Self-healing systems – What are they?

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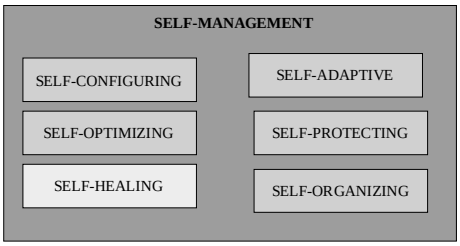
Seminar introduction, 2007
Earlier version: AMICT, Aug 2006

Content

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

Overview



Autonomic Computing Initiative by IBM, 2001

Self-* (selfware)

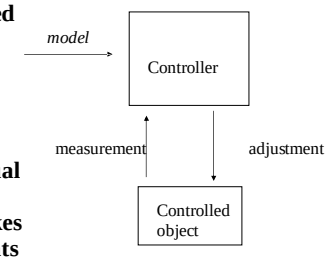
- **Self-configuring**
- **Self-healing**
- **Self-optimising**
- **Self-protecting**
- **Self-aware**
- **Self-monitor**
- **Self-adjust**
- **Self-adaptive**
- **Self-governing**
- **Self-managed**
- **Self-controlling**
- **Self-repairing**
- **Self-organising**
- **Self-evolving**
- **Self-reconfiguration**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

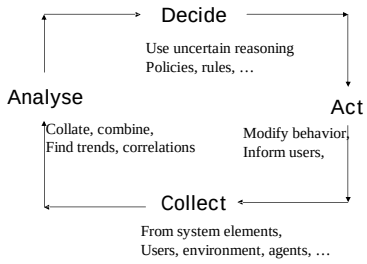
Autonomic Computing

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



SEE: Any control-theory books

Autonomic Control Loop



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**

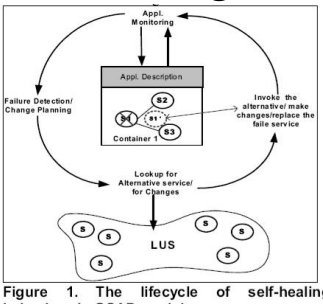


Figure 1. The lifecycle of self-healing behaviour in OSAD model.

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**

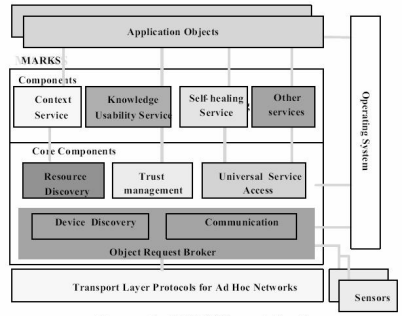


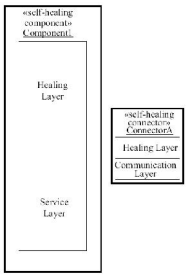
Figure 1. MARKS architecture

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

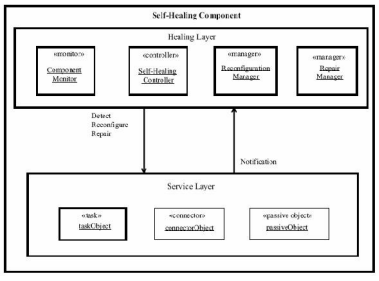
- **Healing layer**
  - **Monitoring and reconfiguration decisions**
- **Service layer**
  - **Normal functionality**
  - **Report all events to healing layer**



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**



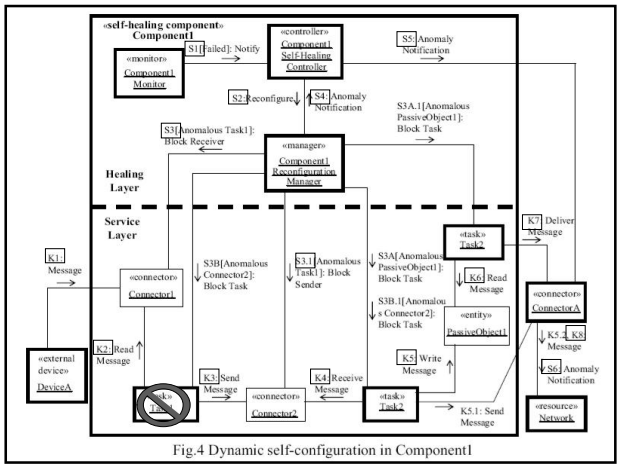


Fig.4 Dynamic self-configuration in Component1

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
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PAC

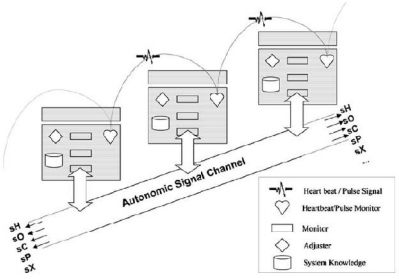

Fig. 3. Autonomic environment.

PAC

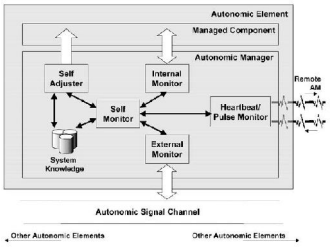

Fig. 2. Architecture of a PAC element.

- **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

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   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 CoopErating**
   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**