The challenges of open-world software

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What is "open world"?

- Software methodologies and technologies have been evolving from
  - *closed world*
  - to *controlled evolution*
  - to *open world*
- Progress in the field may be analyzed through this perspective

The external world with which the system interacts is fixed and known

The structure of the solution is fixed, monolithic, and centralized

Changes in the external world require system re-design

Changes in the architecture are localized to restricted parts

Changes in the world occur as system is running

Architecture evolves as system is running

Plan of the talk

- Briefly revisit software progress through the closed to open world evolution perspective
- How object orientation fits into the picture
- Identify challenges and opportunities
  - In particular, dependability issues

Postulates

- Open world asks for dynamic software compositions
- Software structure may change at run-time, even in unanticipated ways
- We need to rethink the way we validate systems
  - from pre run-time validation to perpetual validation

Viewpoint

- Focus on composition/structuring
  - how is an application made out of parts?
    - how/when is binding among parts established?
  - what is its structure/architecture?

  also at process level
  - how is an application's lifecycle structured?
  - how are phases and activities organized?

Archeology

- Software engineering "officially" born in 1968, as a recognition of
  - increasing importance of software in society
  - failures, poor quality, out-of-control costs

  and a quest for methods to support industrial-strength quality
  - because software production did not follow any precisely formulated process
    - continuous iteration of coding and error fixing

Early day assumptions

- Monolithic organizations
  - centralized solutions
- The **closed world** assumption
  - the boundary between the real and the virtual world is clearly identified and fixed
    - owner of problem and owner of solutions clearly identified
  - requirements are there, they are stable
    - *just elicit them right!*
  - changes considered harmful
    - *avoid them! they disrupt the "normal" flow! they are the culprit of schedule and cost problems!*

Early day solutions

- Process level
  - –the sequential (waterfall) process model
    - refinement, from clearly and fully specified requirements down to code
    - top-down development → formal deductive approaches
- Product level
  - –programming languages and methods producing static, centralized, verifiable architectures
    - static and centralized system compositions, frozen at design time

Early lessons learned

- Requirements cannot be fully gathered upfront
- Requirements cannot be frozen
- Requirements intrinsically decentralized, ... and pre-plan illus...
- ... whole product/process
- ... intrinsic to software
  - it is NOT a “post-delivery” nuisance

The source of change is in the world

Controlled evolution

- Evolution should be anticipated and controlled
  - progressive departure from the closed (and fixed, static, centralized) world assumption
- Process level
  - evolutionary models
    - incremental, prototyping-based

Product level

- Methods
  - likely changes anticipated at requirements level
  - design for change (Parnas)
    - information hiding
    - specification/interface vs. implementation/body
- Technology (languages)
  - from monolithic structures
    - changes imply complete re-compilation+ re-deployment

    to incremental construction mechanisms
    - partial re-compilations + re-deployment
    - interface separated from implementation

    to distributed solutions
    - client-server architectures

OO design and languages: further controlled evolution

- Accommodate limited anticipated dynamic product changes
- New subclasses (and new objects) defined even as the system is running → methods invoked may become known at run time
- Partially open world + type safety
  - if changes are anticipated and they can be cast into the subclass mechanism, dynamic evolution and dynamic binding can co-exist with static checking (and type safety)

OO design

interface

body

Δ-interface

Δ-body

Fax

Polymorphism

Fax f

Fax with phone

Dynamic binding

f.sendFax();

Binding may cross network boundaries

server

client

RMI

code base

Components: opening the process world

- Systems not developed from scratch, but rather out of existing parts
- Open world at process level
  - decentralized developments
  - multiple owners/stakeholders
    - improved flexibility/reduced control
  - components cooperate through middleware

Summing up

- The need for adapting to external changes
  - of the business world
  - of the physical world

  has been the dominating force
- We have been ***reasonably*** successful at supporting it without compromising the dependability of our solutions through ***controlled evolution***

What is happening today?

- Open world
  - Unprecedented degrees of change
  - "Perpetual beta"

Where are the sources of change? (1)

- Changes originate in the business world
  - agile networked organizations
    - dynamic, goal-oriented, opportunistic federations
    - reacting with fast responses to rapidly changing requirements
    - intra and extra organization changes require continuous changes in their information system

Where are the sources of change? (2)

- Physical mobility generates environment changes in ubiquitous/ pervasive computing settings
  - request for context-aware dynamic bindings
    - *invocation of a print service binds to a printer based on proximity*
    - *request to light a room binds to actuator that opens shades or to switch turning electric light on depending on external conditions*

Open world

- In an open world requirements change continuously and upredictably
- The boundary between the systems we build and the real world cannot be frozen
  - In the extreme case, it changes as the systems we build runs and must continue to provide service
    - the system structure cannot be frozen
    - mechanisms needed for the structure to evolve dynamically
- Compositions change because both **components** and the **structure** change
- No single authority is in charge of all parts

Closed world

- In a closed world there is a sharp separation between **pre**-runtime and runtime

structuring
verifying
deploying

executing

- Changes require switching from runtime back to development time where software is changed and validated

From components to **services**

- Both are developed by others
- Components are run in the application's domain, they become part of the application
- Services are run in their own domains
- Normally, components chosen and bound at design/construction time
- Services chosen and bound at run-time
- Services must support explicit contracts to allow independent party access
  - allow for SLAs that deal not just with functionality
- Services can be composed to form new services

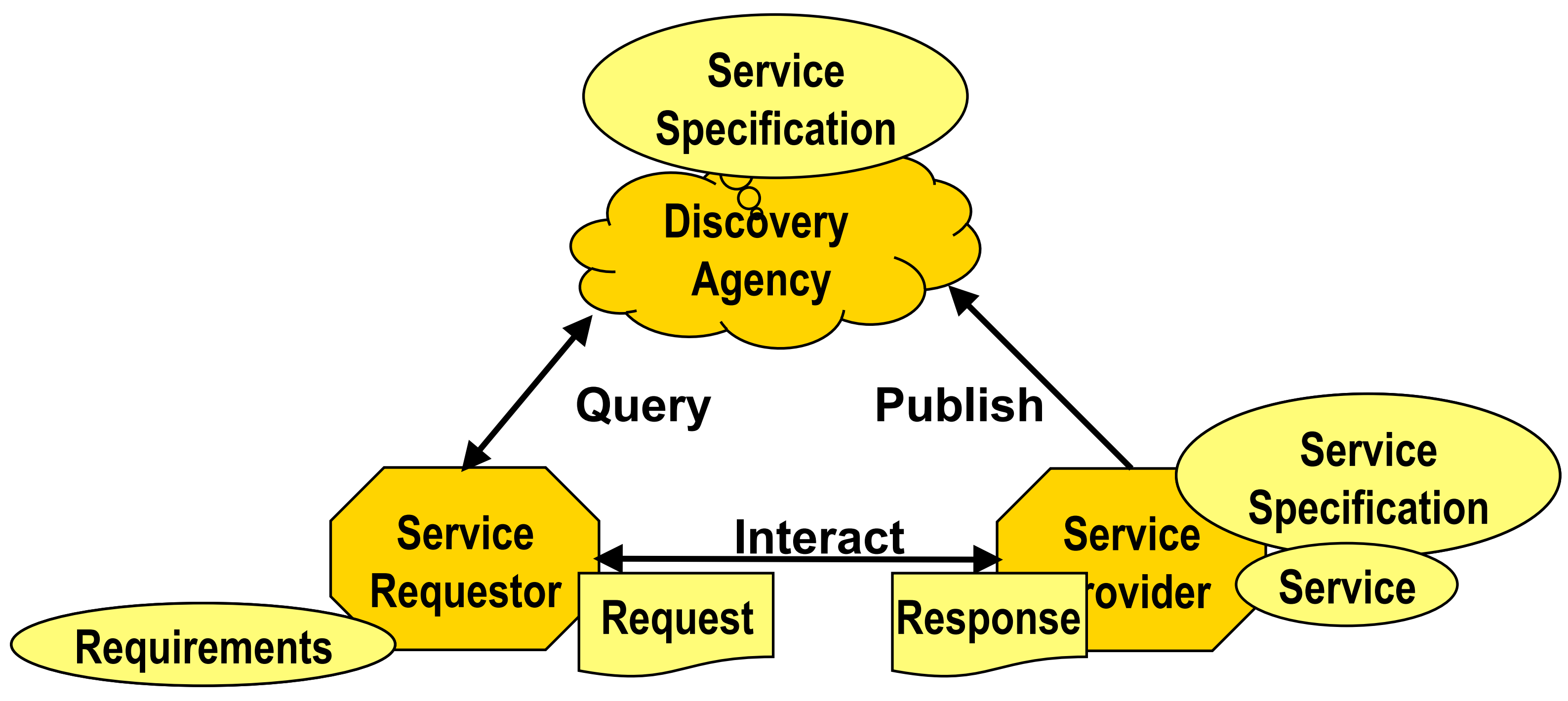
Ownership

- Traditional applications are largely owned by the organization that runs them
- Components are run but not really owned
  - organization depends on owner for enhancements
- Services are used, not run

Binding mechanisms

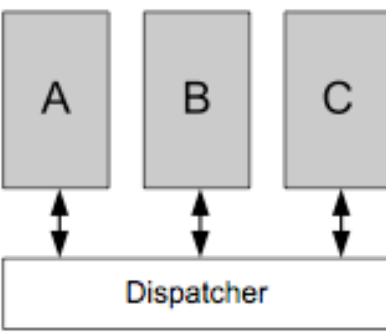
- Two-phase explicit
  - discovery-based
    - publication states all functional and nonfunctional properties
    - discovery/selection may involve optimization/negotiation
- Implicit
  - via some "logical" coordination space
    - E.g., publish/subscribe
    - ***by contract?***

Discovery-based binding



Implict binding: Publish-Subscribe

- Asynchronous communication mediated by a *dispatcher*
  - anonymous
  - multipoint
  - implicit addressing
    - subject vs. contents-based
- Application components
  - *subscribe* to relevant message patterns
  - *publish* messages
- The dispatcher matches published messages against previously issued subscriptions
- Support dynamic addition, removal and replacement of application components



Binding by contract

interfaces described by a
SPECIFICATION

Specification describes
- signature
- functional behavior
- nonfunctional behavior

We must manage contract violation

Potential benefits

- Clear separation between the "what" and the "how" and "when"
  - different policies possible
    - early/late
    - context-aware
    - optimizing certain figures of merit
      - bind to the "current best"
  - "self-organization" possible
  - "rich" interface descriptions needed
    - "contracts" specify QoS

The challenges of open world

- How can flexibility and dynamism coexist with the required dependability?
- All phases of software development are affected and must be re-thought
  - requirements
  - specification
  - design&implementation
  - verification&validation

Verification&validation

- **Good news** is flexibility and dynamism
- **Bad news** is continuous V&V
  - Late binding+dynamic compositions add flexibility at the expense of reduced safety
  - Full range of binding regimes imply full range of V&V activities