Architecting Smart Homes as Active Database-Centric Systems

The Case of the Halmstad Intelligent Home

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Several features of modern database management systems being employed to address functional (e.g. well-being and security monitoring, automated control, data processing) and non-functional (e.g. data security and privacy) requirements of smart environments.
A few concepts?

**System Architecture**
Structured solution that meets all of the technical, operational and functional requirements, while optimizing common non-functional requirements. [Microsoft, 2009]

**Smart homes**
Monitor the household, learn the habits and preferences of the residents to anticipate needs or actions. [Wilson et al., 2014]

**Intelligent Age-Friendly Homes**
Integrated systems that evolve to sense, reason and act to individual needs, preferences and behaviours as these change over time.

**Database-Centric Approach**
The reactive behavior and semantic of a domain-specific application are implemented, stored, executed and managed in the Database Management System.
Non-technical motivation

- Prevent & Manage
  - Home & Community
    - Home care
    - Aging in Place
    - Active Aging

- ICT
  - Smart homes
    - Ambient Assisted Living (AAL)
    - Intelligent Age-Friendly Homes

- Healthcare resources

- Demand for care

- Time

- ICT

- Qty.
Technical motivation

Smart environments are difficult to build, configure, use and maintain!

Evolving diversity

- Integratability
- Interoperability
- Extensibility
- Privacy
- Security
- Portability
- Scalability
- Dependability
- Usability
## Smart home platforms

1. AMIGO
2. android@home
3. Apple HomeKit
4. AT&T Digital Life
5. Aware Home
6. Belkin - WeMo
7. CASAS
8. Control4
9. Crestron
10. GatorTech Smart House
11. Google Home
12. Hive - Honeycomb
13. HomeMatic
14. Homescenario
15. Honeywell
16. House_n
17. Humax
18. i2home
19. INSTEON
20. Logitech
21. LonWorks
22. MavHome
23. MisterHouse
24. MonAMI
25. M-POWER
26. Nest
27. Netcarity
28. Nexa
29. Nexia
30. Nokia
31. OASIS
32. openHAB
33. ORCATECH
34. OXYGEN
35. PERSONA
36. PlaceLab
37. Proove/Telldus
38. ReAAL
39. Revolv
40. RocketHome
41. RWE SmartHome
42. Savant
43. Sensei
44. SOCRADES
45. Somfy
46. SOPRANO
47. Tiger place, Aging In Place
48. Vivia
49. Vivant Smart Home Cloud
50. Viva Labs
51. Vera
52. Vivint

### Components

- **Environment**: Standard API
- **Users**: Middleware
- **Applications/UI**: Database Management System
- **Services**: Most common component
- **Device**: Storage is a requirement
- **Middleware**: Mature, powerful, and dependable
- **Database Management System**: and several more…
Smart home platforms

- Standard API
- Specific API
- Middleware
- HW Interface
- Devices
- Environment
- Applications/UI
- Users
- DB

Database Management System
- Most common component
- Storage is a requirement
- Mature, powerful, and dependable
Database-Centric Approach

- Resource Adapters
  - data
  - Sensors/UI

- Actuators/UI
  - tasks
- Resource Adapters

Database Interface

Active Database
- UDFs
- IPC
- Security
- Views
- User Access Control
- Triggers
- Dependability

Active Rules

Extensions
- Data mining

Storage
Active Database

• Data management
  – Query processing, concurrency control, on-the-fly management
• Extensibility
  – Abstraction (VIEWs and UDFs)
  – In-database processing (VIEWs, UDFs and database extensions)
  – Event-Driven Architecture (Triggers)
  – Interprocess communication mechanisms
• Privacy and Security
  – Authentication (certificates)
  – Authorization mechanisms (ROLES)
• Dependability
  – Availability, reliability and maintainability
• Scalability
  – Replication and load balancing
Database model

a) Resources
b) Res. adapter configuration
c) Location of resources
d) Notification mechanism
e) Configuration active rules
f) Sense and actuation data
g) In-database processing
Resource Adapters

Abstraction and integration
Hardware and software technologies
Programming Language Independent
Lightweight gateway
No data aggregation
No peer-to-peer
Database-Centric Approach
Reactive Behavior

Initialization

Sensor | Actuator | Resource Adapter Sensor | Resource Adapter Actuator | Database Interface

connect() ← init() ← config → listen() ← config → connect() ← init() ← config → listen()

event → insert(ev) ← trigger → trigger → trigger → NOTIFY

task() ← ack()
Halmstad Intelligent Home (HINT)
Halmstad Intelligent Home

Fully functional living area of 50 m².
- Funded by Center for Applied Intelligent Systems Research (CAISR)
- Supported by Hälsoteknikcentrum Halland (HCH)

More than 60 sensors
- PIR sensors
- Magnet Switches
- Occupancy sensors
- Load cells
- Temperature
- Infrared cameras
- Thermal cameras

Actuators
- Light
- Robots
SELECT insert_resource_trigger( 'a7beeca677d348648142e4b2a3f86354', 'AFTER', 'INSERT', 'BEGIN
PERFORM insert_a471f13ecb8247b281fd43574e0c7840(new.SAMPLE = TRUE);
RETURN NULL;
END;' );
User Interfaces
Current Projects

Education and research (ITE)
- Smart environments
- Behavior informatics
- Brain-computer interfaces
- Social robots

Intelligent age-friendly homes to support medication self-management
- Health monitoring
- Digital binder
- Smart medication dispenser

Packaging and testing of the “Smart Bed” in nursing homes (HCH)
- Weight and sleep hygiene monitoring

Smart in-home health monitoring and coaching for patients with heart failure
- Adherence monitoring
- Weight monitoring
- Sedentary behavior monitoring
- Context-aware prompting

HINT as Testbed
Current Challenges

**Technical**

- Zero effort
  - Installation
  - Configuration
  - Maintenance
- Integrated
- Always on and ready to use
- Context recognition
- Generalization over different individuals and environments
- Personalization
- Privacy and integrity
- Security

**Non-technical**

- Acceptance and adoption
  - Perceived benefits
  - Associated cost
  - Fitness for purpose
  - User friendliness
  - Trustworthiness
  - Ethics
  - Regulations
Modern DBMS can successfully serve as a platform for smart homes and AAL systems

- Functional requirements as database extensions
- Integration via lightweight programming language independent resource adapters
- In-database interoperation
- Active in-database processing
- Cross-platform solution
- Extensible
- Scalable
Thank you!