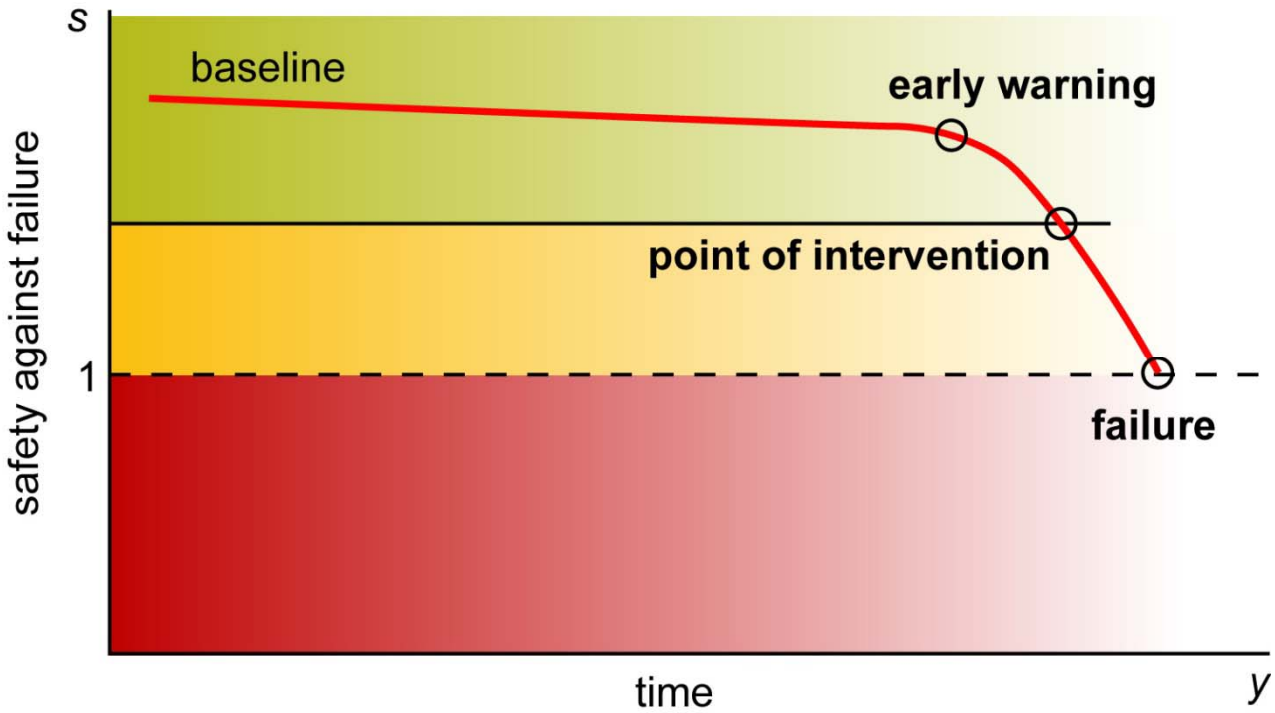
EU Project (FP7)

- IRIS – Integrated European Industrial Risk Reduction System
  - About 40 Partners, one form University of Tokyo (Bridge & Structure Laboratory)
- Motivation
  - Risk assessment and management for industrial systems of different sectors are methodically varying and fragmented – integration desired
- Basic Concept
  - Develop integrated safety technologies, standards and services
- WP7: Monitoring, Assessment, Early Warning, Decision Support
  - FAW has its main task in this work package

IRIS

EU Project (FP7)

Overall Goal



Knowledge Discovery in Measurement Analysis

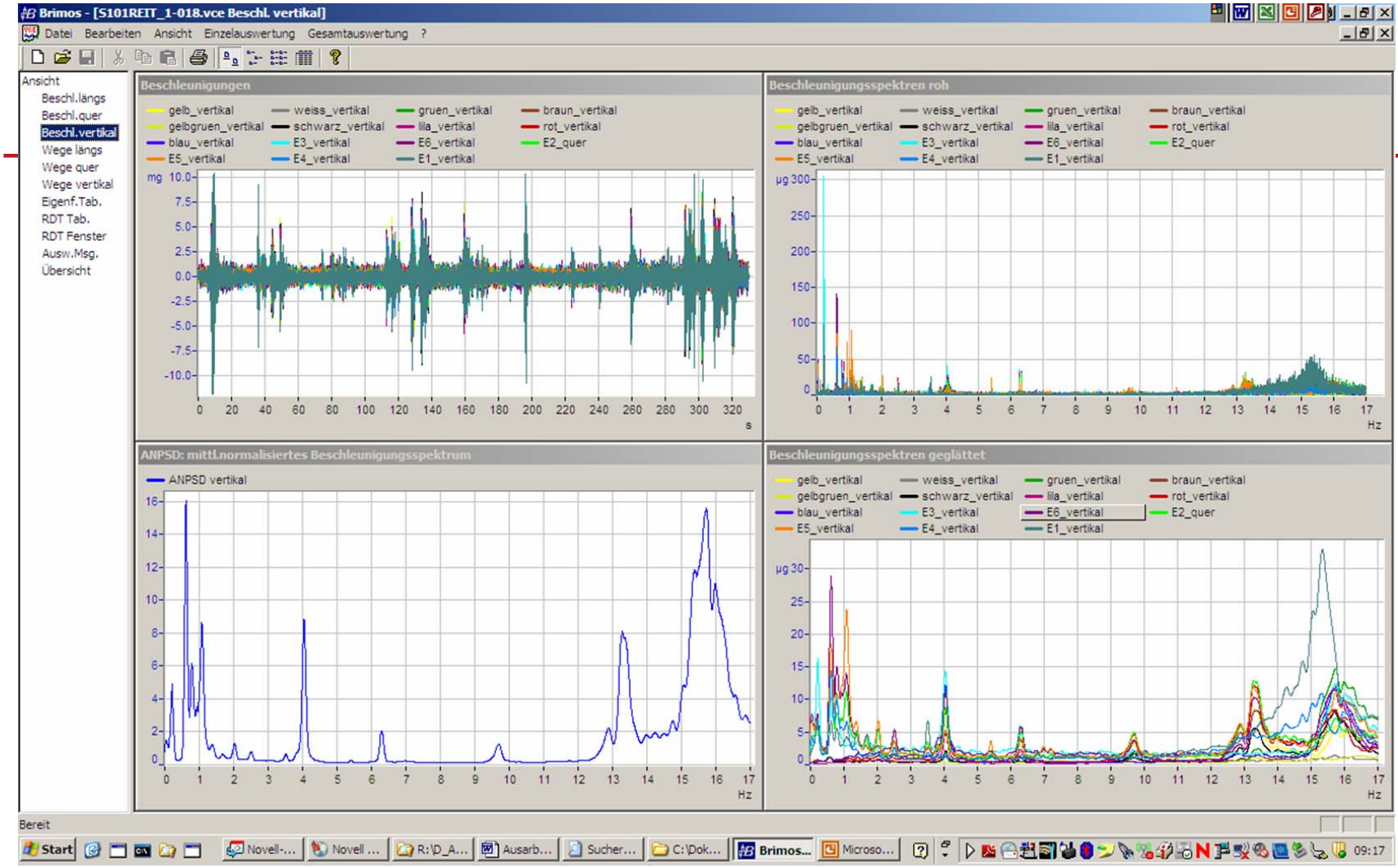
Waikato Environment for Knowledge Analysis (WEKA)

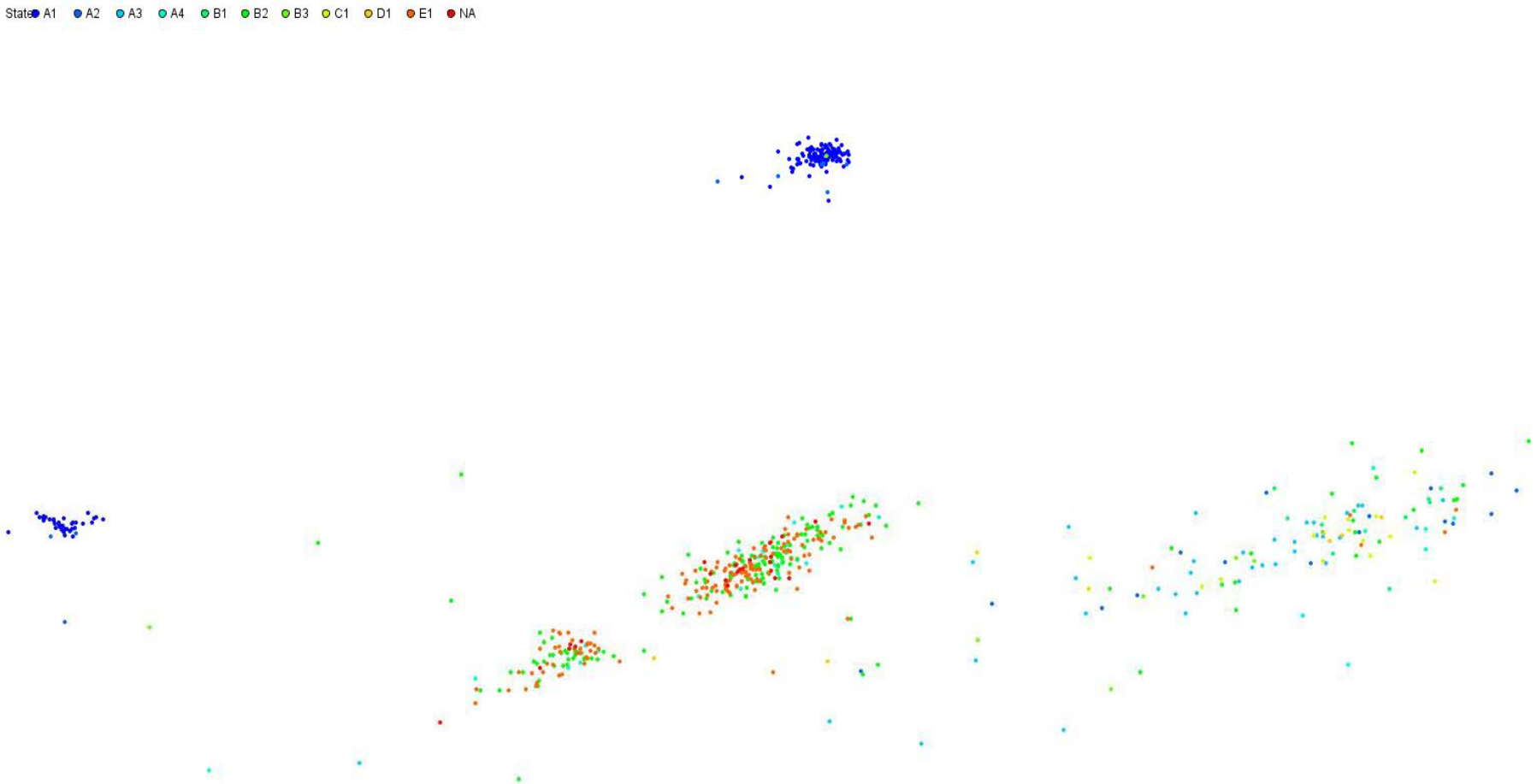
- Data mining Software in Java
- Open Source
- Used for research, education, and applications
- Main features:
  - Data pre-processing tools, learning algorithms and evaluation methods
  - Graphical user interfaces (incl. data visualization)
  - Environment for comparing learning algorithms
- http://www.cs.waikato.ac.nz/ml/weka

Knowledge Discovery in Measurement Analysis

Rapidminer

- A very comprehensive open-source software tools
  - intelligent data analysis, data mining, knowledge discovery, machine learning, predictive analytics, forecasting, and analytics in business intelligence (BI).
- Implemented in Java and available under GPL among other licenses
- Available from http://rapid-i.com
- Data mining processes as a net of operators
- Has over 400 data mining operators

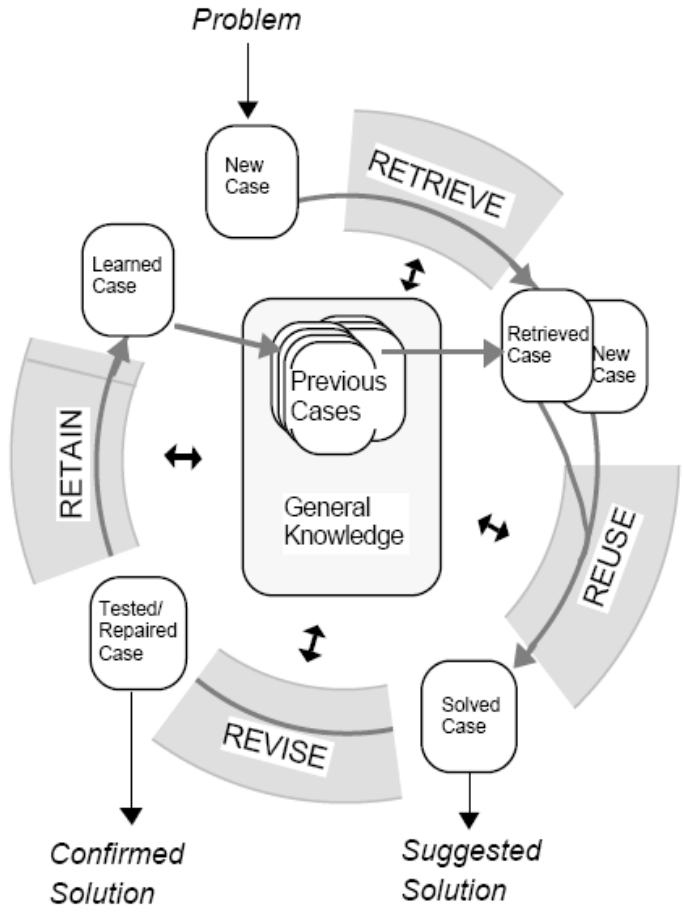

Brimos - [S101REIT_1-018.vce Beschl. vertikal]
Datei Bearbeiten Ansicht Einzelauswertung Gesamtauswertung ?
Ansicht
Beschl.längs
Beschl.quer
Beschl.vertikal
Wege längs
Wege quer
Wege vertikal
Eigenf.Tab.
RDT Tab.
RDT Fenster
Ausw.Msg.
Übersicht
Beschleunigungen
Beschleunigungsspektren roh
ANPSD: mittl.normalisiertes Beschleunigungsspektrum
ANPSD vertikal
Beschleunigungsspektren geglättet
gelb_vertikal
weiss_vertikal
gruen_vertikal
braun_vertikal
gelbgruen_vertikal
schwarz_vertikal
lila_vertikal
rot_vertikal
blau_vertikal
E3_vertikal
E6_vertikal
E2_quer
E5_vertikal
E4_vertikal
E1_vertikal
mg
µg
s
Hz
Bereit
Start
09:17

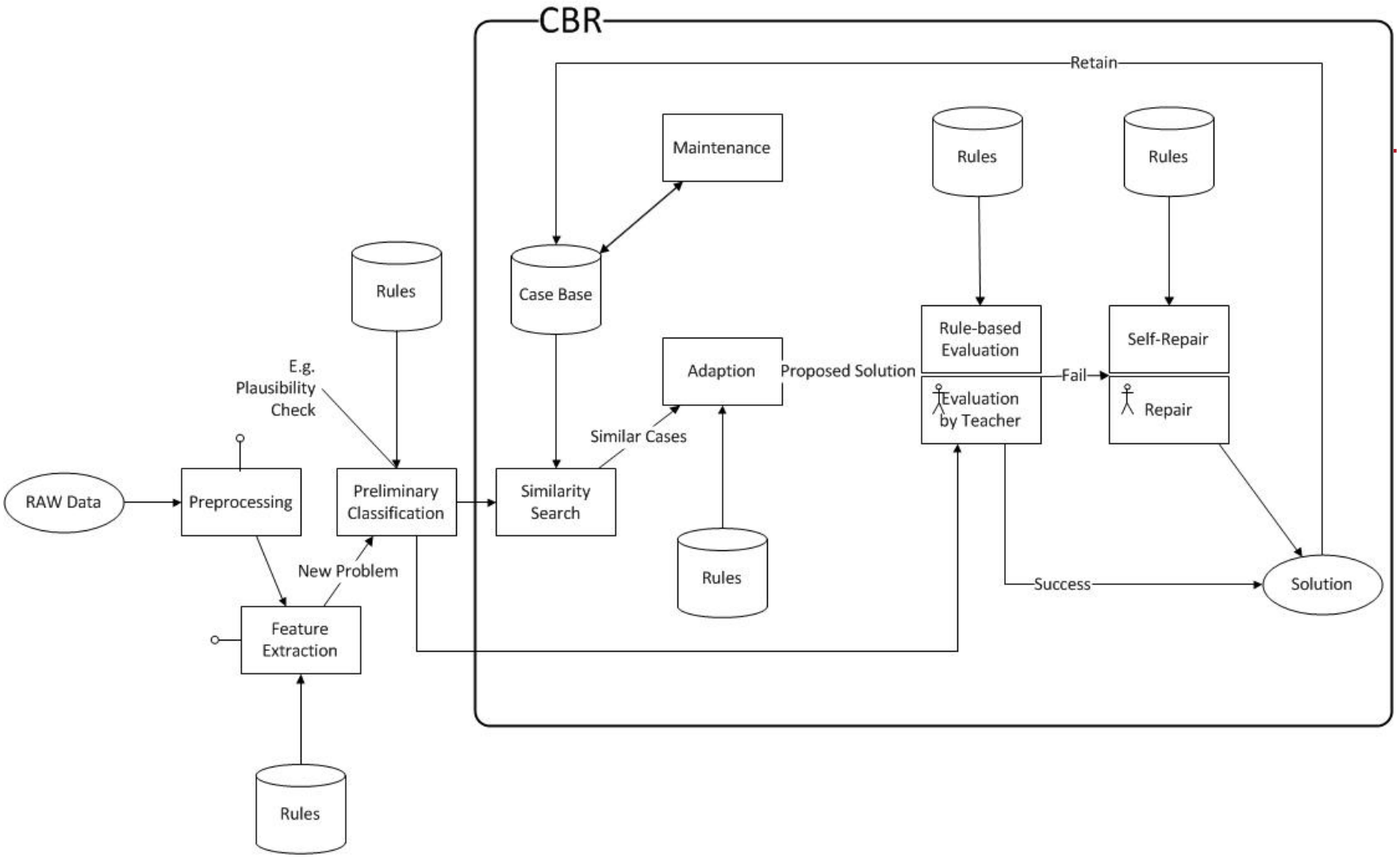

State
A1
A2
A3
A4
B1
B2
B3
C1
D1
E1
NA

Case-based Decision Support

Case-based Reasoning

- "Case-based reasoning is a recent approach to problem solving and learning […]." (Aamodt & Plaza, 1994)
- Cyclic Problem Solving Process
  - Continuous learning
- Objectives
  - Reuse knowledge of known cases (reduce knowledge acquisition effort)
  - Rapid and cost-effective solutions




CBR
Retain
Maintenance
Rules
Rules
Rules
Case Base
Adaption
Proposed Solution
Rule-based Evaluation
Self-Repair
E.g. Plausibility Check
Similar Cases
Fail
Evaluation by Teacher
Repair
RAW Data
Preprocessing
Preliminary Classification
Similarity Search
Rules
New Problem
Success
Solution
Feature Extraction
Rules

Case-based Decision Support

Assessment of Lamp Posts

- Decision Parameters
  - Design (Type, Height, Material)
  - Set of selected eigenfrequencies
  - Visual inspection (oxidation, condition of concrete)
- Assessment by engineer (Classes A-F)
- CBR Task: (Re-)Classification of lamp post's condition
- 85-90% „correct" classifications

Evaluation

Problem

Case Name: TestCase1

Eigenfrequency 3, Longitudinal, Stimulated:	14,3798828125
Eigenfrequency 3, Longitudinal, Ambient:	11,7919921875
Eigenfrequency 3, Transverse, Stimulated:	13,51318359375
Eigenfrequency 3, Transverse, Ambient:	4,4921875
Eigenfrequency 2, Longitudinal, Stimulated:	9,326171875
Eigenfrequency 2, Longitudinal, Ambient:	3,594970703125
Eigenfrequency 2, Transverse, Stimulated:	11,63330078125
Eigenfrequency 2, Transverse, Ambient:	3,57666015625
Eigenfrequency 1, Longitudinal, Stimulated:	3,662109375
Eigenfrequency 1, Longitudinal, Ambient:	1,507568359375
Eigenfrequency 1, Transverse, Stimulated:	3,79638671875
Eigenfrequency 1, Transverse, Ambient:	2,996826171875
Height:	9
Stand:	Seal to the Conrete - Good
Arm:	2-fold
Accretion:	1-fold
Condition Outside:	No Rust
Condition Inside:	No Rust
Condition Lower Region:	Coat available, good Condition
Condition Upper Region:	Coat available, good Condition

Solution

Class A

Retain Solution

Discard Solution

Class A

Correct Solution

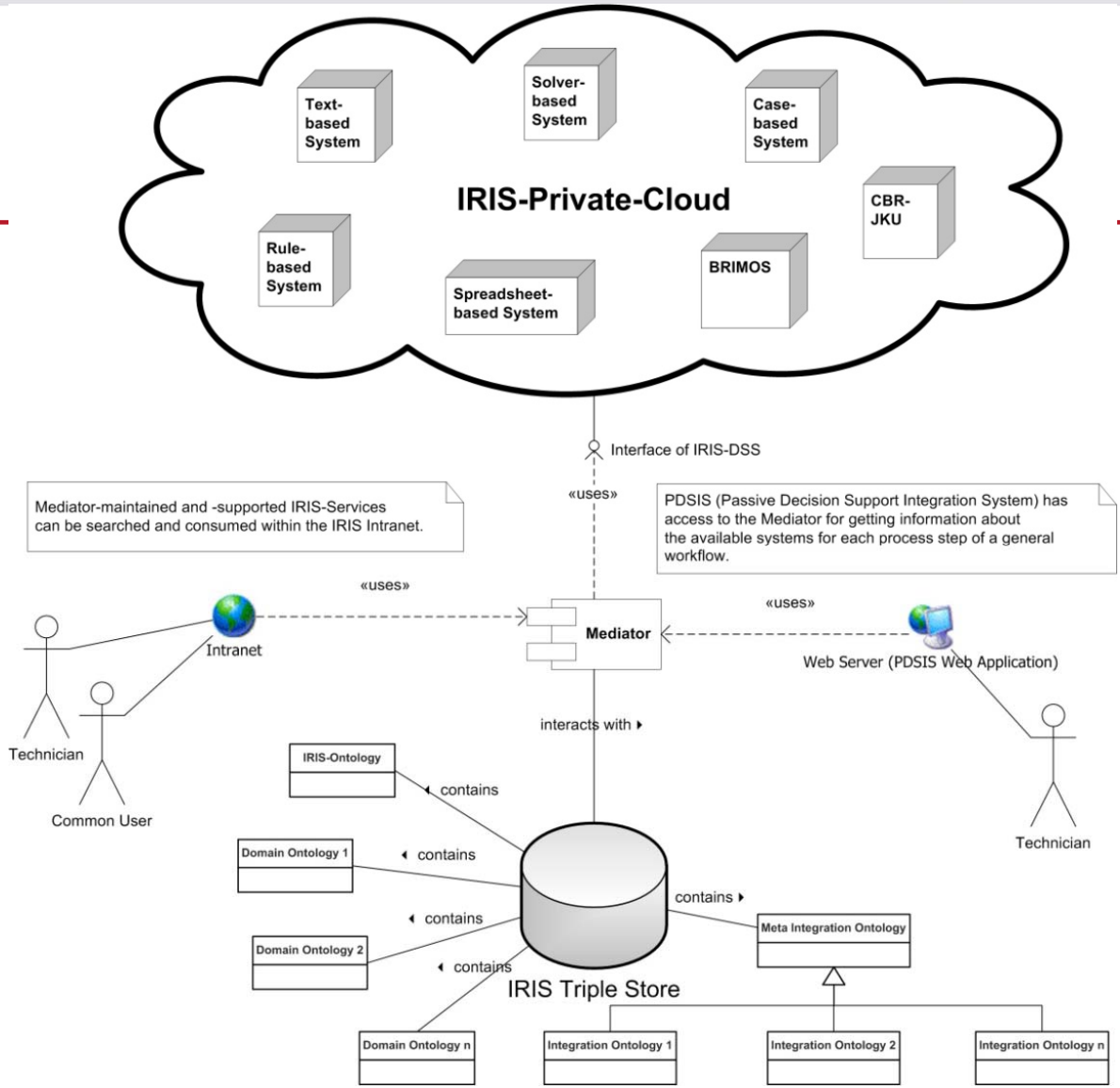
Integration of Decision Support Systems

- FAW approach based on …
  - Distributed stand-alone applications (Decision Support Systems)
  - Different syntax and semantic of operations, in- and outputs
  - Ontologies used for modeling semantics explicitly
- Measurement analysis process – single ontology approach
  - General workflow with in- and outputs for each process step
  - Semantic association between systems and workflow
  - Global conceptualization for classifying of systems
  - Quality measures for each system per process step

Integration of Decision Support Systems

- Mediator-based integration system
  - Guided workflow
  - Suggestion of adequate systems
  - Assessment of systems (accept/deny)

Question: Which level of detail can be reached by describing input and output parameters of certain Decision Support Systems (DSS) in general and especially its specific operations, if we use Semantic Web concepts like Ontologies (e.g. DAML+OIL, OWL, etc.) and Rule Languages (e.g. RIF)?


Text-based System
Solver-based System
Case-based System
IRIS-Private-Cloud
CBR-JKU
Rule-based System
Spreadsheet-based System
BRIMOS
Interface of IRIS-DSS
«uses»
Mediator-maintained and -supported IRIS-Services can be searched and consumed within the IRIS Intranet.
PDSIS (Passive Decision Support Integration System) has access to the Mediator for getting information about the available systems for each process step of a general workflow.
«uses»
«uses»
Intranet
Mediator
Web Server (PDSIS Web Application)
Technician
Common User
interacts with
IRIS-Ontology
contains
Technician
Domain Ontology 1
contains
contains
contains
Meta Integration Ontology
Domain Ontology 2
contains
IRIS Triple Store
Domain Ontology n
Integration Ontology 1
Integration Ontology 2
Integration Ontology n

Summary

- Structural Health Monitoring
  - Measurement analysis, challenges/problems
- EU-FP7-Project “IRIS”
- Knowledge Discovery in Measurement Analysis
  - WEKA, Rapidminer
- Case-based Decision Support
  - Assessment of simple structures (lamp posts)
- Ontology-based Integration of Decision Support Systems

JOHANNES KEPLER UNIVERSITY LINZ | JKU

Thank you for your attention!

Reinhard Stumptner

FAW - Department for Applied Knowledge Processing

Johannes Kepler University, Linz, Austria

Phone: +43-7236-3343-764

Email: rstumptner@faw.jku.at

http://www.faw.jku.at