Travelling Through Time in aid of Sustainability:
Building Design & Maintenance System

Professor Farzad Khosrowshahi
27 October 2010
Building Maintenance

Generations

- Maintenance on failure
- Preventative planned maintenance
- Time-based maintenance
Promise

. Building Maintenance Scheduling
  - Too soon: uneconomical
  - Too late: Poor service

Ideal (1):
  - Just-in-time maintenance
  - live through it twice - virtual

. IDEAL (2) - Alternative Design Solutions
  - Life cycle evaluation
  - sustainability
Building Visualisation Generations

- Visualisation of Building.
  2D, 3D, animation, VR

- 4D Visualisation.
  In time

- Visualisation through time.

Visualisation of the degradation of an object like a building: application in maintenance
Traditionally, architects produce building outlines and designs. However, the lifecycle of a building is not just about the design phase. It involves long-term and periodical maintenance scheduling.

**Client briefing:**
Define **functional** and **strategic** needs

**Architect:**
Produce building **outline** design

**Define Project Environment:**
(climate, usage, locality)

**Building Component:**
Selection for lifecycle, sustainability, energy.

**Construction Phase:**

**Lifecycle engine**
(knowledge-based OR visual-based)

**Long Term & Periodical maintenance scheduling**

Use to design for lifecycle and generate repair & maintenance program.
Visual Building Design Information

Properties of Items in Building Design

Maintenance Scheduler

Cad output (convert to XML) contains all building details

Default properties of each standard ‘item’.

Produce a map of building ‘items’ and assign the suitable properties to each one based on project initials.

‘Items’ attributes and properties.

Maintenance time period and type of maintenance.

Calculate building maintenance procedure for the given time and for the given scheduler.

Add building visual data and calculated data for the given time and maintenance scheduler and produce output VUI.

Eg. VRML Browser
Program from visualisation

Solution One

- Architectural Design
- Building Components
- Maintenance Scheduler Simulator
- Visualisation Simulator
- Maintenance Program Generation

Solution Two

- Architectural Design
- Building Components
- Maintenance Scheduler Simulator
- Visualisation Simulator
- Virtual Reality Output

Visualise the program
Development Process

- Event-Effect relationship model
  - Events: list, agents
  - Component: list, elements, time related variables
  - Event / Component interaction
  - Auxiliary events

- Maintenance scheduling expert system
  - Automate the maintenance decisions

- Data generation: collect, generate, knowledge conceptualisation, mobilisation

- Data Validation: case based, multi-modal

- Event-effect modelling / database design

- Product Development (software); interface design, web-based

- Visualisation; VUI
LIFE CYCLE SIMULATION
Generalised life span model

Dead Components

T2 T1

Time

β PDF represent the lifetime

If \( p_i(t) \leq RND(t) \) then “Item i is broken at the \( t_j \)”
eg. Light - Time Related Parameters

- Age
- Life
- Dirt & Dust
- Voltage
- Usage rate
- Room Temperature
Color of Component I at the time T

Red = Initial_Red_Colour * PDF_FNr(I, T) * MaintenanceFactor;

Green = Initial_Green_Colour * PDF_FNg(I, T) * MaintenanceFactor;

Blue = Initial_Blue_Colour * PDF_FNb(I, T) * MaintenanceFactor;

End of Colour calculation.
Example life span algorithm for general light source.

Lumens of lamp I at the time T

\[
\begin{align*}
\text{Red\_Lumens} &= \text{Initial\_Red\_Lumen} \times \\
&\quad \text{PDF\_Fn\_R(I,T)} \times \text{Dust\_Factor}; \\
\text{Green\_Lumen} &= \text{Initial\_Green\_Lumen} \times \\
&\quad \text{PDF\_Fn\_G(I,T)} \times \text{Dust\_Factor}; \\
\text{Blue\_Lumen} &= \text{Initial\_Blue\_Lumen} \times \\
&\quad \text{PDF\_Fn\_B(I,T)} \times \text{Dust\_Factor}; \\
\text{The\_Lamp\_Lit\_Colour} &= \text{RGB(}\text{Red\_Lumens}, \\
&\quad \text{Green\_Lumen, Blue\_Lumen}); \\
\end{align*}
\]

End of Lumens calculation.

Death status of lamp I at the time T

\[
\begin{align*}
\text{Probability\_of\_Death} &= \text{PDF\_Fn\_d(I,T)} \times \\
&\quad \text{Environment function based on Maintenance factor (I)}; \\
\text{if} \quad \text{Probability\_of\_Death} \geq \text{RND(I,T)} \text{ then} \\
&\quad \text{Bulb is in broken state;} \\
\text{Else} \\
&\quad \text{Bulb is not in Broken State;} \\
\end{align*}
\]

End of lamp death status.
Changing in colour of Spot Light
Narrower Spot Light because of pollution
because of grease in pollution
Example of a bedroom before light manipulation.
Example of a bedroom after supervised light manipulation.
ChamberV1.wrl file before any change.
ChamberV1.wrl file after 1 year, affected by dust and lamp age.
Changes due to lamps' death.

General reduction in lumens due to dust factor and lamp’s age.
EVENT-EFFECT MODELING
- CHALLENGE
Events-Effects

**Event**
Rain

**Component**
Cladding

**Effect**
corrosion

Act on
EVENTS: many and diverse

COMPONENTS (internal / external / outside): many choices

Identify all variables that inflict degradation

Define time-related visual attributes

EVENT & EFFECT MODEL – linear

Identify list of effects and associate with components

Develop data structure for each component – effect of time

Require conceptualisation

INTERRELATIONS – chain events / scenarios / cases

EVENT SIMULATION

Identification of event situations

Heuristic rules for frequency and intensity of events

Maintenance & Repair Complexity

Effect:
Colour rendition, surface texture, shape, mortality, erosion, corrosion, loosing reflective, absorption and transmission properties.
Events-Effects – modeling

Event: Rain

Component: Cladding

Effect: corrosion
Events-Effects Relational Model

Short-circuited?
Combined effect of two or more Agents

Example: Agent-water plus Agent-pollution = Active Agent-acid
Combined effect of two or more Events

Example: Event-rain plus Event-vandalism-x = Active link to Component-Cladding-Element-Steel
Extended model of Events-Effects

Agents → Events → Corrosion → Effects → Elements → Components

Water → Rain → Steel → Cladding → Auxiliary
INTELIGENT OBJECTS

A diagram illustrating the structure of object-based model, with components labeled as follows:

- **Component**
- **EVENT**
- **EFFECT**
- **Yes / no chain**
- **Corrosion**

Legend:
- **Functions**
- **Probes**

Description:

- The diagram represents a high-level view of object-based model components and their interrelationships.
- The structure includes a central component labeled as EVENT, connected to effects and yes/no chains, indicating a method of analyzing or modeling conditions and outcomes.
- Corrosion is highlighted as an effect, suggesting a focus on degradation processes.

The image also contains a note:

- "Example of structure of object-based model"
OTHER CHALLENGES;
Holistic Nature - Several Expertise

- construction & engineering
- facilities management
- environmental science
- materials science
- mechanical engineering
- meteorology
- physics
- chemistry
- management – risk, project, safety, etc..
- architecture
- maths & stats, simulation & modelling
- computer science
- visualisation
- maintenance programming & scheduling
- energy conservation
- geologist
- psychologists
- sociologist
- time geography

- anthropology
- etc.
BEHAVIOURAL PATTERNS
eg. Degradation of Flooring Systems

[Visualisation of Impact of time on internal flooring]

1- Pattern of usage
2- Visualisation of degradation
There are two methods for analysing human spatial behaviour:

- **Activity system** *(Chapin, S., 1968)*; is primarily concerned with the organisation of the sequence of activities taking place in a setting.

- **Behaviour Settings** *(Barker, R., 1968)*; concerned with the relationship between the setting and a recurring pattern of behaviour. [anthropology]
The probability of presentation of one, two and three creatures based on Anthropy.
The expression representing the behaviour of a colony is:

\[ g(x) = \int_{y=i}^{j} \frac{f(x, y)}{y} \, dy \]
Two dimensional representation of the pattern.
The presentation of appearance of $n$ creatures in a long room (Corridor) with **two entries** (Doors).

The presentation of probability of appearance of $n$ creatures in a long room (Corridor) with **one entry** (Door).
Visualisation: The used carpet texture.
ANTI-ANTHROPY
A room with two doors after two years
Room with round table in middle.
Final Product: ‘Universal’ Web-based Design & Maintenance Knowledge Broker

- Manufacturers
- Researchers
- HOLMES

Input Data

Web – HOLMES Knowledge Broker

Output Knowledge (tailored)

Wider Dissemination

Wider Exploitation
- Popularize ~music

Phase 1: Initial population
Phase 2: Promotion & Publicity
Phase 3: Data volunteers

Clients
- Designers
- Public authorities
- Financiers/Insurers
- Maintenance manager
- Community
- General Public
- Pressure Groups
- Etc.
END