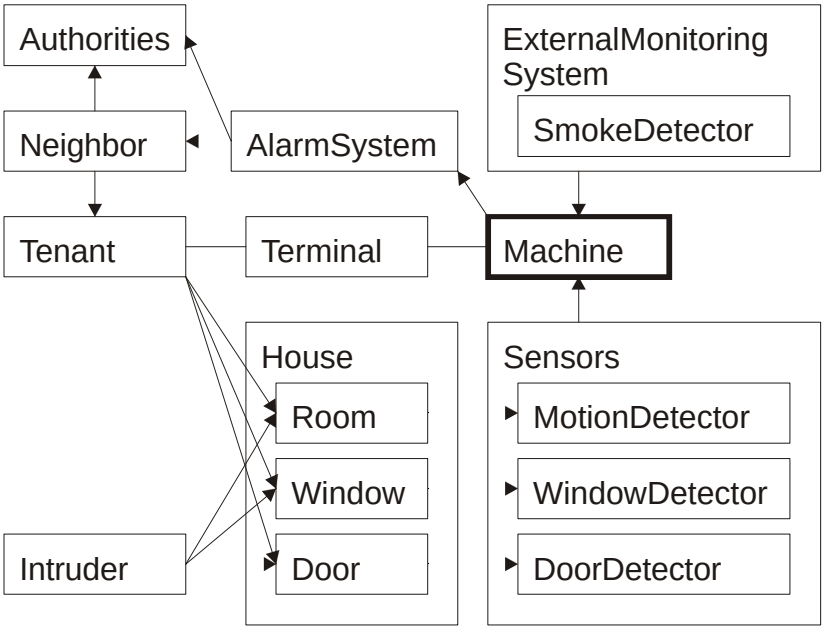
Context Diagram



Designations

Physical Structure

House(h)	h is a building
Room(r)	r is a room of the house
Window(w)	w is a window in an outside wall of the house
Door(d)	d a door in an outside wall of the house
HasDoor(r,d)	room r has a door d
HasTerminal(r,t)	room r has a terminal t

Persons/Roles

Authorities(a)	a are police or local security service authorities
Intruder(i,h)	i is a person forcefully trying to enter the house h
Tenant(t,h)	t is a person living in the house h
Neighbor(n,h)	n is a person living near house h

Input Devices

Sensor(s)	s is a device capable of detecting a problem
SmokeDetector(s,r)	s is a sensor capable of detecting smoke in room r
MotionDetector(m,r)	r is a sensor capable of detecting motion in a room r
WindowDetector(s,w)	s is a sensor capable of detecting an open window w
DoorDetector(s,d)	s is a sensor capable of detecting an open door d
ExternalMonitoringSystem(e)	e is a system monitoring other state

Input/Output Devices

Terminal(t)	t is the device providing a user interface to the security system

Output Devices

AlarmSystem(a)	a is the system that propagates alarms (to sirens/horns/lights and the authorities)

Dynamic Domain Fundamental Definitions

Event(e)	e is an atomic event
Earlier(e,f)	event e occurs before event f

Interval(v)	v is an interval of time
Duration(d,v)	d is the duration (in seconds) of interval v
Begins(e,v)	event e begins interval v
Ends(e,v)	event e ends interval v

Specific Events

Motion(e,r)	in event e, some movement happens in room r
Open(e,x)	in event e, a door or window x opens
Close(e,x)	in event e, a door or window x closes
Signal(e,s)	in event e, sensor s signals a problem
LightMotionIndicator(e)	in event e, light the motion indicator on every terminal
DimMotionIndicator(e)	in event e, dim (switch off) the motion indicator on every terminal
LightWindowIndicator(e)	in event e, light the open window indicator on every terminal
DimWindowIndicator(e)	in event e, dim (switch off) the open window indicator on every terminal
LightDoorIndicator(e)	in event e, light the open door indicator on every terminal
DimDoorIndicator(e)	in event e, dim (switch off) the open door indicator on every terminal
SwitchOnAlarm(e)	in event e, the alarm system switches on an acoustic and/or visual feedback (supposed to capture neighbors' attention and/or drive the intruder away)
SwitchOffAlarm(e)	in event e, the alarm system switches off the alarm
SendNotification(e)	in event e, the alarm system sends a notification about an alarm to the authorities
Authenticates(e)	in event e, someone correctly authenticates himself to gain access
PressAway(e)	in event e, someone presses the "away" button
PressHome(e)	in event e, someone presses the "home" button
PressOff(e)	in event e, someone presses the "off" button

System States

Away(v)	in interval v, the system is in "away" mode
Home(v)	in interval v, the system is in "home" mode
Off(v)	in interval v, the system is in "off" mode

Definitions

Dynamic Domain Definitions

InitialInterval(v)	:	Interval(v) and not exists e: Begins(e,v)
FinalInterval(v)	:	Interval(v) and not exists e: Ends(e,v)
Includes(v,e)	:	Interval(v) and exists e,i,f: Begins(i,v) and Ends(f,v) and Earlier(i,e) and Later(f,e)
Duration(d,e,f)	:	Duration(d,v) and Begins(e,v) and Ends(f,v)

Other Definitions

MotionDetected(e,s,r)	:	MotionDetector(s,r) and Signals(e,s)
OpenWindowDetected(e,s,w)	:	WindowDetector(s,w) and Signals(e,s)
OpenDoorDetected(e,s,d)	:	DoorDetector(s,d) and Signals(e,s)

Refutable Descriptions

Static: Rooms, windows and doors are protected

Room(r) => MotionDetector(s,r)
Window(w) => WindowDetector(s,w)
Door(d) => DoorDetector(s,d)

Static: Easy to read the current state of the system & Authentication is straightforward

Room(r) and HasDoor(r) and => exists t: Terminal(t) and HasTerminal(r,t)

Dynamic: Sensors actually detect problems

Room(r) and Motion(e,r) and MotionDetector(s,r) => MotionDetected(e,s,r)
Window(w) and Open(e,w) and WindowDetector(s,w) => OpenWindowDetected(e,s,w)

Door(d) and Open(e,d) and DoorDetector(s,d) => OpenDoorDetected(s,d)

Dynamic: Easy to read the current state of the system
MotionDetected(e,s,r) and Away(v) and Includes(v,e) => LightMotionIndicator(e)
MotionDetected(e,s,r) and Home(v) and Includes(v,e) => LightMotionIndicator(e)
OpenWindowDetected(e,s,w) and Away(v) and Includes(v,e) => LightWindowIndicator(e)
OpenWindowDetected(e,s,w) and Home(v) and Includes(v,e) => LightWindowIndicator(e)
OpenDoorDetected(s,d) and Away(v) and Includes(v,e) => LightDoorIndicator(e)
OpenDoorDetected(s,d) and Home(v) and Includes(v,e) => LightDoorIndicator(e)

Dynamic: Detected problems actually initiate alarms
MotionDetected(e,s,r) and Away(v) and Includes(v,e) => SwitchOnAlarm(f) and Duration(10,e,f)
OpenWindowDetected(e,s,w) and Away(v) and Includes(v,e) => SwitchOnAlarm(f) and Duration(10,e,f)
OpenWindowDetected(e,s,w) and Home(v) and Includes(v,e) => SwitchOnAlarm(f) and Duration(10,e,f)
OpenDoorDetected(s,d) and Away(v) and Includes(v,e) => SwitchOnAlarm(f) and Duration(10,e,f)
OpenDoorDetected(s,d) and Home(v) and Includes(v,e) => SwitchOnAlarm(f) and Duration(10,e,f)

Initiated Alarms actually lead to authority notifications
SwitchOnAlarm(e) => SendNotification(e,u)

Switching between modes
Off(v) and Authenticates(e) and PressHome(e) => Home(w) and Begins(e,w) and Ends(e,v)
...dito for every other operating mode change
Off(v) and Begins(e,v) => DimMotionIndicator(e) and DimWindowIndicator(e) and DimDoorIndicator(e)
Off(v) and Begins(e,v) => SwitchOffAlarm(e)

Informal Refutable Descriptions
Authenticates(t) must be possible within 20 seconds from entering any door.
A sensor must be installable in 5 minutes.
Every terminal must have a brief user manual attached.

Rough Sketches

- Various levels of security (away and at home). *[OK, formalized by the three security levels above]*
- Windows, doors, and rooms are protected. *[OK, formalized above]*
- Sensors can be installed without requiring major modification to the home's infrastructure (e.g. prefer wireless devices over running cable through walls). *[Partially addressed with the informal requirement above]*
- Easy to read the current state of the system. *[Partially addressed by the requirement that alarms have to be indicated on the terminals, and that every room with a room has to have a terminal]*
- If an alarm is activated there shall be given enough information to respond appropriately. *[Partially addressed by the requirement that alarms have to be indicated on the terminals]*
- If an alarm goes off, the authorities are automatically notified. *[OK, formalized above]*
- The system is authenticated such that only tenants can modify the system's operating mode. *[Partially addressed by using the Authenticates(e) predicate above]*
- Authentication is straightforward (so as not to take too much time). *[Partially addressed by the requirement that every room with a door must have a terminal, and with the informal refutable description above]*
- The security system can integrate other monitoring systems, such as a home's smoke alarms. *[not addressed in refutable descriptions yet, only listed here for future specification in a fashion similar to the existing sensors]*

Remarks:

I started out using a rigorous predicate logic approach. But I found that doing that forces me to define way too many details, especially in the dynamic part. I think that starting with the rough sketch, which, in my opinion corresponds to what you provided in the problem statement, would have been better.

In general I think that creating the formal predicate logic definitions and refutable descriptions leads to a structure which is very similar to a procedural system, but with much more details. I think that abstracting details away is much harder to do in this predicate logic structure than in an object-oriented structure. The only kind of abstraction provided by predicate logic actually is the substitution of predicates defined in terms of other predicates. In OO, we would have the more powerful means of composition and inheritance, but also already predefined abstractions for time (the order of program execution) and the same abstraction we have in predicate logic, functional decomposition (method calls). And we would also have powerful means of encapsulation, which are completely absent in predicate logic (in this respect, predicate logic seems to be the worst possible choice, since it's universal and existential quantifier break any kind of encapsulation). I remember from the algebraic specification languages (like Larch and JML), that using an OO approach on the outside (the relationships between subdomains/classes), and only using predicate logic to specify the internal workings of a class (like for class/object invariants and method pre- and postconditions) can be very benefitial.