Secure Systems Development with UML: Applications to Telemedicine

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A need for Security

Society and economies rely on computer networks for communication, finance, energy distribution, transportation...

Attacks threaten economical and physical well-being of people and organizations.

Interconnected systems can be attacked anonymously and from a safe distance.

Networked computers need to be secure.

Telemedicine

Telemedicine particularly critical:

- Human life/health (telesurgery)
  → availability, integrity
- Big money (medical (genetic !) data vs. insurance companies)
  → secrecy

Problems

Many flaws found in designs of security-critical systems, sometimes years after publication or use.

Example (1997):

NSA hacker team breaks into U.S. Department of Defense computers and the U.S.electric power grid system. Simulates power outages and 911 emergency telephone overloads in Washington, D.C..

Causes I

- Designing secure systems correctly is difficult.
- Designers often lack background in security
- Security as an afterthought.

Even experts may fail:

- Needham-schroeder protocol (1978)
- attacks found 1981 (Denning sacco), 1995(Lowe)

Causes II

Cannot use security mechanisms „blindly“:

- Security often compromised by circumventing (rather than breaking) them.
- Assumptions on system contex, physical environment.

„Those who think that their problem can be solved by simply applying cryptography don`t understand cryptography and don`t understan their problem“ (Lampson/Needham).

Difficulties

Exploit information spreads quickly.

No feedback on delivered security from customers.

Previous approaches

„Penetrate-and-patch“: unsatisfactory.

- insecure (damage until discovered)
- disruptive (distributing patches costs money, destroys confidence, annoys customers)

Traditional formal methods: expensive.

- training people
- constructing formal specifications.

Goal: Security by design

Consider security

- from early on
- within development context
- in a seamless way.

„An expansive view of the problem is most appropriate to help ensure that no gaps appear in the strategy“ (Saltzer, Schroeder 1975).

But „no complete methode applicable to the construction of large general-purpose systems exists yet“ -since 1975.

Quality vs. cost

Correctness in conflict with cost.

Thorough methods of system design not used if too expensive.

Using UML

UML: unprecedented opportunity for high-quality critical systems development feasible in industrial context:

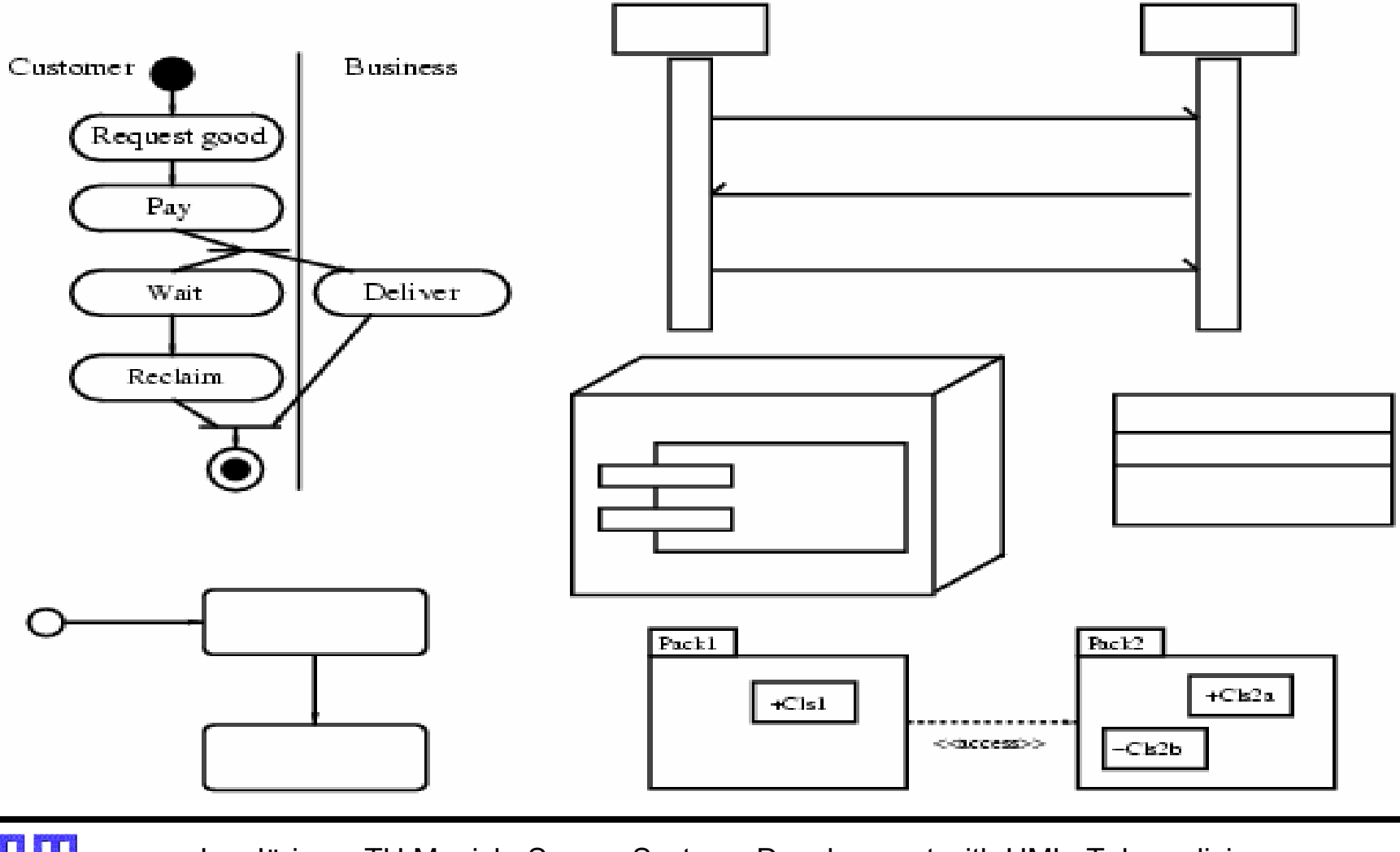
- De-facto standard in industrial modeling: large number of developers trained in UML.
- Relatively precisely defined (given the user community).
- Many tools in development (also for analysis, testing, simulation, transformation).

Using UML

Unified modeling Language (UML):

- visual modeling for OO systems
- different views on a system
- high degree of abstraction possible
- de-facto industry standard (OMG)
- standard extension mechanisms

A glimpse at UML



Used fragment of UML

Activity diagram: flow of control between system components

Class diagram: class structure of the system

Sequence diagram: interaction between components by message exchange

Statechart diagram: dynamic component behaviour

Deployment diagram: Components in physical environment

Package: collect system parts into groups

Current: UML 1.4 (released Feb. 2001)

UML Extension mechanisms

Stereotype: specialize model element using <<label>>

Tagged value: attach {tag =value} pair to stereotyped element

Constraint: refine semantics of stereotyped element

Profile: gather above information

UMLsec

UMLsec: extension for secure systems development.

Goals :

- evaluate UML specifications for vulnerabilities in design
- encapsulate established rules of prudent security engineering
- make available to developers not specialized in security
- consider security from early design phases, in system context
- make certification cost-effective

The UMLsec profile

Recurring security requirements offered as stereotypes with tags (secrecy, integrity,...).

Use associated constraints to evaluate specifications and indicate possible vulnerabilities.

Ensures that stated security requirements enforce given security policy.

Ensures that UML specification provides requirements.

UMLsec profile (excerpt)

Stereotype	Base class	Tags	Constraints	Description
Internet	link			Internet connection
secure links	subsystem		dependency security matched by links	enforces secure communic. links
secrecy	dependency			assumes secrecy
secure dependency	subsystem		call, send respect data security	structural data security
no down-flow	subsystem	high	prevents down-flow	information flow
data security	subsystem		provides secrecy integrity	basic datasec requirements
fair exchange	package	start, stop	after start eventually reach stop	enforce fair exchange

<<Internet>>, <<encrypted >>, <<LAN >>, …

Denote kinds of communication links resp. system nodes.

For adversary type A, stereotype s, have set $Threats_A(s) \in \{delete, read, insert, access\}$ of actions that adversaries are capable of.

Default attacker:

Stereotype	$Threats_{default}$ ()
Internet	{delete, read, insert}
encrypted	{delete}
LAN	∅
smart cart	∅
POS device	∅

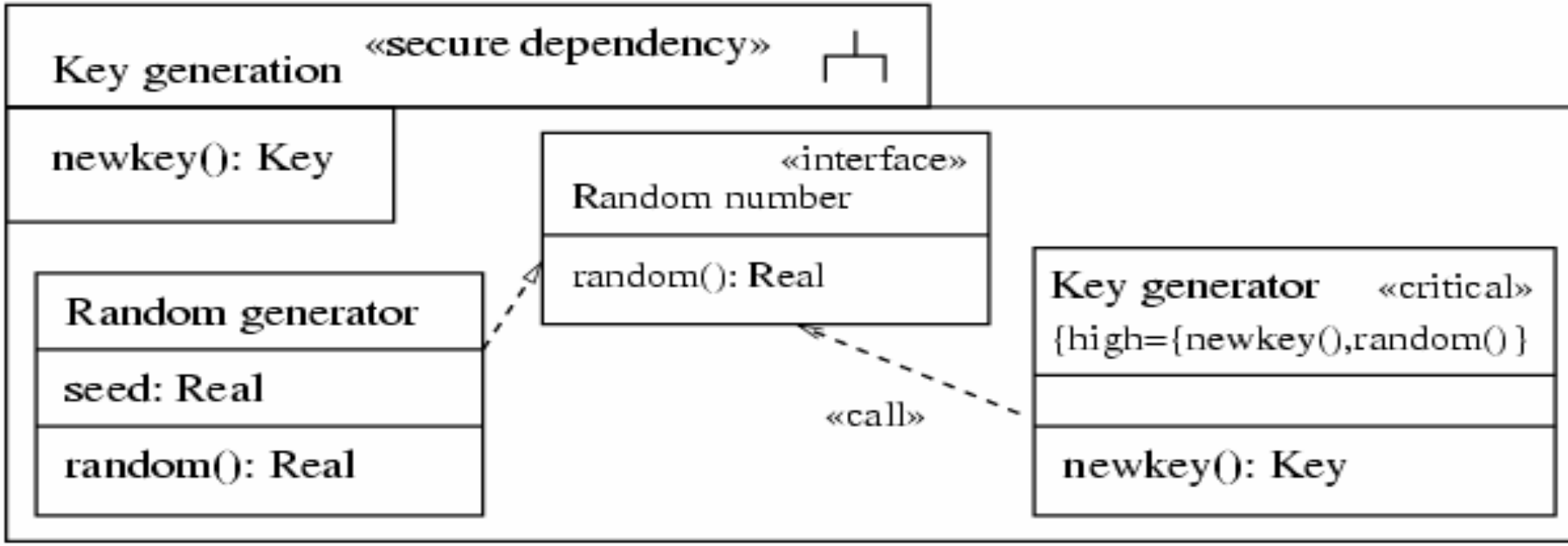
<<secure dependency>>

Ensures that <<call>> and <<send>> dependencies between components respect security requirements on communicated data given by tag {high}.

Constraint: given <<call>> or <<send>> dependency from *C* to *D*:

- Any message *n* in *D* appears in {high} in *C* if and onl if does so in *D*.
- If message in *D* appears in {high} in *C,* corresp. dependency stereotyped <<high>>.

Example <<secure dependency>>



Specificaton violates constraint for <<secure dependency>>: Random generator and <<call>> dependency do not provide security levels for random() required by key generator.

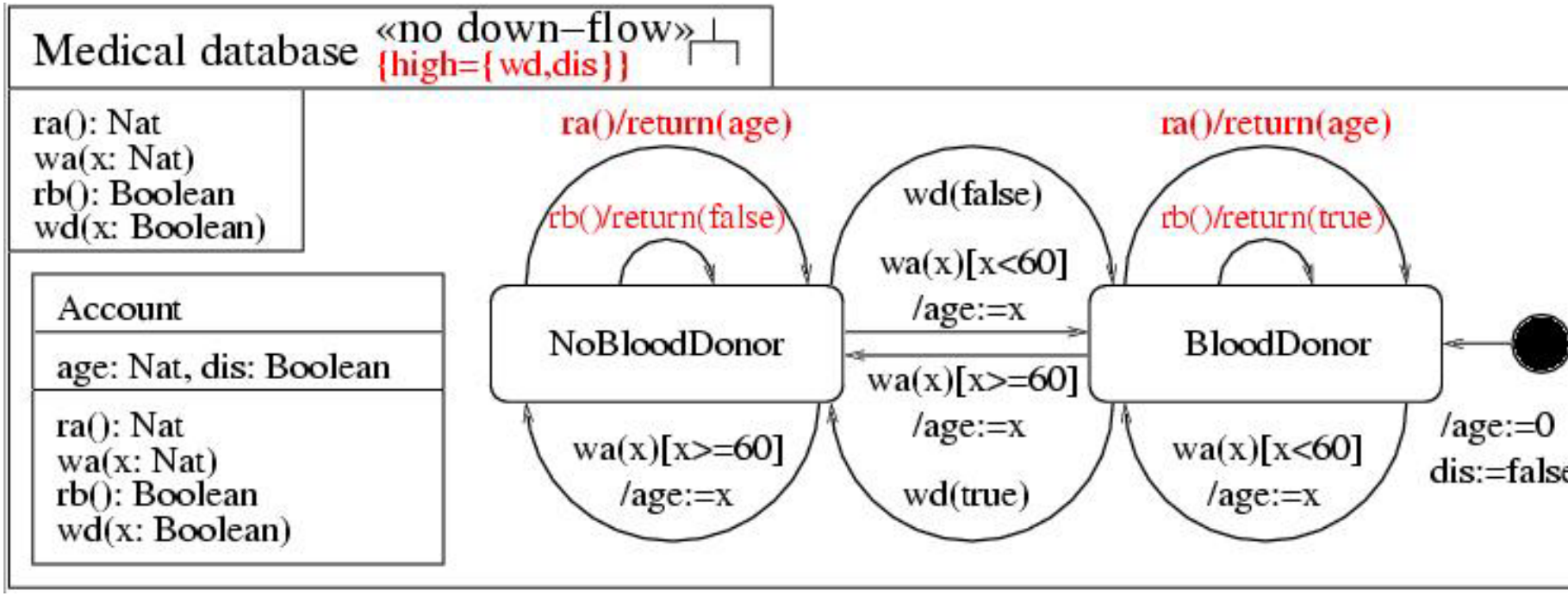
<<no down–flow>>, <<no up flow>>

Enforce secure information flow. Constraints:

<<no down-flow>>: component prevents down flow: Value of any data specified in {high} may influence only the values of data also specified in {high}.

<<no down-flow>>: component prevents up-flow: Value of any data specified in {high} may be influenced only by the values of data also specified in {high}.

Example <<no down-flow>>



Database object allows age, fitness to be blood donor to be read. Does not provide <<no down–flow>>: derive partial information about dis.

Formal semantics for UML: Why

Meaning of diagrams stated imprecisely in (OMG 2001).

Ambiguities problem for

- tool support
- establishing behavioral properites (e.g. security)

Need precise semantics for used part of UML, especially to ensure security requirements.

Formal semantics for UML: How

Diagrams in context (using subsystems).

Model actions and internal activities explicitly.

Message exchange between objects or components (incl. event dispatching).

For UMLsec: include adversary arising from threat scenario in deployment diagram.

Use Abstract State Machines (pseudo-code).

Distributed Systems

Objects distributed over untrusted networks.

„Adversary“ intercepts, modifies, deletes, inserts messages.

Cryptography provides security.

Security Analysis

Model classes of adversaries.

May attack different parts of the system in a specified way.

Example: insider attacker may intercept communication links in LAN.

To evaluate security of specification, execute jointly with adversary.

Risk Analysis

- Within adversary model: attach probabilities to failures (e.g. compromise of key)
- Derive probabilities for hazards

Connection with analysis tool

Commercial modelling tools: only syntactic checks and code-generation.

Current work: connect to verification tools.

Industrial CASE tool with UML-like notation: AUTOFOCUS (http://autofocus.informatik.tu-muenchen.de)

- verification
- code generation
- test-sequence generation

Conclusion

- Use UML extension UMLsec for model-based development of security-critical systems
- Apply to telemedicine systems

- Work-in-progress: mechanical tool-support

Resources

Book: Jan Jürjens, Secure Systems Development with UML, Springer-Verlag, 2003

Satellite workshop at UML'02 (Dresden/Germany, 30 Sep-4 Oct) on Critical Systems Development with UML

More information (also slides, papers etc.):

http://www.jurjens.de/jan

Thanks for your attention !