Self-healing systems – What are they?

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Seminar introduction, 2007

Earlier version: AMICT, Aug 2006

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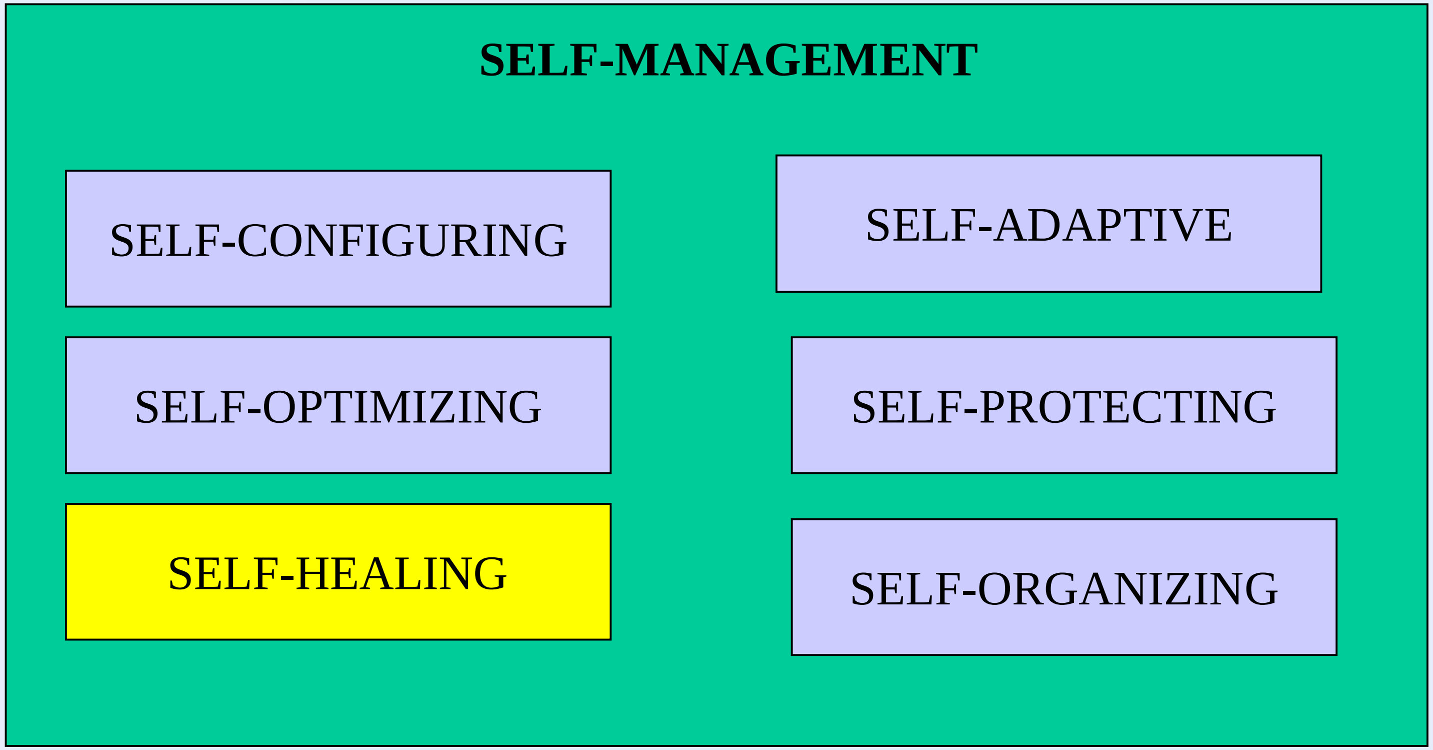
- **Overview**
- **Autonomic Computing**
- **Elements of Self-Healing**
- **Architectural approach**
- **Examples**

Overview



SELF-MANAGEMENT

SELF-CONFIGURING

SELF-ADAPTIVE

SELF-OPTIMIZING

SELF-PROTECTING

SELF-HEALING

SELF-ORGANIZING

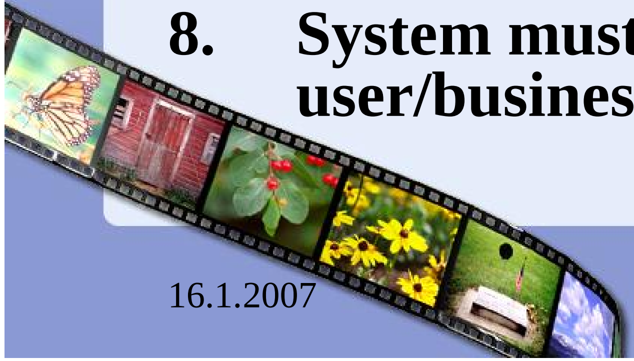
Autonomic Computing Initiative by IBM, 2001

Self-* (selfware)

- Self-configuring
- Self-healing
- Self-optimising
- Self-protecting
- Self-aware
- Self-monitor
- Self-adjust
- Self-adaptive
- Self-governing
- Self-managed
- Self-controlling
- Self-repairing
- Self-organising
- Self-evolving
- Self-reconfiguration
- Self-maintenance

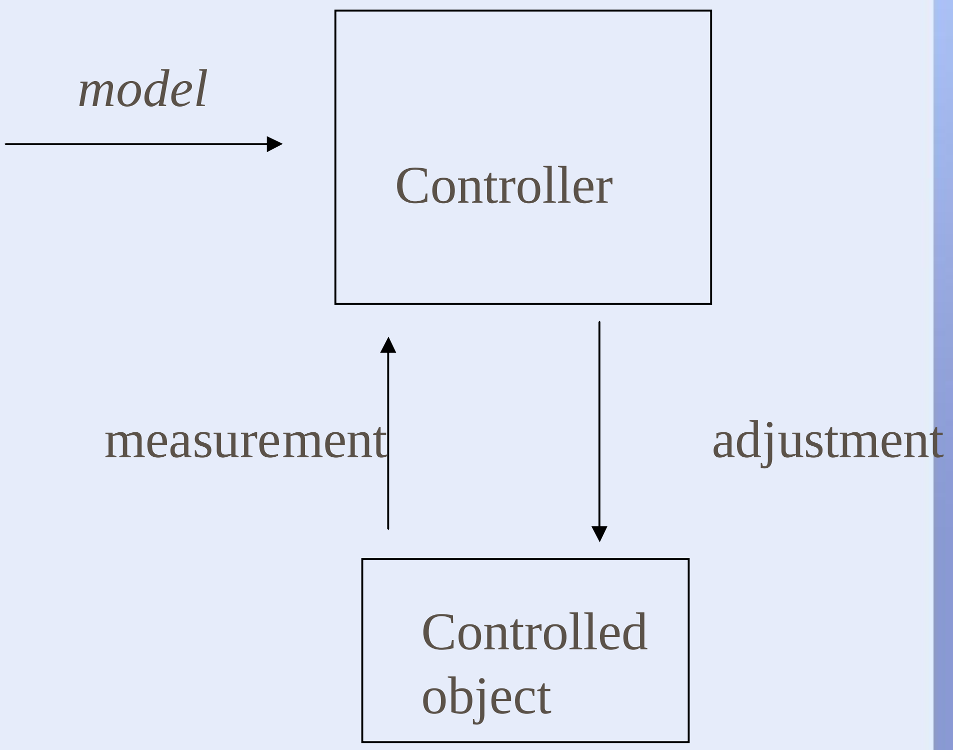
Eight Goals for a System

1. System must know itself
2. System must be able to reconfigure itseld within its operational environment
3. System must pre-emptively optimise itself
4. System must detect and respond to its own faults as they develop
5. System must detect and respond to intrusions and attacks
6. System must know its context of use
7. System must live in an open world
8. System must actively shrink the gap between user/business goals and IT solutions



Autonomic Computing

- Basic model: closed control loops
  - Based on Process Control Theory
- Controller continuously compares the actual and expected behavior and makes needed adjustments



model

Controller

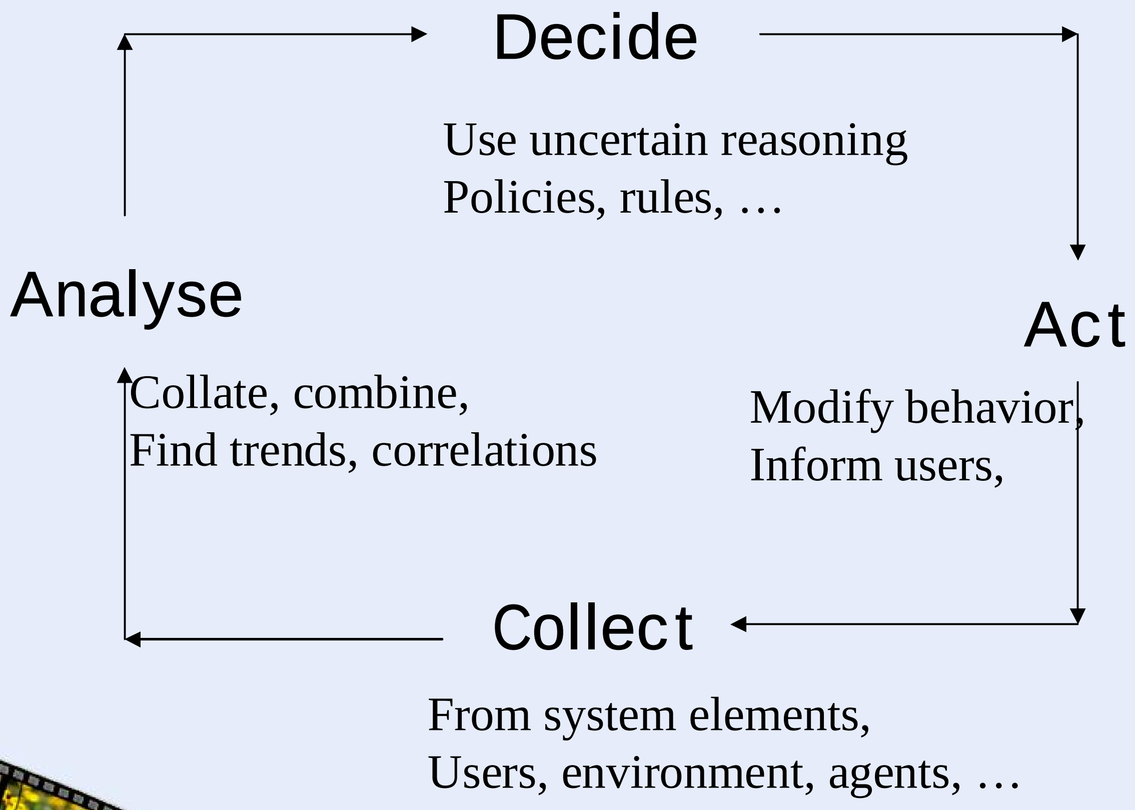
measurement

adjustment

Controlled object

SEE: Any control-theory books

Autonomic Control Loop



Decide

Use uncertain reasoning
Policies, rules, …

Act

Modify behavior,
Inform users,

Collect

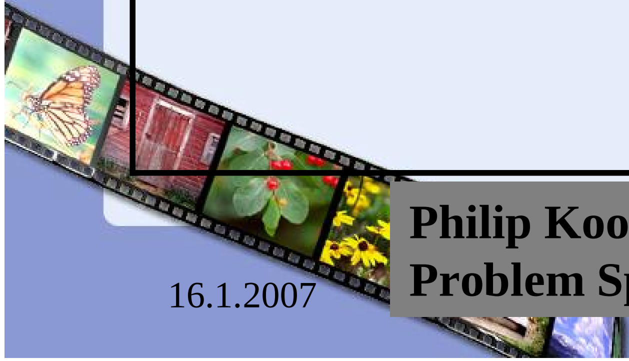
From system elements,
Users, environment, agents, …

Analyse

Collate, combine,
Find trends, correlations

Elements of Self-Healing 1/2

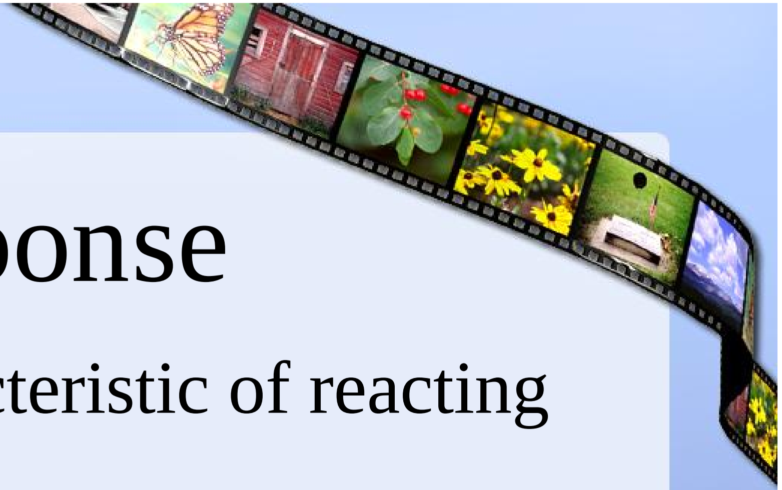
Fault model	Fault duration Fault manifestation Fault source Granularity Fault profile expectations
System response	Fault Detection Degradation Fault response Fault recovery Time constants Assurance



Philip Koopman: Elements of the Self-Healing System Problem Space. In Proceedings of ICSE WADS 03.

Fault models

- Each aspects describes a characteristic of the fault.
  - Duration: Is the fault permanent?
  - Manifestation: What does the fault do to the system?
  - Source: Where does the fault come from?
  - Granularity: Is the fault global or local?
  - Occurrence expectation: How often will the fault occur?

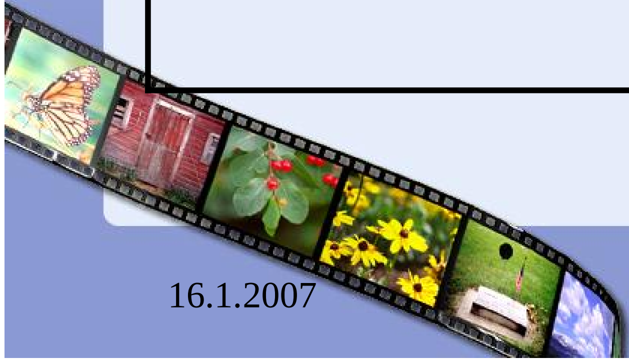


System Response

- Each aspect describes a characteristic of reacting to faults.
  - Detection: How does a system detect faults?
  - Degradation: Will the system tolerate running in a degraded state?
  - Response: What does a system do when the fault occurs?
  - Recovery: Once a fault occurs, can the system return to a healthy state?
  - Time: How much time does the the system have to respond to a fault?
  - Assurance: What assurances does a system have to maintain while handling a fault?

Elements of Self-Healing 2/2

System completeness	Architectural completeness Designer Knowledge System self-knowledge System evolution
Design context	Abstraction level Component homogeneity Behavioral predetermination User involvement in healing System linearity System scope



System Completeness

- Each aspect describes how system implementation affects self-healing.
  - Architecture completeness: How does the system deal with incomplete and unknown parts?
  - Designer knowledge: How do developers deal with unavoidable abstractions?
  - System self-knowledge: What does the system need to know about its components perform self-healing?
  - System evolution: How does the system cope with changing components and environments?

Design Context

- Each aspect describes how system design affects self-healing.
  - Abstraction level: What abstraction level performs self-healing.
  - Component homogeneity: Are the system’s distributed components homogeneous?
  - Behavioral predetermination: Is the system non-deterministic?
  - User involvement: Does a user do some of the healing?
  - System linearity: Is the system constructed out of composable components?
  - System scope: Does the size of the system affect self-healing possibilities?

Alternative taxonomy

- Maintenance of health
  - Redundancy, probing, ADL, component relation and regularities, diversity, log-analysis
- Detection of failure, discovery of non-self
  - Missing, monitoring model, notification of aliens
- System recovery back to healthy state
  - Redundancy, repair strategies, repair plan, self-assembly, recovery-oriented computing, replication, gauges, event-based action,

Ghosh, D., Sharman, R., Rao H.R., and Upadhyaya:
Self-healing – survey and synthesis. Decision Support Systems 42 (2007) 2164-2185 – available online www.sciencedirect.com

Size of the self-healing unit?

- **Component**
  - **Focus on connectors and component discovery**
- **Service**
  - **Service interfaces, Service discovery, restart**
- **Node**
  - **Network and interface failures, change to new connection**

Architectural approach

- The healing or recovery part often requires reconfiguration and adaptation
- They change the architecture
  - Locate and use alternative component
  - Restart (or rejuvenation or resurrection) the failed component
- Self-healing can be build on reflective middleware

Experiments

- OSAD – model (On-demand Service Assembly and Delivery)
- MARKS – Middleware Adaptability for Resource discovery, Knowledge usability and Self-healing
- PAC – Autonomic Computing in Personal Computing Environment
- Using self-healing components and connectors

Life-cycle of Self-Healing

- **OSAD – On-demand Service Assembly and Delivery**
- **Prototype in JINI environment**
- **Looking for alternatives only by name**

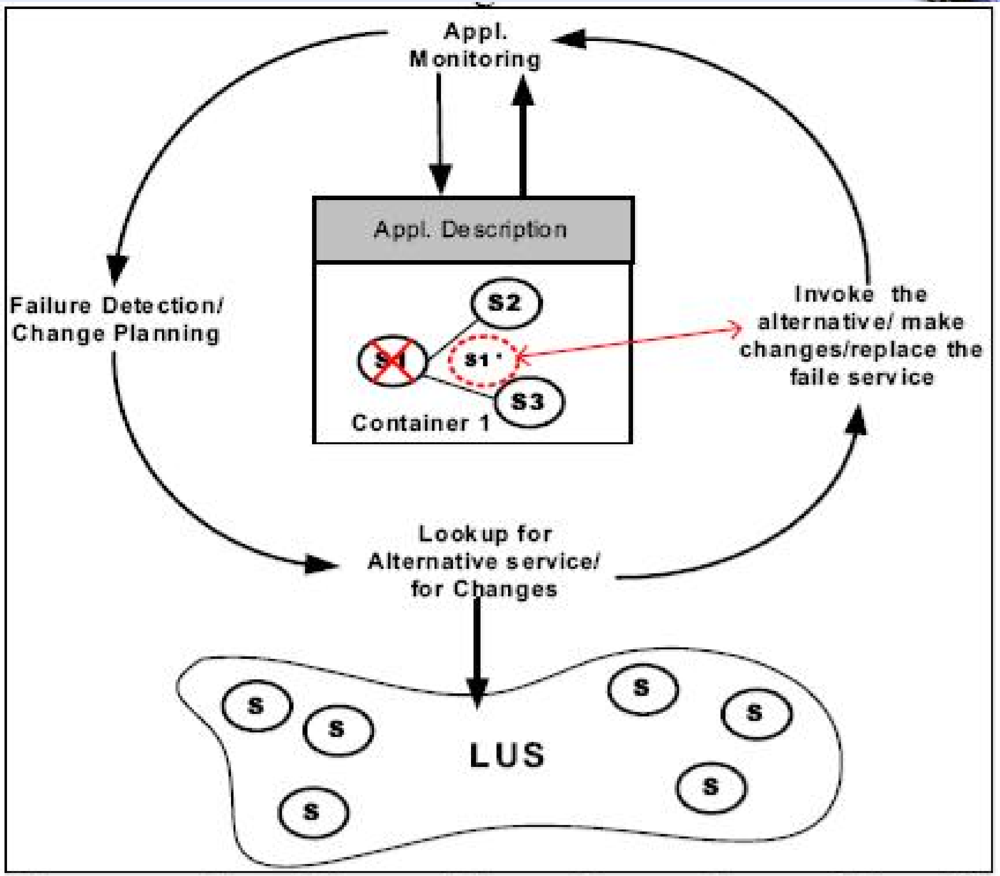

Appl. Monitoring
Appl. Description
Failure Detection/ Change Planning
S2
S1
S1'
S3
Container 1
Invoke the alternative/ make changes/replace the faile service
Lookup for Alternative service/ for Changes
S
S
S
S
S
S
LUS

Figure 1. The lifecycle of self-healing behaviour in OSAD model.

Grishikashvili, E.; Pereira, R.; Taleb-Bendiab, A.; **Performance Evaluation for Self-Healing Distributed Services** Parallel and Distributed Systems, 2005. Proceedings. 11th International Conference on Volume 2, 20-22 July 2005 Page(s):135 - 139

MARKS

- Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing

- Marks is targeted at embedded and pervasive, small mobile handheld devices.
- New Services: Context, Knowledge Usability and Self-Healing
- Prototype: Dell Axim 30 pocket PC & .NET

Sharmin, M.; Ahmed, S.; Ahamed, S.I.;**MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing) for Mobile Devices of Pervasive Computing Environments**
Information Technology: New Generations, 2006. ITNG 2006. Third International Conference on
10-12 April 2006 Page(s):306 - 313

MARKS Architecture

- **Services**
- **Core components**
- **ORB**

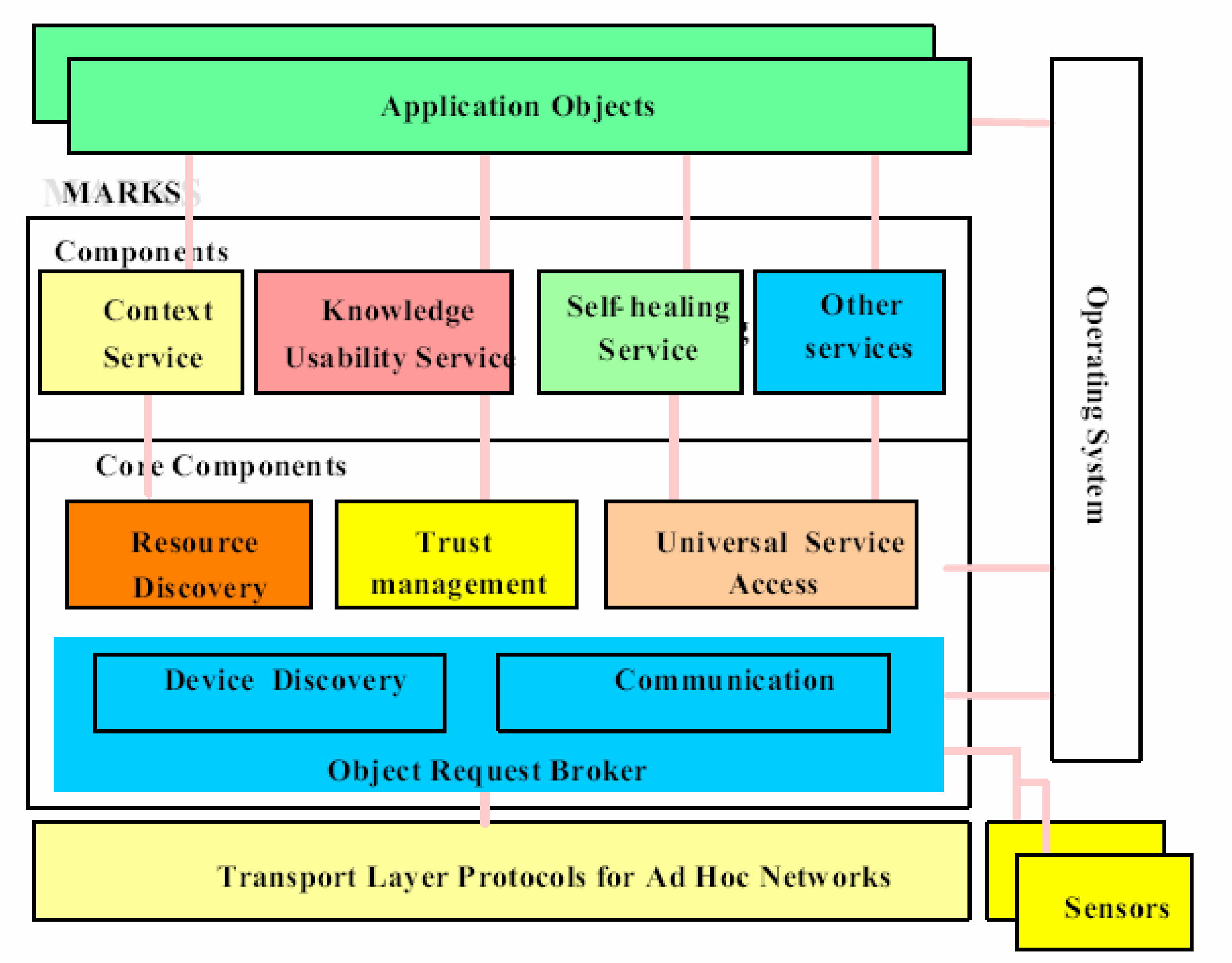


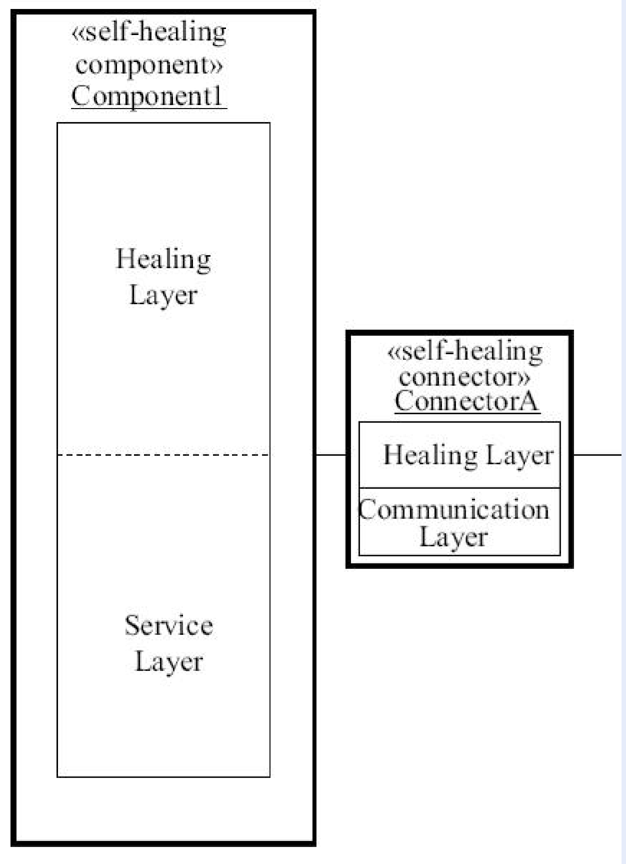
Figure 1. MARKS architecture

Self-healing in MARKS

- *Healing manager* (of the network) to handle all fault types
  - To isolate faulty device (Fault containment)
  - Select surrogate device or share load among working members
- Resource manager used as repository of information for backup purposes
- *Self-healing unit* (on each device)
  - One process named *rate of change of status*
  - For monitoring the device and announcing the conditions

Self-healing components and connectors

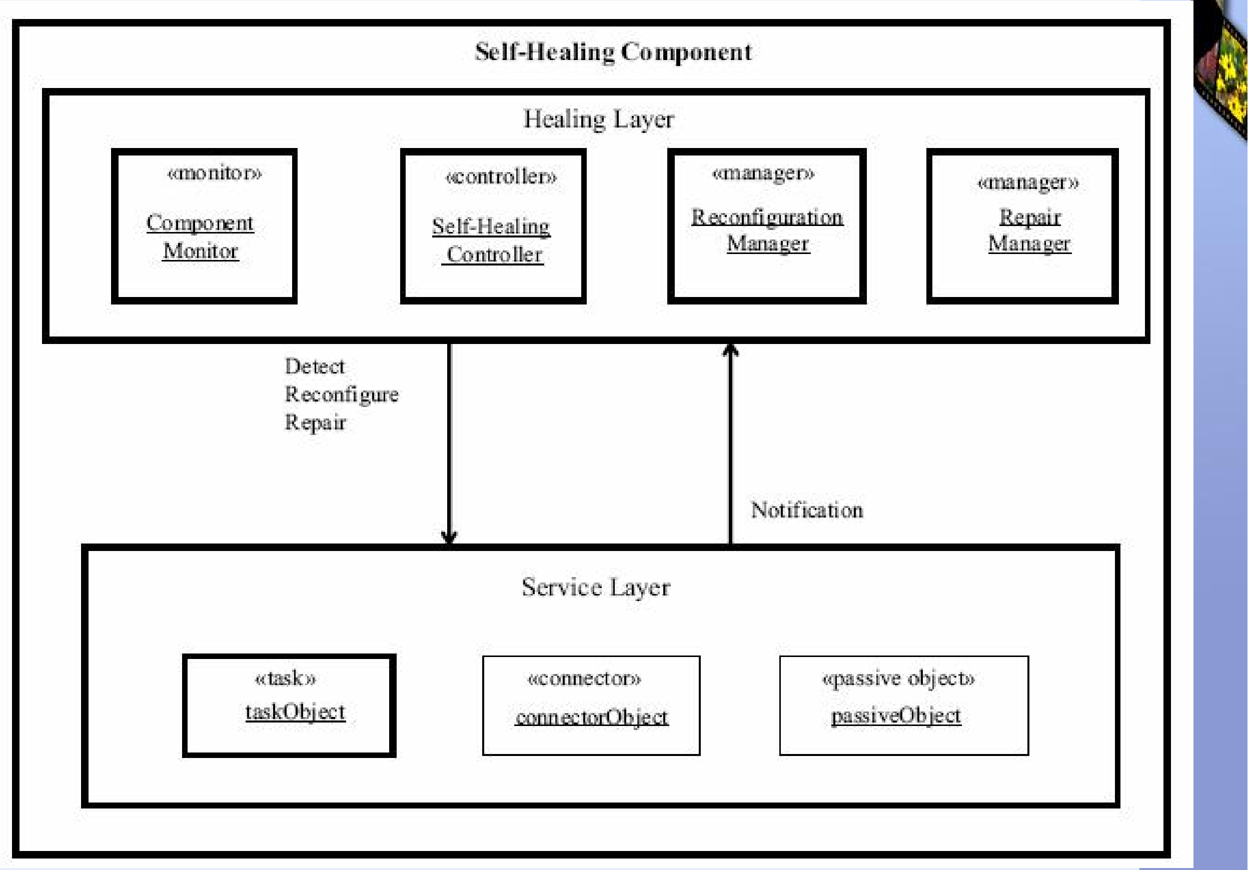
- **Healing layer**
  - **Monitoring and reconfiguration decisions**
- **Service layer**
  - **Normal functionality**
  - **Report all events to healing layer**



Shin, M.E.; Jung Hoon An; **Self-Reconfiguration in Self-Healing Systems**
Engineering of Autonomic and Autonomous Systems, 2006. EASe 2006. Proceedings
of the Third IEEE International Workshop on 27-30 March 2006 Page(s):89 - 98

Self-healing component

- **For healing:**
  - **Self-Healing controller**
  - **Component monitor**
  - **Reconfiguration manager**
  - **Repair manager**



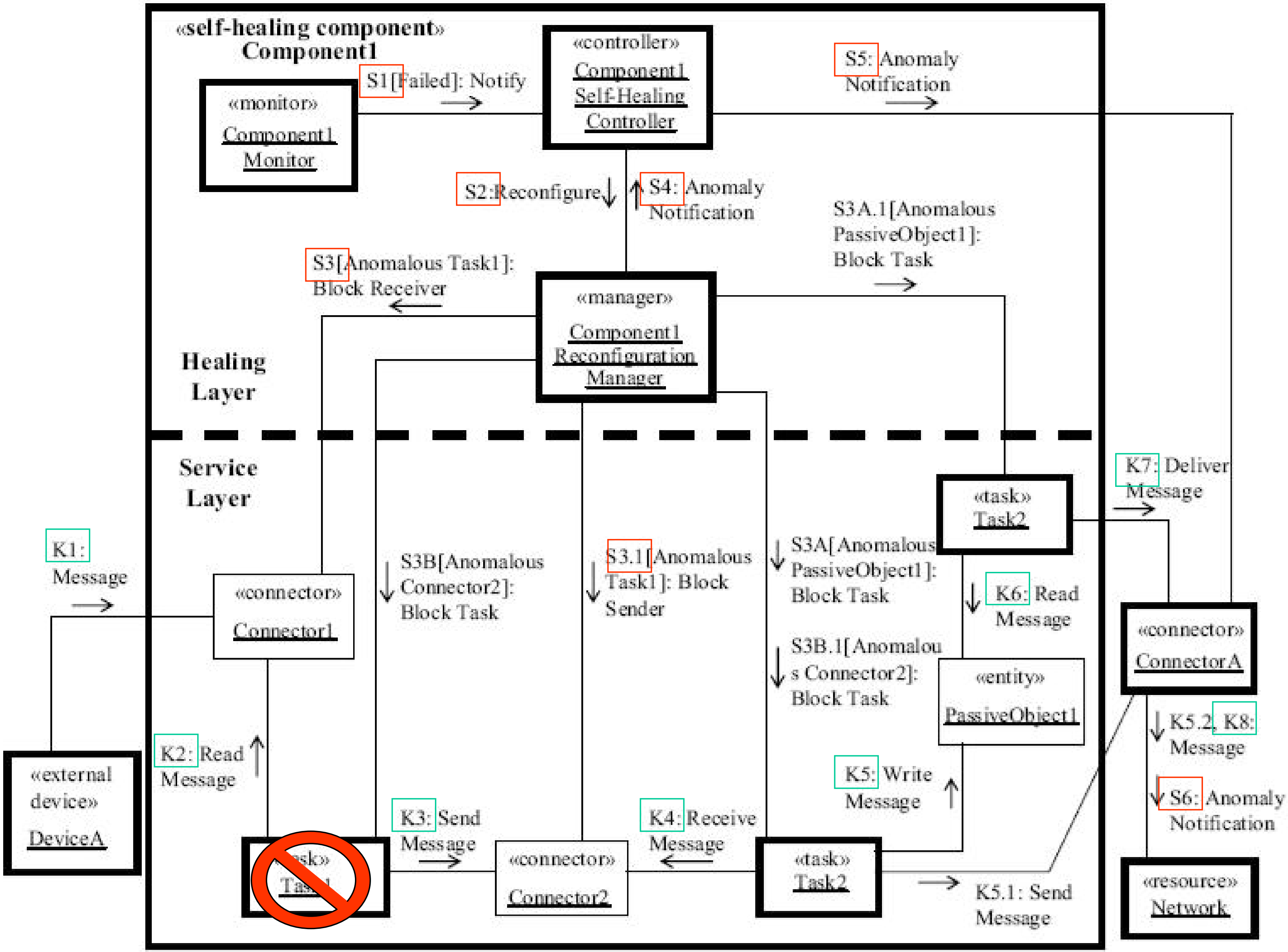


Fig.4 Dynamic self-configuration in Component1

Reconfiguration decision

- **Anomaly detection:**
  - **Compare observed and expected behavior**
- **Isolate the ’faulty’ object**
- **Repair or replace the faulty object (and return back to normal operation)**

PAC – Personal Autonomic Computing

- **Goal: collaboration among personal systems to take a shared responsibility for self-awareness and environment awareness**
- **Proof of concept: *self-healing tool* utilizing pulse monitor (heart beat)**

Sterritt, R.; Bantz, D.F.;
Personal autonomic computing reflex reactions and self-healing
Systems, Man and Cybernetics, Part C, IEEE Transactions on
Volume 36, Issue 3, May 2006 Page(s):304 - 314

PAC

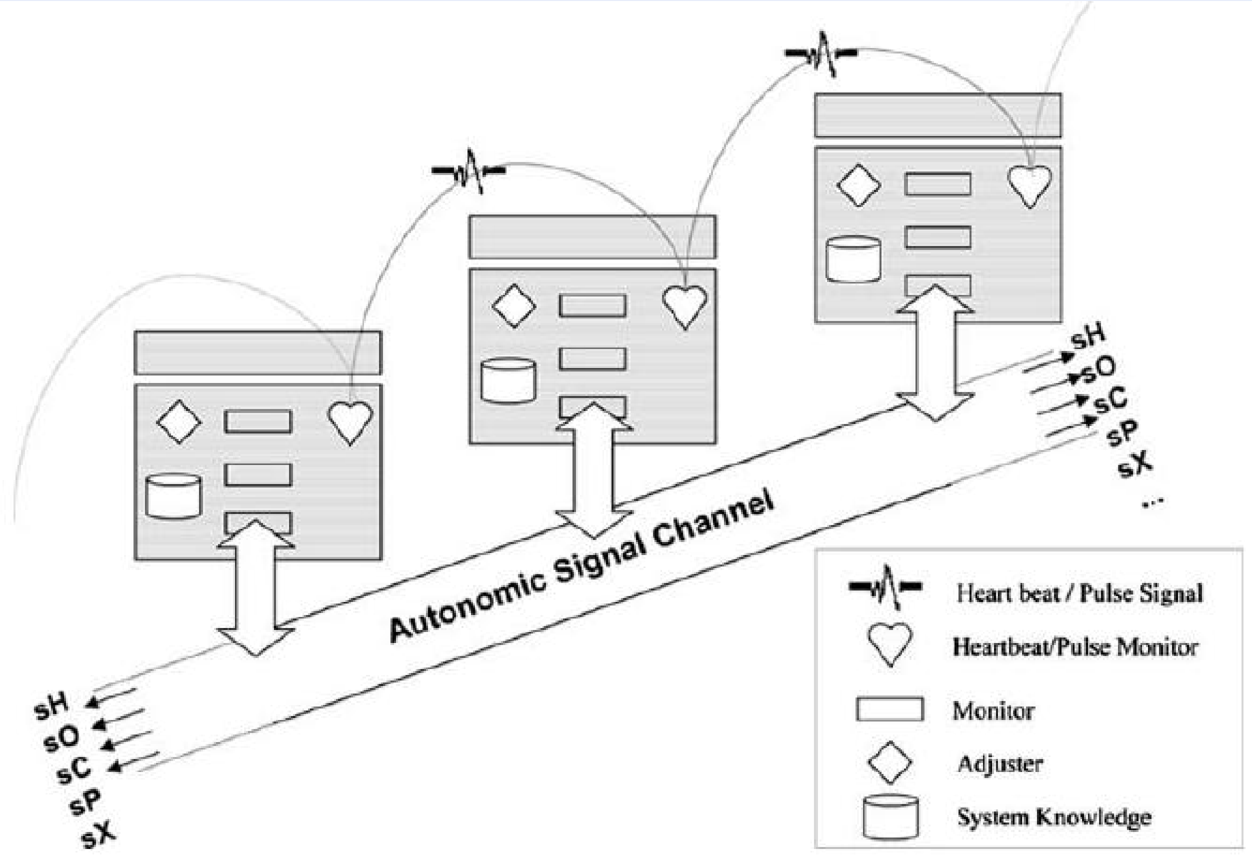


Fig. 3. Autonomic environment.

PAC

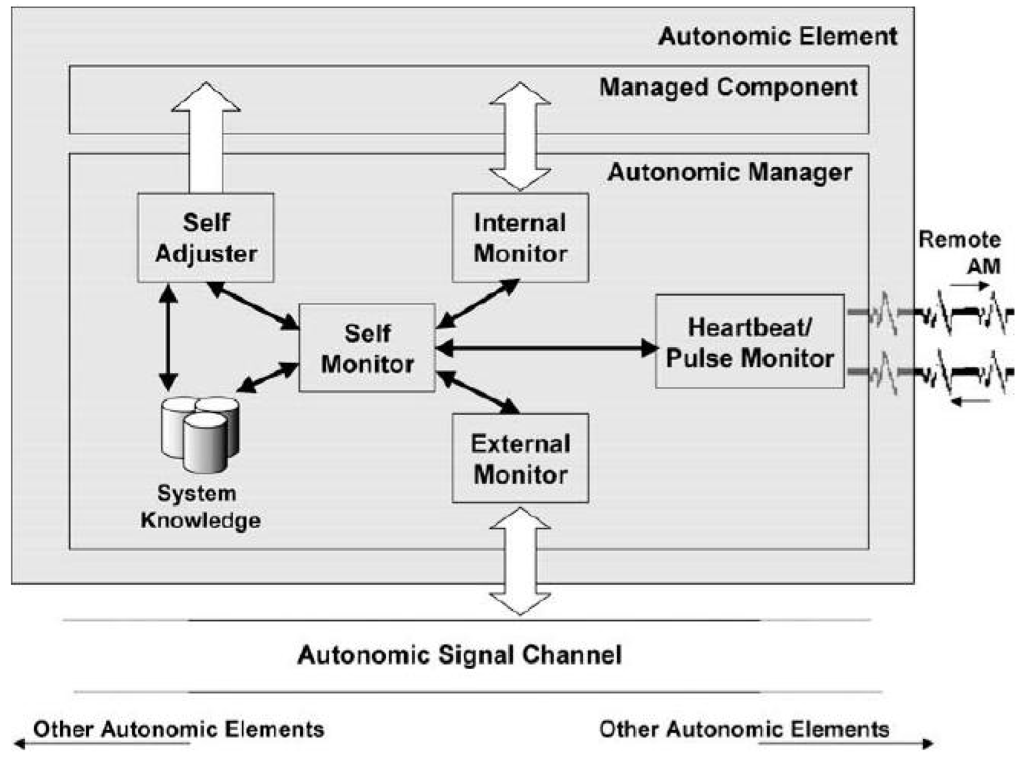


Fig. 2. Architecture of a PAC element.

- **Autonomic manager**
  - **Self-adjuster**
  - **Self-monitor**
  - **Internal-monitor**
  - **External-monitor**
  - **Pulse-monitor (and generator)**

Conclusions

- Self-healing has three roots:
  - Autonomic and self-management world
  - Distributed systems world (especially middleware)
  - Dependable and fault-tolerance world
- The failure recognition and repair decisions might be faster if autonomic
- However: effects of incorrect decisions can be large (and correct them time consuming)

References

- Philip Koopman: Elements of the Self-Healing System Problem Space. In Proceedings of ICSE WADS 03
- Jeffrey O. Kephart and David M. Chess: The Vision of Autonomic Computing. IEEE Computer, January 2003, pp. 41-50
- D. Ghosh et.al.: Self-healing systems – survey and synthesis. Decision Support Systems 42 (2007) pp. 2164-2185

Additional material

1. **George Heineman A Model for Designing Adaptable Software Components**
   In 22nd Annual International Computer Software and Applications Conference, pages 121--127, Vienna, Austria, August 1998.
2. **Vikram Adve, Vinh Vi Lam, Brian Ensink Language and Compiler Support for Adaptive Distributed Applications**
   ACM SIGPLAN Workshop on Optimization of Middleware and Distributed Systems (OM 2001) Snowbird, Utah, June 2001 (in conjunction with PLDI2001)
3. **Marija Rakic, Nenad Medvidovic Increasing the Confidence in Off-the-Shelf Components: A Software Connector-Based Approach**
   Proceedings of SSR '01 on 2001 Symposium on Software Reusability : Putting Software Reuse in Context

4. **Richard S. Hall, Dennis Heimbigner, Alexander L. Wolf** A **Cooperative Approach to Support Software Deployment Using the Software Dock**
International Conference on Software Enginering, May 1999

5. **Sarita V. Adve, et.al. The Illinois GRACE Project: Global Resource Adaptation through CoopEration**
In proceedings of Workshop on Self-Healing, Adaptive and self-MANaged Systems (SHAMAN) 2002

6. **Yennun Huang, Chandra Kintala, Nick Kolettis, N. Dudley Fulton Software Rejuventation: Analysis, Module and Applications**
Proceedings of the 25th International Symposium on Fault-Tolerant Computing (FTCS-25), Pasadena, CA, pp. June 1995, pp. 381-390

7. **IBM director software rejuvenation. – white paper**

6. **David Patterson, et.al. Recovery Oriented Computing (ROC): Motivation, Definition, Techniques, and Case Studies**
   UC Berkeley Computer Science Tech. Rep. UCB//CSD-02-1175, March 15, 2002
7. **George Candea, James Cutler, Armando Fox, Rushabh Doshi, Priyank Garg, Rakesh Gowda Reducing Recovery Time in a Small Recursively Restartable System**
   Appears in Proceedings of the International Conference on Dependable Systems and Networks (DSN-2002), June 2002
8. **Aaron B. Brown, David A. Patterson Rewind, Repair, Replay: Three R's to Dependability**
   To appear in 10th ACM SIGOPS European Workshop, Saint-Emilion, France, September 2002
9. **Sheng Liang, Gilad Bracha Dynamic Class Loading in the Java(TM) Virtual Machine**
   Conference on Object-oriented programming, systems, languages, and applications (OOPSLA'98)

Schedule (conference simulation)

- 1. period: Writing the paper
  - 2. meeting: List of references, refinement of the topic
  - 3. meeting: Table of content
  - 4. meeting: draft (to show to Tiina)
  - 5. meeting: Paper ready for review
  - 6. meeting: Review feedback (from two members)
  - Paper ready and submitted before second period
- 2. period: Presentations

Seminar topics for Spring 2007

- Faults / Recovery / Autonomic computing
- Self-adaptive services
- Configuration-level adaptation
- Self-healing architectures
  - Agent-based
  - Components
  - Middleware
- Performance issues
  - Self-optimisation etc.

Seminar topics for Spring 2007

- **Detection and monitoring**
- **Instrumentation**
- **Diagnosis (*intelligent systems area*)**
- **Repair**
  - **Dynamic updates**
  - **Hot-swap & reconfiguration (software /hardware)**
  - **Remote healing**
- **Network related**
  - **Survivable networks**
  - **Sensor networks**
- **Software analysis / design for healing**