Software Systems Adaptation by Composition

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Adaptive mechanism in natural world

- Different chameleon species are able to vary their coloration and pattern through specialized cells contain pigments in three layers below their transparent outer skin.
- Color change in chameleons has functions in social signaling and in reactions to temperature and other conditions, as well as in camouflage.
- The relative importance of these functions varies with the circumstances, as well as the species.
Why Engineering Adaptive software?

- Control the **developmental process** of software
- Control the **behavior** of software
- Control the **quality** of software

![Diagram]

"Feedback loop" in goal-oriented RE (Liu, et al, IWSC, 2007)
A Typology of Systems with Goal Models

with Yunsong Jian, Tong Li, Eric Yu
Static Systems Scenario

- The system requirements remain unchanged at run-time.
- It means that the system responds to the operating environment and users’ requests in a fixed and predefined way.
- In the requirements model for static systems, the goal set $G$ is fixed, goal refinement and operationalization is determined at design time.
- Environment variables associated to the goal model take constant value.
Traffic Light Control Example

- static

\[ a = \{ \text{Rpulse}[i], \text{Gpulse}[i] \} \]
\[ b = \{ \text{Stop}[i], \text{Go}[i] \} \]
\[ i = \{ \text{left}, \text{right} \} \]

(Jackson, 2001)

Under Construction

(Stop[left], Stop[right]) for 50 seconds;
(Stop[left], Go[right]) for 100 seconds;
(Stop[left], Stop[right]) for 50 seconds;
(Go[left], Stop[right]) for 100 seconds
Goal Model for the static Traffic Light System

$g_0$: Traffic go smoothly while there are road construction

$g_1$: let the traffic on both ways pass the road

$sg_0$: the traffic on both ways should have fair passing time

$a_1$: let the traffic from left to right go for 100 seconds

$a_2$: let the traffic from right to left go for 100 seconds

$a_3$: give 50 seconds to make the switch

$a_4$: (stop[right], go[left]) for 100 seconds

$a_5$: (stop[left], go[right]) for 100 seconds

$a_6$: (stop[left], stop[right]) for 50 seconds

Design time Goal Refinement
Reconfigured Traffic light

Under Construction

Stop[left], Stop[right] for 50 seconds;
Stop[left], Go[right] for 75 seconds;
Stop[left], Stop[right] for 50 seconds;
Go[left], Stop[right] for 150 seconds;

Observe the environment at deployment time, change the setting when necessary.
The Sensitive/Reactive Systems Scenario

- The system does change its behavior at run-time and the system could respond to certain predefined operating environmental changes and users’ requests.
- This kind of systems has some adaptation ability but the ability is limited by a set of predefined rules.
- The adaptation is the result of non-deterministic goal refinements at design time.
- The achievement of goals depends on the states of the run-time environmental variables. This is a vivid example of gradually adding uncertainty into requirements analysis and system development.
Sensitive One-way Traffic Light System

Lights Controller → a → Light Units

Road Sensors → c → Light Units

Vehicle Traffic → d → Light Units

Lights Sequence

\[ a : = \{ R_{\text{pulse}[i]}, G_{\text{pulse}[i]} \} \]
\[ d : = \{ \text{VehiclePassSensor}[i] \} \]
\[ b : = \{ \text{Stop}[i], \text{Go}[i] \} \]
\[ e : = \{ \text{VehicleTraversing}[v] \} \]
\[ c : = \{ \text{SensorOn}[i] \} \]
\[ i : = \{ \text{left}, \text{right} \} \]

Under Construction
Design time refinements with run-time trigger condition

g₀: Traffic go smoothly while there are road construction

sg₁: let the traffic on both ways pass the road
sg₂: let the traffic on both ways pass the road more efficiently
sg₃: let the traffic from left to right waiting time short
sg₄: let the traffic from right to left waiting time short

a₁: let the waiting time of the first vehicle in the left to right waiting queue less than 5 minutes
a₂: let the waiting time of the first vehicle in the right to left waiting queue less than 5 minutes

a₃: (stop[right], go[left]) for 100 seconds
a₄: (stop[left], go[right]) for 100 seconds
a₅: (stop[left], stop[right]) for 50 seconds

a₆: stop[right]
a₇: stop[left]
The Run-Time Adaptation Scenario

- The system requirements changes and the system adaptation actions and the adaptation rules are not completely predefined, there is greater uncertainty at the design time.
- At first the adaptation rules set R only contain some predefined rules.
- When the system is running, in order to handle the changes of the operational environment and the users’ needs, new goals, new environment conditions, new activities and new rules are added to the sets G, E, A and R at run-time respectively.
Adaptive One-Way Traffic Light System

Under Construction

Sensor

left

Sensor

right
With Run-time goal and refinement

\[ g_0: \text{Traffic go smoothly while there are road construction} \]

\[ g_1: \text{let the traffic on both ways pass the road} \]

\[ g_2: \text{the traffic on both ways should have fair passing opportunity} \]

\[ g_3: \text{let the traffic from left to right waiting time shortened} \]

\[ g_4: \text{let the traffic from right to left waiting time shortened} \]

\[ g_5: \text{let the traffic on both ways pass the road more efficient} \]

\[ g_6: \text{let the traffic on both ways pass the road safer} \]

\[ g_7: \text{let the traffic on both ways pass the road waiting queue less than 5 minutes} \]

\[ g_8: \text{warning the violation of traffic} \]

\[ a_1: \text{stop[right] for 100 seconds} \]

\[ a_2: \text{stop[left] for 100 seconds} \]

\[ a_3: \text{stop[right], go[left] for 100 seconds} \]

\[ a_4: \text{stop[left], go[right] for 100 seconds} \]

\[ a_5: \text{stop[right]} \]

\[ a_6: \text{stop[left]} \]

\[ a_7: \text{stop[left], stop[right] for 50 seconds} \]

\[ a_8: \text{repeat stop[left], stop[right] on and off} \]
Collaborative One-way Traffic Light System

Under Construction

R    G
left

R    G
right
With Run-time actor, goal, action, binding, and monitoring.

Traffic light controller

\[ g_0: \text{Traffic go smoothly while there are road construction} \]

\[ g_1: \text{let the traffic on both ways pass the road} \]

\[ g_2: \text{let the bus go first} \]

\[ g_3: \text{let the traffic from left to right waiting time short} \]

\[ g_4: \text{Stop[right], go[left] for 50 seconds} \]

\[ g_5: \text{Stop[left], go[right] for 50 seconds} \]

\[ g_6: \text{let the traffic on both ways pass the road more efficient} \]

\[ g_7: \text{quickly go through the road} \]

\[ a_8: \text{Speed lower than 30km/h} \]

\[ a_9: \text{Speed faster than 30km/h} \]
Provide online education \((g_0)\)  
Identity managed \((g_1)\)  
Respond-time less than 3 seconds \((sg_1)\)  
Authentication and Authorization \((a_1)\)  
Respond time >3 seconds, Network speed < 50KB/s

Provide remote exam \((g_4)\)

Design training plan \((g_3)\)

Answer questionnaire \((a_4)\)

Provide Teaching Course Materials \((a_2)\)

Provide Video Tutorials \((a_4)\)

Use speed accelerator \((a_3)\)

E_1: Exam test component can satisfy \(g_4\)

E_2: Design plan component can satisfy \(g_3\)

Design learning plan \((g_3')\)

Collect user information \((a_5)\)

Analyze the finished questionnaire \((a_6)\)

Prepare questionnaire \((g_5)\)

Generate questionnaire \((a_7)\)

Generate examination paper \((a_8)\)

Provide questionnaire \((g_6)\)

Provide remote exam testing \((g_7)\)

Provide remote exam \((g_4')\)

Generate questionnaire \((a_6)\)

Generate examination paper \((a_8)\)

Judge the examination paper \((a_{10})\)
Collaboration

- The software collaboration means that the software entities are being aware of the existence of others, and could collaborate to achieve a common goal.
- There are delegation and informing activities between them.
- The states of other components are partially observable by other components, as environment variables.
- An abstract collaboration model for components has associated goal-action refinement structures, interconnected, and maintained through protocols supporting the requesting, publication, searching, binding, delegation and revoking relationships among individual components.
Adaptive Design in Response to Changing Requirements

- Systems as organisations
  - Framework that facilitates the development of adaptive role-based system structure, with role-role contracts
- Contracts define (rich) interaction protocols and measure performance – implemented with association aspects
- Strict separation of role from player – roles define the function, players do the work: role-player bindings
- A role is stateful and is defined as a set of provided/required service interfaces
- Organisation (system) is a recursive hierarchy of self-managed composites, with each having an organiser role
- Roles can be filled by players of different capabilities
  - Services, Objects, Self-managed composites, Agents, Humans
Composition-based development of software systems from a set of software components distributed over the Internet.

- Ideally, the software components are autonomous, self-contained and distributed.
- It is able to respond to the perceived changes in the environment by means of reconfiguration and reorganization.
- It collaborates with one another on demand, which adopts an iterative composition process turning various “disordered” resources into an “ordered” software system.
- Brings promptness, flexibility and reusability in building distributed software systems.
- As a new requirement emerges, or a new software technology becomes available, or an unexpected change happens, existing requirements-solutions bindings can be adjusted for optimization purpose.
An Analogue: **Software vs. Data**

- **Software** are like the pipes and pumps and storage tanks in a plumbing system.
- **Data** is like the water flowing through those pipes.
- And there is also data about the requirements, design and run-time status of the software…
- If you suspected that your water was poisoned, Would you call the plumber? What if you saw water leaking, or reduction of water volume, …?
Call for Papers and Panel Proposals

11th International Workshop on Software Cybernetics

IWSC 2014

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Thanks!