

# Integrated Access Control for Smart Buildings using Building Information Models

Ed Dawson

Nimal Skandhakumar   Jason Reid   Farzad Salim

Institute for Future Environments  
Science and Engineering Faculty  
Queensland University of Technology

## Introduction

- Smart buildings and security-sensitive critical infrastructures are operated using network connected electronic systems
- Our reliance on information networks to access and control both physical and information resources has increased
- An integrated approach for access control coupled with integrated facility management approaches is needed



## Introduction

- Current approaches to access control do not address the specific challenges and requirements of smart building environments
- Integrated approach to security across all aspects of facilities operation and management is necessary
- Integration of disparate systems through BIMs requires an overarching access control mechanism



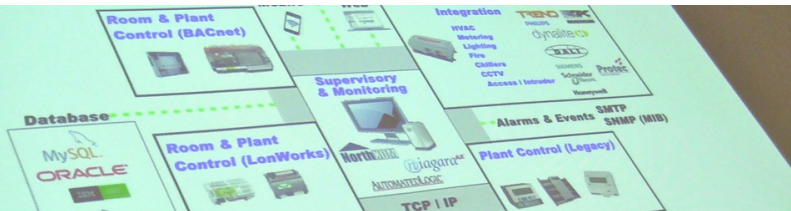
## Security of critical infrastructure

- In the context of this research, the focus is mainly on “critical infrastructures with large facilities spanning across multiple buildings and complex spatial arrangements”
- Providing adequate security for the critical assets is a key responsibility of owners and operators of such infrastructures
- Access control is an important measure in ensuring security in these environments



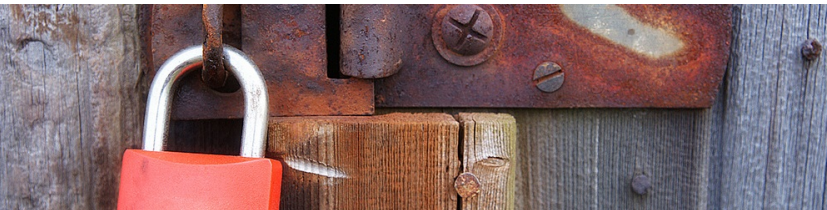
## Smart buildings

- In the context of this research, a smart buildings is “a building comprised of advanced and integrated systems for building automation, life safety, and telecommunication systems”
- Incorporate information technology into all aspects of facility management and operation
- Integration and dynamic operational decision making



## Smart buildings and critical infrastructure

- The purpose of physical access control is protecting critical assets contained within protected areas
- However, with smart buildings, many of these assets can also be remotely controlled through networks
- Convergence of physical and logical security operations is key to ensure protection at both levels



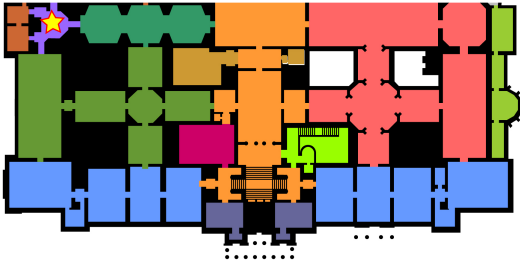
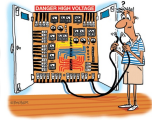
## Access control and security challenges

- Large-scale infrastructures, multiple sites, several multi-storey buildings, multiple security zones
- Dependency on expert knowledge and decision making for access provision and revocation
- Difficult to comprehend three dimensional nature of the environment through two-dimensional floor plans



# Access control and security challenges

An example scenario





## Usability in Security Administration and Management

- Resource owners are the people with the best knowledge about their access control requirements
- It is often difficult for these resource owners to express their security needs in computer terms correctly
- Published research into the usability of physical access control administration tools is limited



## Converged physical and logical access control

- Merges physical security and logical security operations
- Enable using two-way interaction between these two systems in decision-making
- Use information from work-flow and scheduling systems for configuration



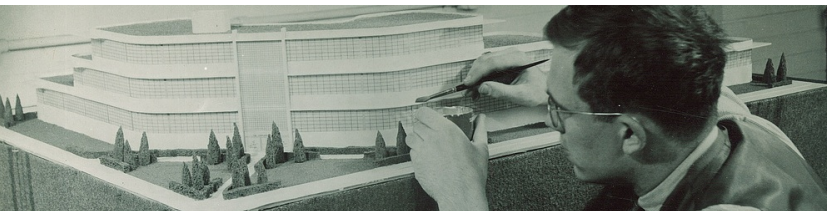
## Spatial data models

- Defines how spatial data are stored and represented
- Outdoor models and indoor models
- Provide vocabulary for representing location data



# Building Information Modelling

- Centralised repositories of objects and processes within a building
- Designed initially and evolve throughout the lifecycle
- Used by designers, engineers and operators





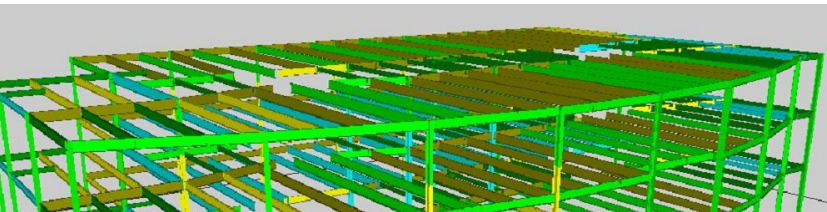
# Complex Infrastructure and Building Information Modelling

- BIMs have the capability of integrating multi domain systems, and provide a common repository for all control systems
- Expected to become common practice in future smart buildings
- Government endorsements in Australia, Europe, and USA
- BIMs are seamless solutions as spatial data models for complex and critical infrastructures



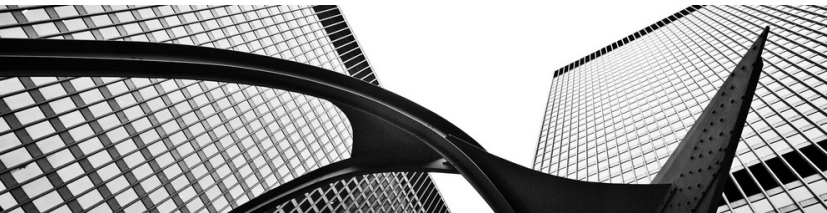
## Industry Foundation Classes

- Industry Foundation Classes (IFC) is an official International Standard ISO/IS 16739 for open BIM, registered with the International Standardization Organization
- IFC format is commonly used for BIMs in architectural, engineering, and construction industries
- IFC specification provides data types required for BIM classes, objects and relationships



## Why BIMs in IFC?

- City Geography Markup Language (CityGML) is an XML based storage and exchange format for virtual city models
- Both CityGML and IFC are semantic models that are targeted at different scales and scopes of spatial representations
- IFC based BIMs have been more widely adopted compared to CityGML, especially among the architecture, engineering, and construction industries and governments alike



## Utilising building information models for access control

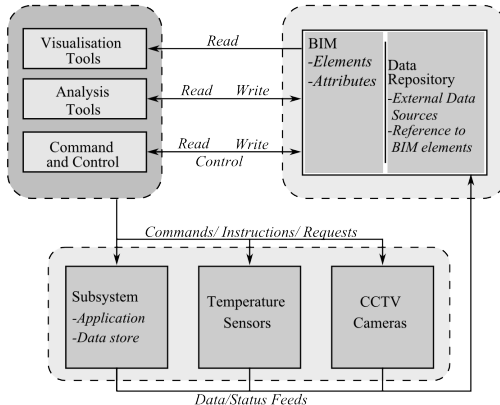
- Using BIM as spatial data model
- Utilising BIMs in three key stages of access control:
  - Policy specification
  - Policy administration
  - Decision making
- Convergence of access control





## Forms of BIM-based access control

- Using a common framework to address different types of access control requirements
- Two proposed categories of resources:  
BIM internal content and BIM external resources

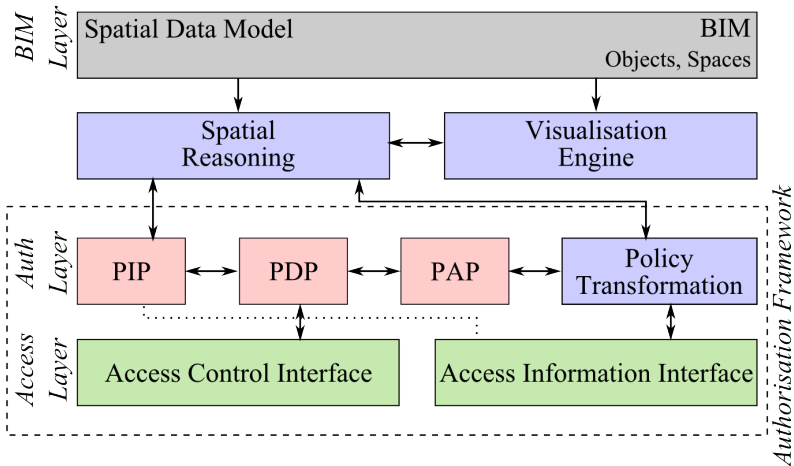


## Authorisation Framework

- Brings in knowledge and expertise from two significantly distinct domains of research and technology:
  - Building information modelling
  - Access control
- Functions as an overarching access control for BIM elements, internal resources and external resources

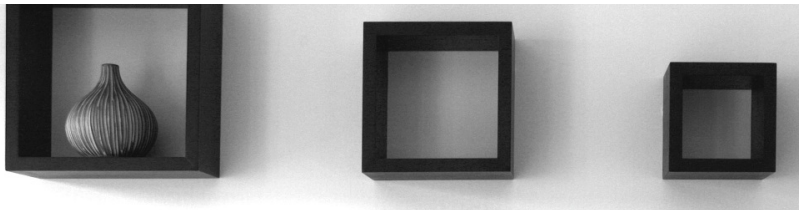


# Authorisation Framework

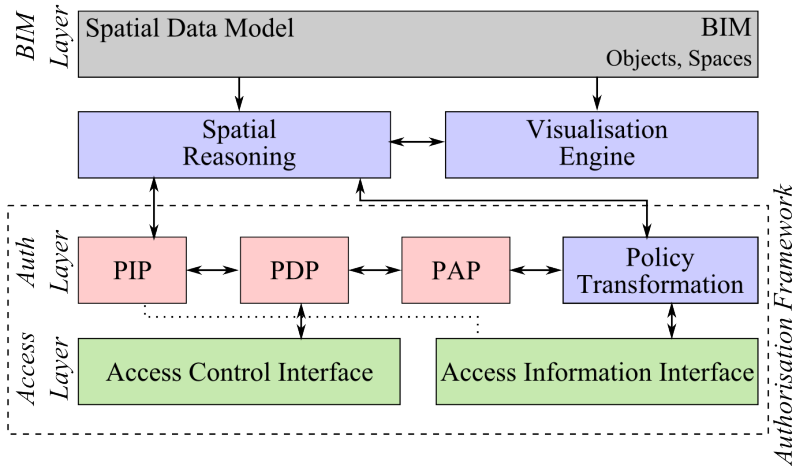


## External spatial modules

- Components that interact with building information models directly
- Platform and implementation dependent for functionalities to manipulate BIMs
- Shared across different systems and not exclusively part of the authorisation framework



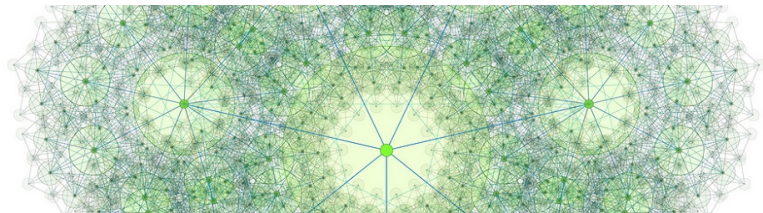
# Authorisation framework modules



## Access control processes

This authorisation framework will utilise building information models in three key stages of access control:

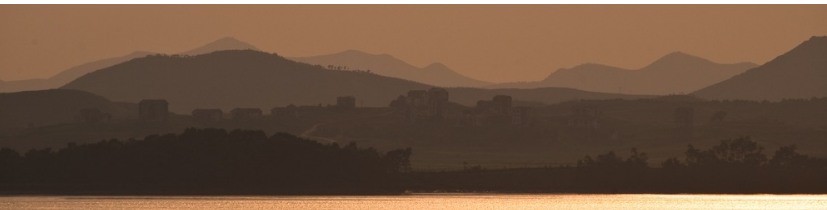
- Policy specification – creating access control policies
- Policy administration – managing access control policies
- Decision making – making access decisions within the framework and externally using the same policies



## Unified access control

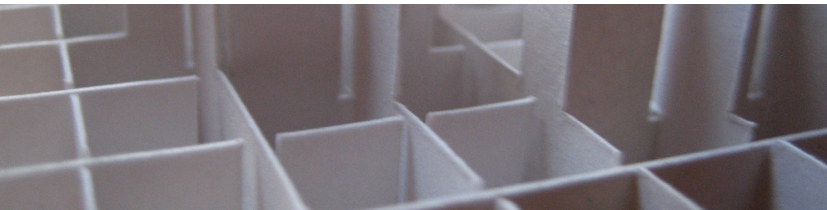
Access control unification addresses two additional processes of the authorisation framework:

- Convergence – For both physical and logical resources
- Policy transformations – Supporting legacy systems



## Understanding building information models

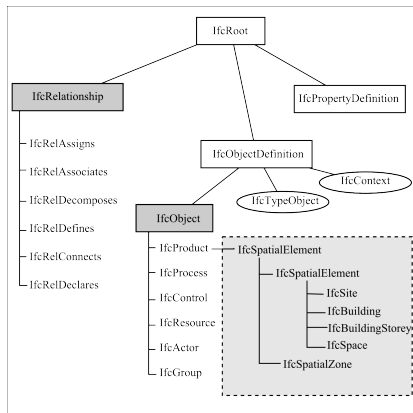
- The use of BIMs as spatial data models for any security applications including access control has not previously been established
- Thus, we identify the essential technical details of building information models that are part of the proposed authorisation framework





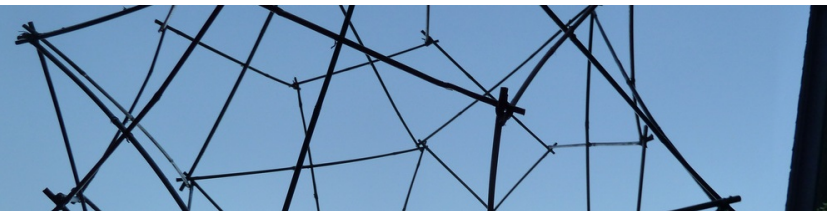
## IFC for access control

- Hundreds of entity types for objects and relationships
- Select group of entities key to representing access control scenarios
- Zones, property sets, adjacency of spaces, portals connecting spaces, and size of spaces



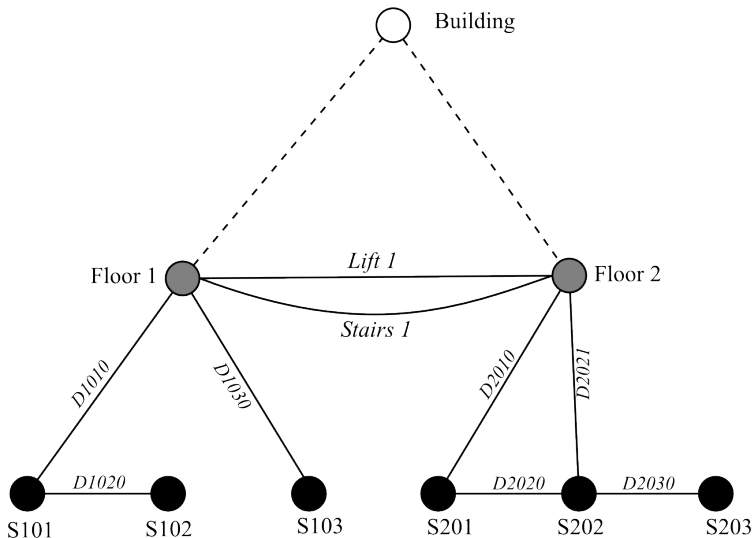
## Graph modelling

- Lack of formal representation of BIMs to describe functions that manipulate BIM data
- Proposed graph theoretic model to formally describing BIMs and formally describing functions using BIMs
- Graph models are widely used in indoor and outdoor navigation applications

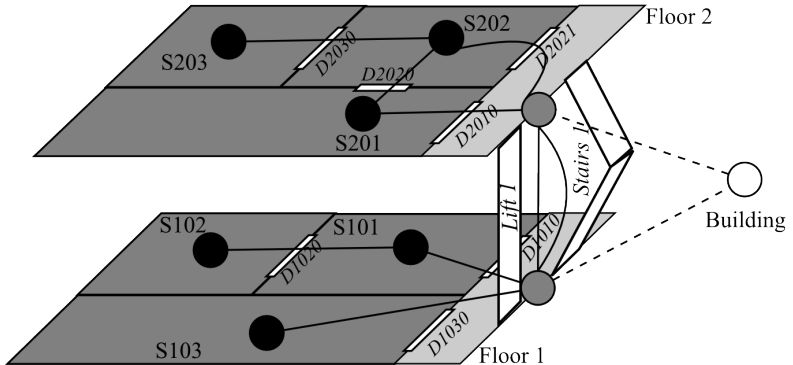




# BIM graph



# Building a BIM graph



# Access control functions using BIM graph

---

**Algorithm 1** findpath( $n_a, n_b, H$ )

---

**Input:**  $H$ : BIM graph,  $n_a$ : Space node,  $n_b$ : Space Node,  $type$ : Path type search condition

**Output:**  $P_{ab}/false$

$H_{sc}$  = Remove from  $H$  edges and/or nodes that violate search condition

$paths_{ab}$  = Run shortest path algorithm on  $H_{sc}$

for  $(n_a, n_b)$

if  $paths_{ab} = empty$  then

    return  $false$

else

    Set  $paths_{ab}$  set of paths  $P_{ab}$

end if

---

- Formally defining various applications that use BIMs
- Different functions manipulating BIMs for access control processes

---

**Algorithm 2** accessibility( $user, n_{start}, n_{end}$ )

---

**Input:**  $user$ : An identifier for user/role,

$n_{start}$ : current location,

$n_{end}$ : destination,

**Output:**  $P_{ab}/false$

Set  $accessibility = false$

for all  $P_{ab} \in allPaths_{ab}$  do

    for all  $n_i \in P_{ab}$  do

        if  $canaccess(user, n_i)$  then

            Set  $accessibility = true$

            continue

        else

            Set  $accessibility = false$

            break

    end if

end for

if  $accessibility = true$  then

    return  $P_{ab}$

else

    Progress to next best path

end if

end for

return  $false$

---

## Representing spatial access control policies

- Using BIMs for authorisation creates unique possibilities and requirements
- Identify requirements for a policy model for such an access control system
- Propose BIM-XACML, a new policy language extension to XACML



## Policy requirements for BIM access control

- There are two key requirements for a policy model for an access control system using building information models
- It must be possible to enforce access control restrictions based on object relationships
- The policy model should enable access restrictions based on spatial relationships



## Policy structure for BIM access control

- This policy model performs rule-based access control
- The access control policy set comprises multiple access control policy rules, which are the basic building block for declaring and enforcing access restrictions
- Each policy rule consists of four elements: Subject, Object, Action, and Condition, the evaluation of which results in a Permit or Deny decision

$$\mathcal{AR} = \{S, O, A, C\} \rightarrow \{Permit, Deny\}$$



## BIM-XACML

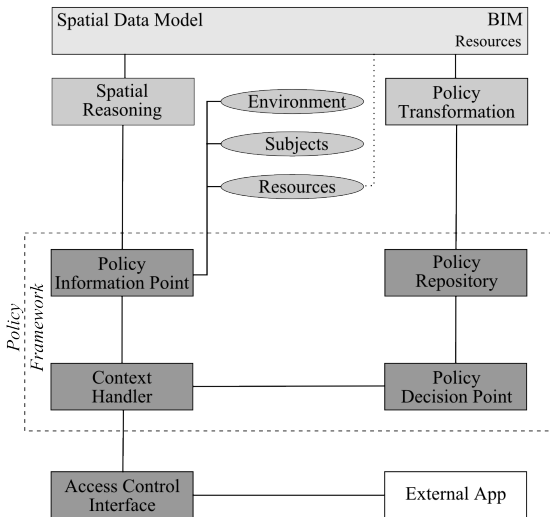
- Using the extension points available in XACML
- Similar to the GeoXACML for GIS
- Combines the XACML architecture and proposed framework

```
<Condition>  
  <Function FunctionId="http://localhost/bim/ifc2x3/  
    function#IfcRelDecomposes"/>  
  <AttributeValue DataType="http://www.iai-tech.org/  
    ifcXML/IFC2x3/FINAL#IfcSpace">  
    <IfcSpace id="bu1sp4">  
      <GlobalId>7qXakT6cDAD2uccYUIFcs$4</GlobalId>  
      <Name>Management Area</Name>  
    </IfcSpace>  
  </AttributeValue>  
</Condition>
```

Listing 1: XACML Encoding for a condition with IFC relationship

# BIM-XACML

## Policy framework



# BIM-XACML

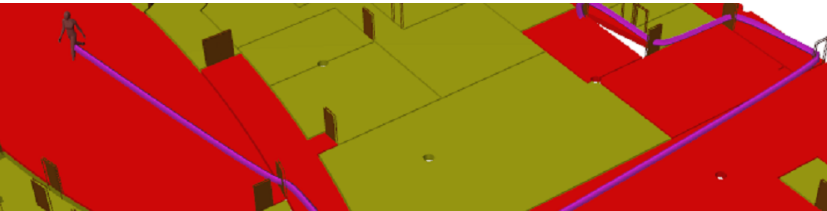
## Extension to XACML

- The major additions to XACML are the introduction of new data types and functions to support access control using building information models
- The newly introduced data types and functions will have IFC-specific URIs that can be matched in the Policy Decision Point and Context Handler
- The information on IFC matched attributes can be inferred using the spatial reasoning module through the policy information point



## Managing physical access control systems

- Proof-of-concept demonstrator to showcase the viability of proposed concepts
- To facilitate security administration for a physical access control system
- Address problems identified through interactions with industry partners of the Airports of the Future project



## Implementation Goals

1. Reduce physical access control configuration errors
2. Manage physical access control policies with less workload
3. Perform user friendly analysis on past access history



## BIM Access Control Functions

- We used a BIM based on Brisbane Airport International Terminal
- Contained Levels 3 and 4 of the building, with 11360 elements
- Consisted of 389 IfcDoor objects and 349 IfcSpace objects
- We implemented functions that map to the spatial reasoning module of our authorisation framework



# BIM Access Control Functions

## Path finding

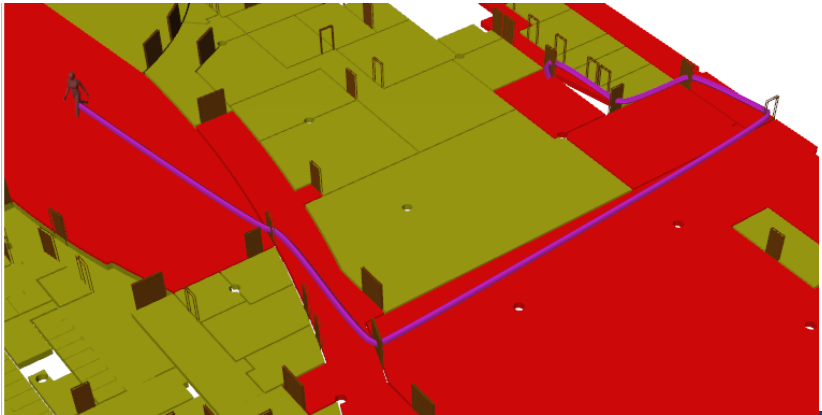
Property	Value
End Point	Space 3L.18
Goal	MinimalDistance
Maximum Security Level	10
Name	Second Floor Repair
Require CCTV	true
Restrict To Roles	Role Temporary Technician
Restrict To Users	User Bob
Start Point	Space 3A.42
Valid From	Fri Nov 01 00:00:00 PDT 2013
Valid To	Sun Dec 01 00:00:00 PST 2013

Time (in Seconds)	3 nodes	5 nodes	10 nodes
on Firefox	~0.9	~0.9	~0.9
on Chrome	~0.8	~0.8	~0.8

Table: Execution times for path finding function

# BIM Access Control Functions

## Accessibility





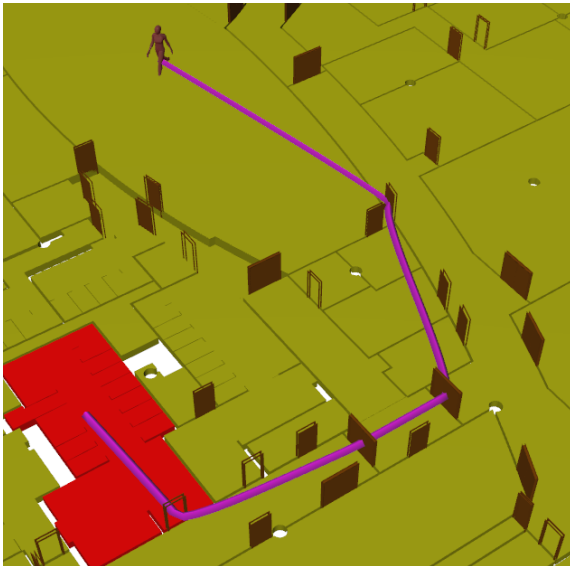
## Authorisation Management using BIM

The proof-of-concept demonstrator addresses the three main physical access control administration problems:

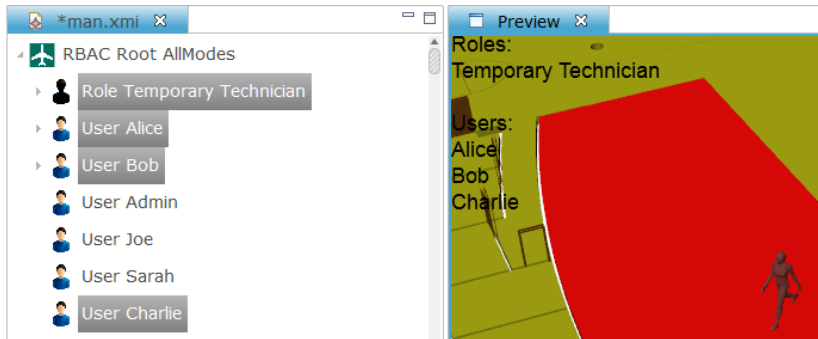
- intuitive PAC policy creation
- automated/assisted PAC policy management
- easy to use analysis of access history



## Intuitive PAC policy creation



# Automated/assisted PAC policy management



## Easy to use analysis of access history

\*man.xml

- RBAC Root AllModes
  - Role Temporary Technician
  - User Alice
  - User Bob
  - User Admin
  - User Joe
  - User Sarah
  - User Charlie

Preview

0 out of 4 rooms are never accessed  
0 out of 4 rooms are forbiddenly accessed

## Limitations and assumptions

### BIM availability:

- Up-to-date BIMs of a facility based on the IFC specification will be available as a fundamental requirement

### BIM efficiency:

- BIMs can become quite large and complex for most realistic situations and availability of efficient BIMs must be ensured

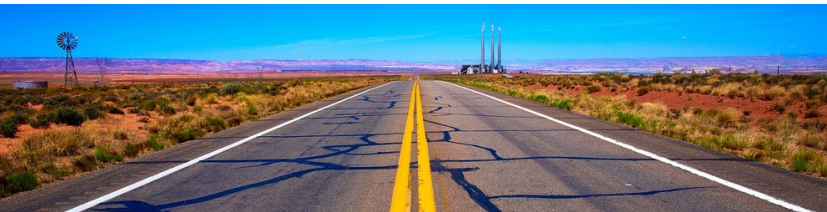
### BIM data security:

- Data stored in BIMs must be securely managed



## Future research opportunities

- BIM-PDP – to enable BIM specific spatial conditional functions to be handled through a spatial reasoning component of the authorisation framework
- Usability testing – to evaluate the effectiveness of using three-dimensional representations of buildings to improve access control and administration
- Practical testing – to prove the practical viability of the proposed capabilities in operational environments



## Summary of contributions and achievements

- Identification of access control challenges in smart buildings and critical infrastructure environments
- Detailed study on building information models and associated data representation standards
- Proposal to use building information models to facilitate access control in complex environments



## Summary of contributions and achievements

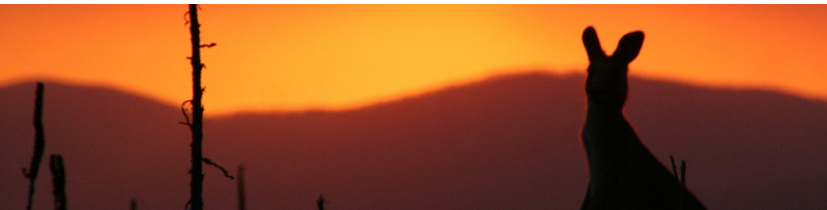
- A proposal for a novel authorisation framework, which uses building information models
- A graph theory based formal representation of building information models, BIM-graph
- A building information models specific extension to XACML called BIM-XACML
- A proof-of-concept demonstrator that utilises building information models to facilitate security administration





## Conclusion

- Using building information models to facilitate access control can improve security of smart building environments
- Convergence of physical and logical access control is necessary in these environments
- The notion of using building information models in the context of security applications is a new idea
- This thesis addresses a range of challenges in access control in complex environments and makes a number of contributions



Background  
○○○○○○○  
○○○○○

Framework  
○○○○○  
○○

BIM-Graph  
○  
○○○

BIM-XACML  
○○  
○○○

Implementation  
○  
○○○  
○○○○○○○○○●



Thank You

