Adaptability and Fault Tolerance

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- <u>Context</u>: self-* and dependability;
- <u>Focus</u>: adaptability and fault tolerance;
- State of the art;
- Conclusions;

Self-* and Dependability

- Dependability:
  - the ability to deliver service that can justifiably be trusted;
- Self-* properties of systems:
  - the support for autonomy;
  - self-adaptable, self-managing, self-optimising, self-healing, self-repairing, self-configuring, etc.
- Adaptability:
  - the ability of a system of accommodating changes while providing its specified services;
    - run-time changes;

Dependability

Dependability - the ability to avoid service failures that are more frequent and more severe than is acceptable;

- **threats** - undesired, but in principle expected circumstances:
  - faults, errors and failures;
- **attributes** – properties of the system:
  - reliability, availability, integrity, confidentiality, and safety;
- **technologies** – methods and techniques for providing and reach confidence on ability to attain dependability:
  - rigorous design, validation & verification, fault tolerance, and system evaluation;

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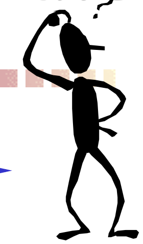
Dependability - Threats

(Yves Deswarte & David Powell)

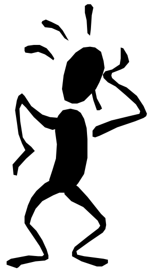
adjudged or hypothesized cause of an error



Fault

that part of system state which may lead to a failure

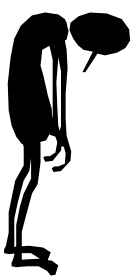
activation



Error

occurs when delivered service deviates from implementing the system function

propagation



Failure

causation → **Fault** *activation* → **Error**

Adaptability - Initiators

- Changes:
  - the act, process, or result of altering or modifying;
  - internal changes:
    - component failures, overload of resources, etc.
  - external changes:
    - environmental, requirements, etc.
- There is no fundamental chain of adaptability initiators;

Threats and Initiators

- Changes correspond to events (faults):
  - changes can be dormant if not activated;
- What is the consequence of change (errors)?
  - what would be the equivalent to error free and erroneous states?
  - these states are created when changes are activated and can remain latent until detected;
- What is the equivalent of failure?
  - unsuccessful adaptation?
  - the system might continue to provide its services, but ignoring the change;

Dependability - Technologies

Fault avoidance: build a system with no faults:

- rigorous design – fault prevention;
  - formal and rigorous notations, processes, adapters, etc.
- verification & validation – fault removal;
  - model checking, fault injection, testing, simulation, etc.

Fault acceptance: impossible to rid the system of faults:

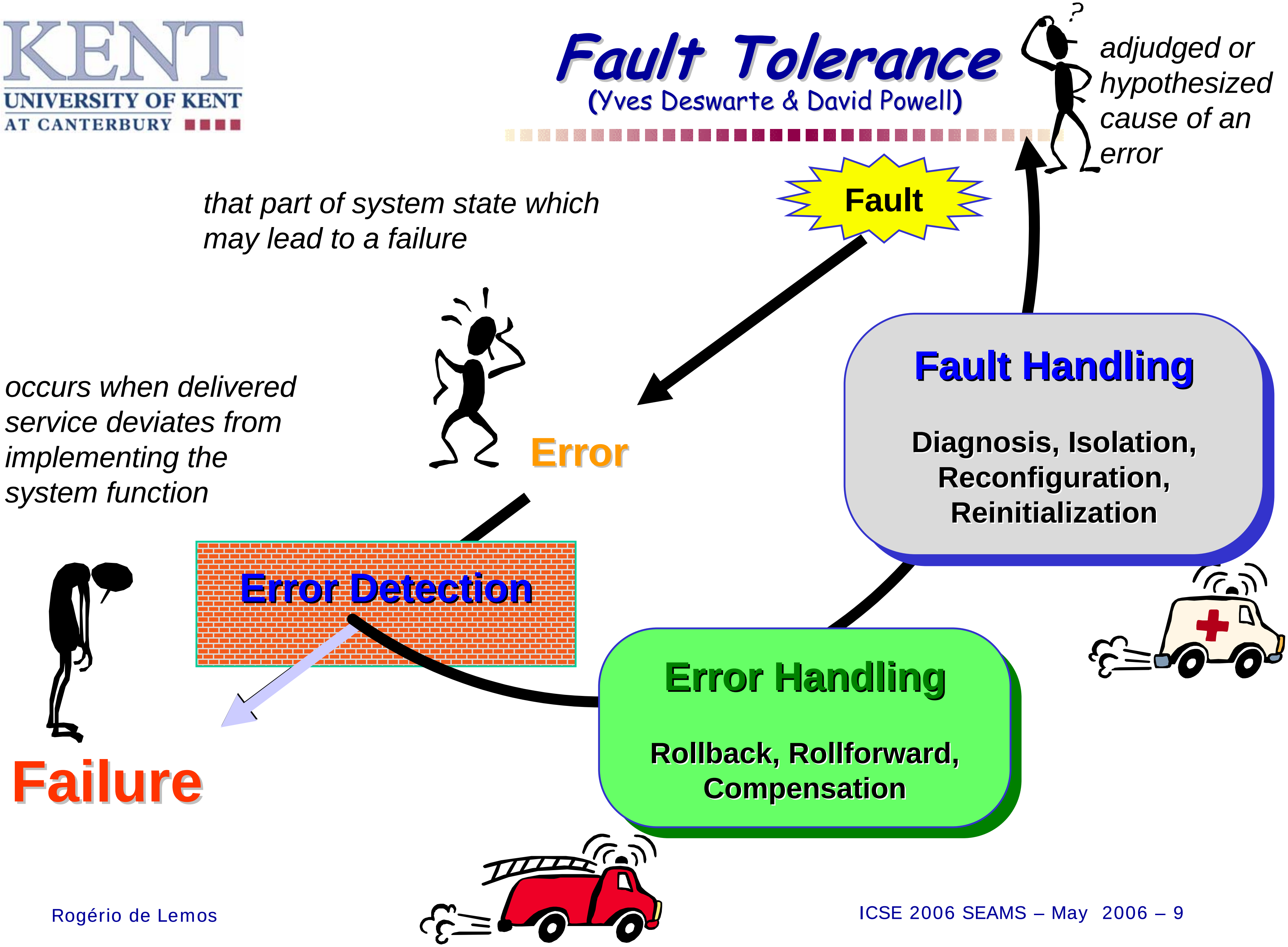
- fault tolerance;
- system evaluation – fault forecasting;
  - empirical approaches, Markov models, etc.

Fault Tolerance

Fault tolerance aims at avoiding the failure of the system:

- **error detection**:
  - detects the presence of errors;
- **recovery**:
  - transforms a system state that contains errors or faults into a error free state, or faults that can be re-activated;
    - error handling:
      - eliminates errors from the system state;
    - fault handling:
      - prevents faults from being activated again;
      - diagnosis, isolation and reconfiguration;

Fault Tolerance
(Yves Deswarte & David Powell)



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System Structure

Fault tolerance is about system structuring;

- structure is what enables the system to generate the behaviour;
- determines how effectively this structuring can be used to provide means of **error confinement**;
  - avoid the propagation of errors;
  - what interactions can exist and at what rate;
- it is not restricted to system architecture;

Structural flexibility the basis for adaptation;

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Fault Assumptions

Faults are undesirable, though expected circumstances:

- systems can fail in many different ways;

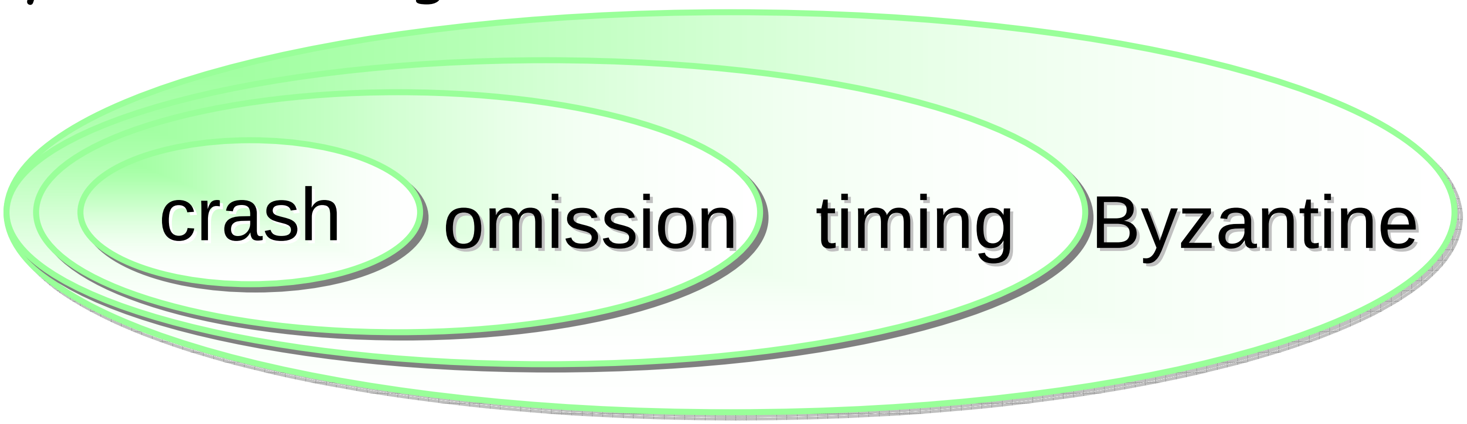
In the design of fault-tolerant systems, it is essential to define assumptions:

- **nature** of faults - dictates the type of redundancy that must be implemented:
    - space or time;
    - replication or diversification;
- **rate** of faults - influences the amount of redundancy needed to attain a given dependability;

Fault Assumptions

How a component behaves when it fails:

- crash fault being the simplest and most restrictive (or well-defined) type;
- Byzantine being the least restrictive;



The different types of changes needs to be classified;

- behavioural assumptions;

State of the Art

Adaptive fault tolerance

- property that enables a system to maintain and improve fault tolerance by adapting to changes in environment and policy;
  - monitor the system;
  - reconfigure the application when its configuration of it is not appropriate for the dependability requirements;
- distributed systems:
  - different layers:
    - middleware / fault tolerance /adaptation;
  - consensus problem;

State of the Art

- AQuA – CORBA based operating system;
  - dynamic replication of objects;
  - Proteus:
    - dynamic fault tolerance through adaptive reconfiguration;
    - allows to specify the degree of dependability at the application level;

State of the Art

- Chameleon - adaptive infrastructure;
  - allows different levels of availability requirements;
  - explicit representation of adaptive policies;
  - provides dependability through the use of ARMORs (Adaptive, Reconfigurable, and Mobile Objects for Reliability):
    - managers for monitoring and recovering resources;
    - daemons for providing communication;
    - common ARMORs for providing application-required dependability;
  - enables multiple fault tolerance strategies to co-exist;

State of the Art

Architectural fault tolerance

- Error detection and recovery;
  - techniques based on exception-handling;
    - application dependent;
    - iC2C and iFTE;
- Fault handling
  - system reconfiguration;
    - replacement of components, connectors and configurations;
  - dynamic reconfiguration;

State of the Art

Bio-inspired computing and **statistical methods**:

- data-oriented approaches
  - data mining large quantities of observations for identifying patterns;
- anomaly (fault and intrusion) detection;
  - neural networks, genetic algorithms, etc.;
  - adaptive error detection using artificial immune systems:
    - problem: how to learn from rare events!
- statistical learning techniques (SLT) applied to system recovery;

Conclusions

- Changes are like faults, though:
  - they might be desired/undesired and expected/unexpected;
- Classification of the types of changes:
  - otherwise becomes application dependent;
    - e.g., exception handling for the support of fault tolerance;
- How system structuring affects adaptability?
  - is software that flexible for supporting run-time change?
    - impact of design-time change;
  - to scope the impact of change;
    - confinement of the consequence of change;

Conclusions

Dependability and adaptability:

- the ability to deliver service:
  - D: rigorous design and **fault tolerance**;
  - A: rigour in the specification/reasoning about adaptability;
  - A: most work has focused on system reconfiguration;
- confidence on that ability:
  - D: V&V and system evaluation;
  - A: very little has been done here;
    - adaptability vs. predictability;