Developing the Crowd Simulation Scenario (CSS) ontology supporting building evacuation design

Calin Boje
Research and Technology Associate
Digital Built Environment Management
Luxembourg Institute of Science and Technology

Fire safety engineering

1. Fire growth
2. Smoke spread
3. Structural protection
4. Detection & suppression
5. Intervention
6. Human factors
7. Risk assessment

PD 7974 (2004), or BS 7974

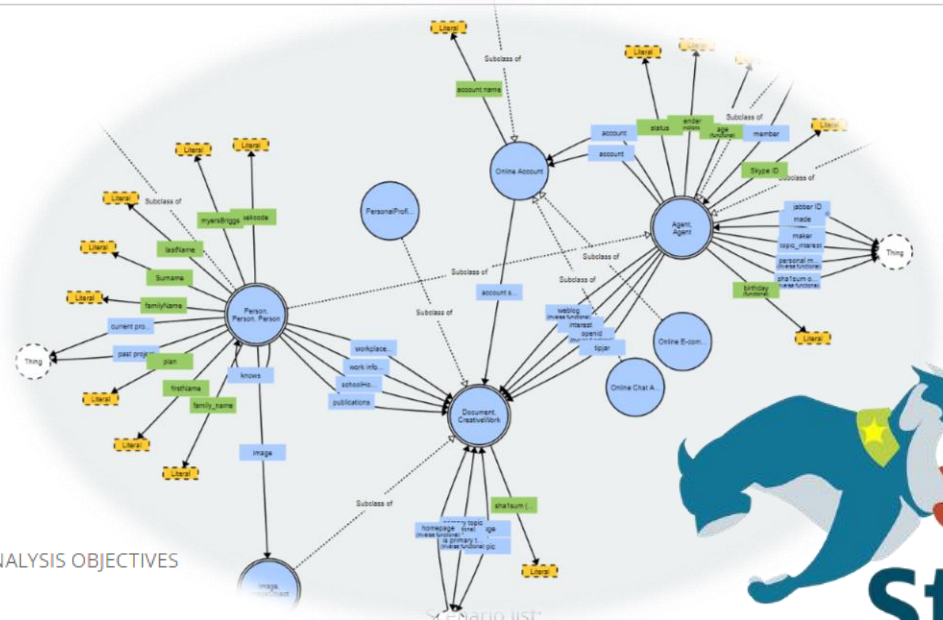
The problem

- Human behaviour in buildings is hard to predict:
  - Diverse human behaviour factors (Ronchi and Nilsson 2013)
  - Building layout
- Designers rely on crowd simulation tools, but:
  - Several scenarios are required (BS 7974)
  - Tools are probabilistic in nature
- Processes of evaluating building performance is:
  - Inefficient
  - Low integration with current BIM-based processes (Wang and Wainer 2015)

Stardog Admin Web Con | ONTOCS

localhost:8080/#!objectives

ONTOCS



SCENARIO OPTIONS

Scenario population data:

- [x] Take population data from my IFC file
- [ ] Take population data from design code (*)
- [ ] Distribute population across all spaces

Scenario population options:

- [ ] Full capacity
- [ ] Th… capacity

Stardog connection

Logged in as

ANALYSIS OBJECTIVES

- [x] Total egress time
- Agent egress times
- …entify bottlenecks
- …ntify high density areas

scenario list:

scenario-1 ad2w scenario-3

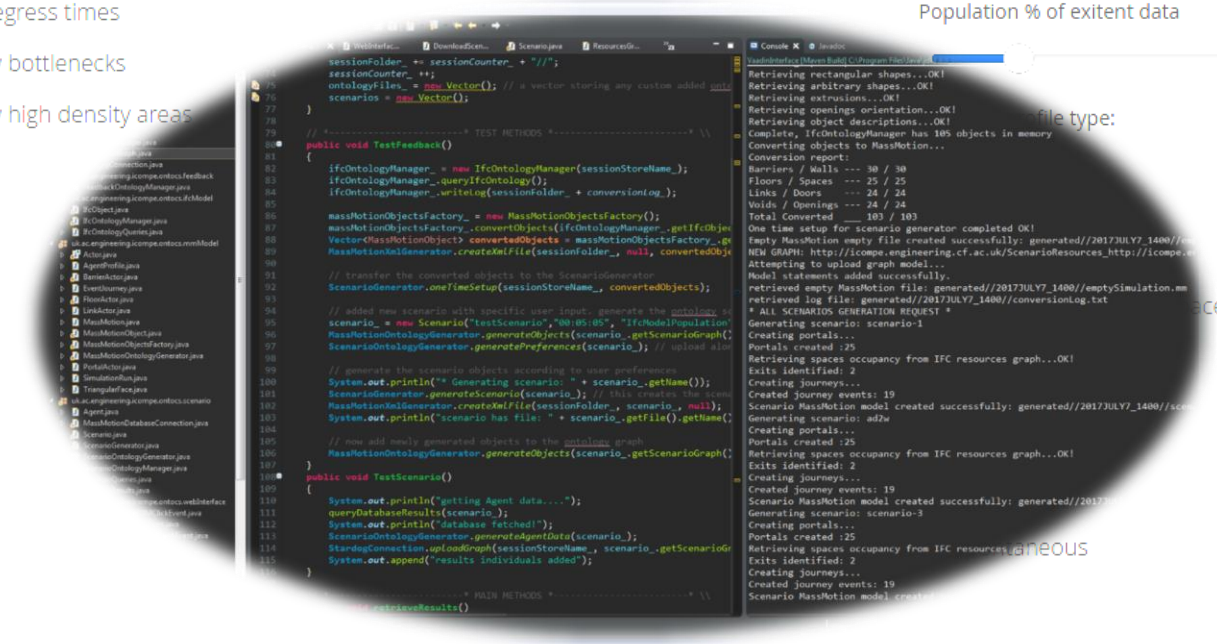
Population % of exitent data

…file type:

…ce types

…aneous

MassMotion



Oasys MassMotion - D:\Eclipse Workspace\ontocs\generated\2017SEPTEMBER15_10551\scenario-1\FullCapacity.mm *

File Edit View Help

MassMotion

Project Scene Activities Simulation & Analysis

New Open Save Close Project Settings Import Export Agent Positions Alembic Movie or Image

All Objects

Search Name or Type...

Name	Type
BasicWall:Wall1:4405...	Barrier
BasicWall:Wall1:4481...	Barrier
BasicWall:Wall1:4534...	Barrier
BasicWall:Wall1:4558...	Barrier
BasicWall:Wall1:4755...	Barrier
BasicWall:Wall1:4830...	Barrier
BasicWall:Wall1:4902...	Barrier
BasicWall:Wall1:5053...	Barrier
BasicWall:Wall1:5309...	Barrier
BasicWall:Wall1:5465...	Barrier
BasicWall:Wall1:5555...	Barrier
BasicWall:Wall1:5790...	Barrier
BasicWall:Wall1:5848...	Barrier
BasicWall:Wall1:5974...	Barrier
BasicWall:Wall1:6092...	Barrier
BasicWall:Wall1:6453...	Barrier
BasicWall:Wall1:6505...	Barrier
BasicWall:Wall1:6721...	Barrier
BasicWall:Wall1:6787...	Barrier
BasicWall:Wall1:6902...	Barrier
BasicWall:Wall1:7009...	Barrier
BasicWall:Wall1:7123...	Barrier
BasicWall:Wall1:7415...	Barrier
BasicWall:Wall1:7476...	Barrier
BasicWall:Wall1:7546...	Barrier
BasicWall:Wall1:7641...	Barrier
BasicWall:Wall1:7736...	Barrier
BasicWall:Wall1:7829...	Barrier
BasicWall:Wall1:8296...	Barrier
BasicWall:Wall1:8348...	Barrier
Doors_Concept_ExtD...	Barrier
Doors_Concept_ExtD...	Link
Doors_Concept_ExtD...	Barrier
Doors_Concept_ExtD...	Link
Doors_Concept_IntD...	Barrier
Doors_Concept_IntD...	Link
Doors_Concept_IntD...	Barrier
Doors_Concept_IntD...	Link
Doors_Concept_IntD...	Barrier
Doors_Concept_IntD...	Link
Doors_Concept_IntD...	Barrier
Doors_Concept_IntD...	Link
Doors_Concept_IntD...	Barrier
Doors_Concept_IntD...	Link
Doors_Concept_IntD...	Barrier

Perspective SimulationRun1

Object

Transform

Position

X Y Z L

Mode

Measure Trace

Operations

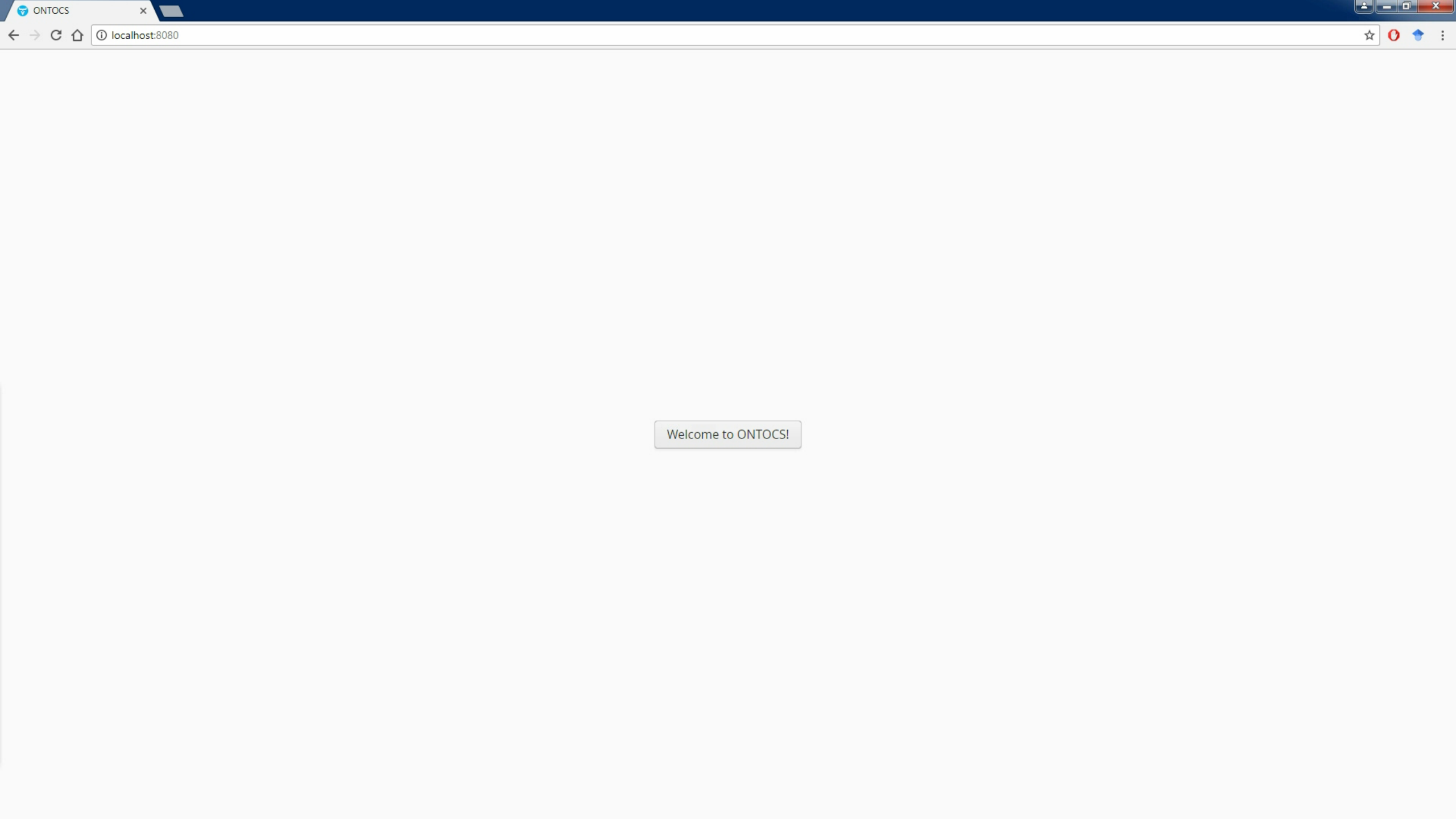
Generate

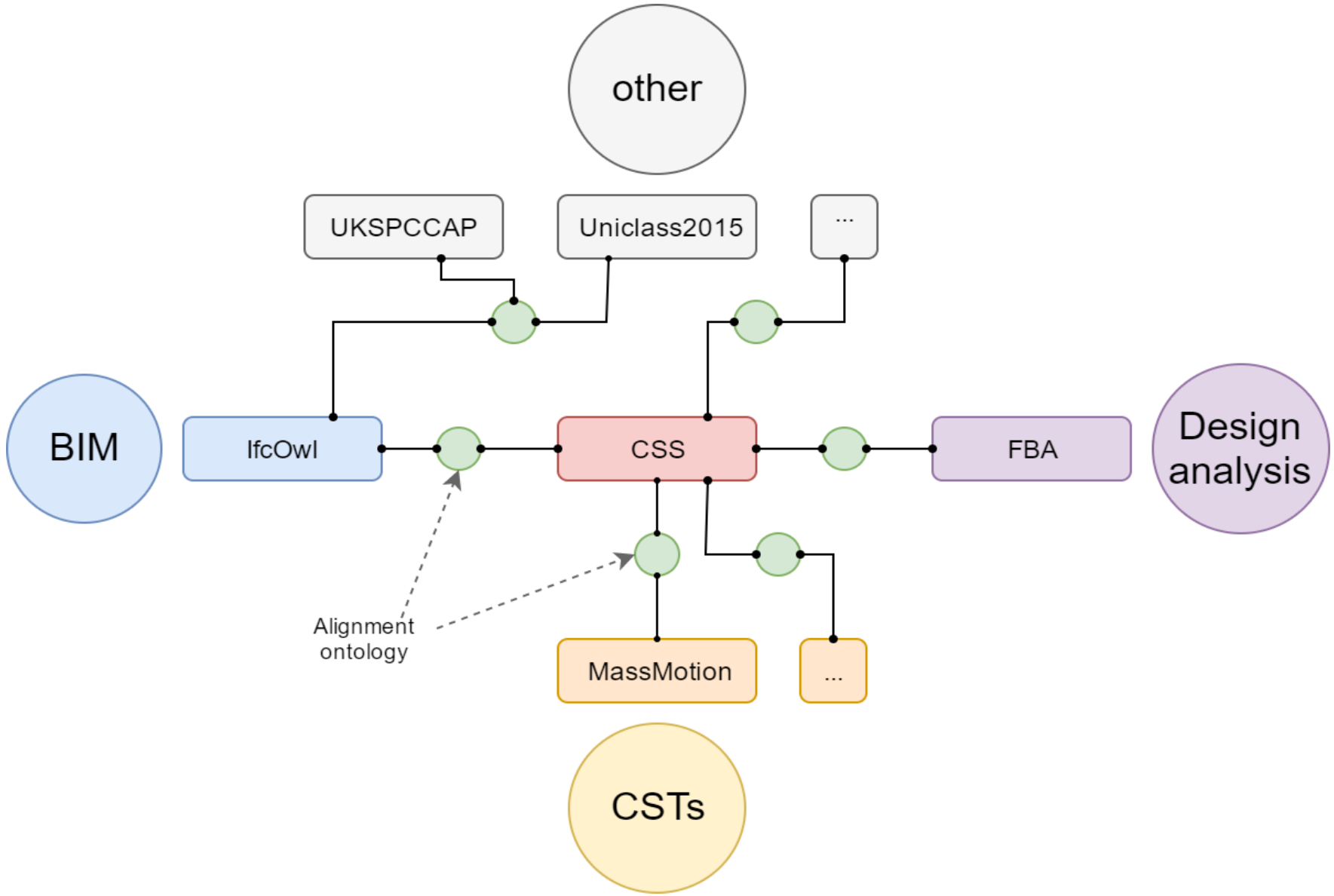
00:00:00 00:04:59

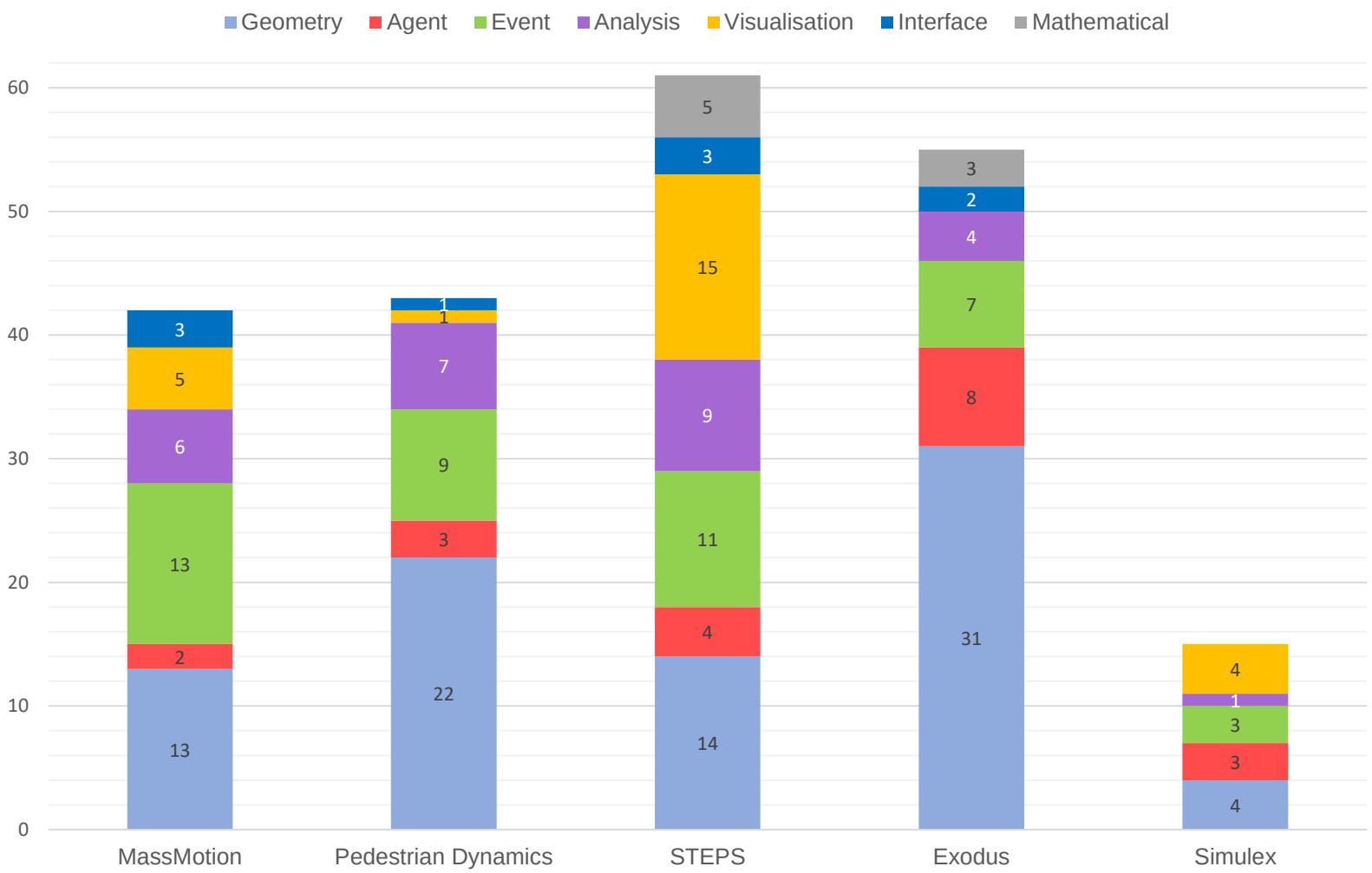
Time: 00:00:13

x1 x2 x5 x10 x20

Selection: Distance: Mode: Object|Agent Population: 145

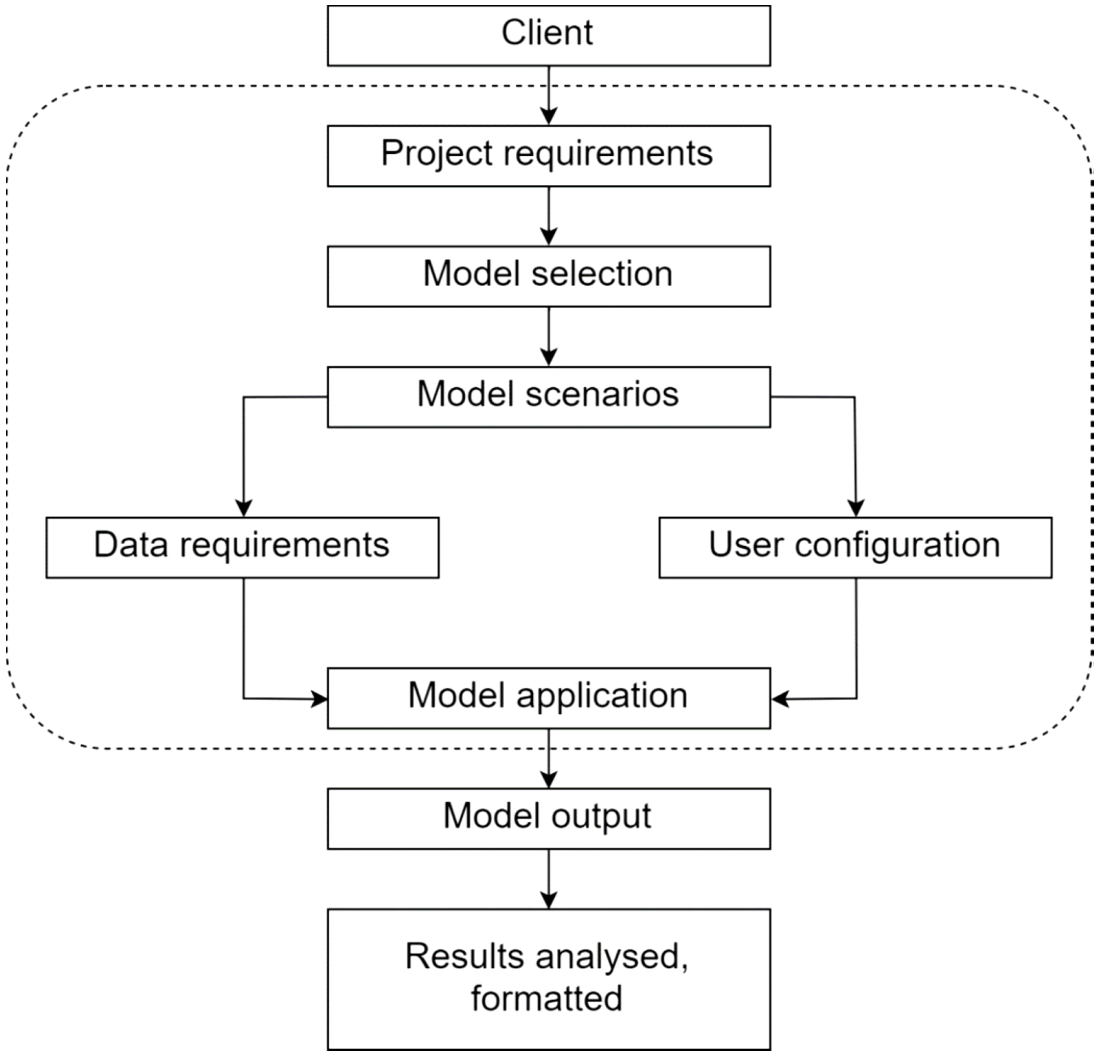

ONTOCS
localhost:8080
Welcome to ONTOCS!


other
UKSPCCAP
Uniclass2015
...
BIM
IfcOwl
CSS
FBA
Design analysis
Alignment ontology
MassMotion
...
CSTs


Geometry
Agent
Event
Analysis
Visualisation
Interface
Mathematical
60
50
40
30
20
10
0
MassMotion
Pedestrian Dynamics
STEPS
Exodus
Simulex
13
2
13
6
5
3
22
3
9
7
1
1
14
4
11
9
15
3
5
31
8
7
4
2
3
4
3
3
1
4

Taxonomy for a Crowd Simulation Model

Concept		Definition	Synonym
Geometry	Space	Walkable surfaces for agents.	Floor, Area
	Barrier	Surfaces which obstruct agent movement.	Obstruction
	Link	Connection between two walkable surfaces.	Transfer
	Portal	Entry and/or exit points for agents.	Entry or Exit Point
Agent	Agent	Representation of a building inhabitant.	Occupant
	Group	A collection of agents.	
	Profile	A definition of agent characteristics.	
Event	Journey	The act of describing agent movement from A to B.	Route
	Circulation	The act of agents following a route of waypoints.	Itinerary
	Evacuation	The act of agents exiting to nearest available exit.	Egress
Analysis	Graph	Simulation data plotted on a graph for user analysis.	
	Map	Simulation data plotted on a map, overlaid on the model.	
	Table	Simulation data in tabular format.	



The computer modelling process for evacuation design, adapted from Kuligowski (2016a)

CSM methodologies

(Gwynne et al. 1999) (Kuligowski 2005) (Kuligowski 2016a)

Application domains

(Kuligowski 2005),

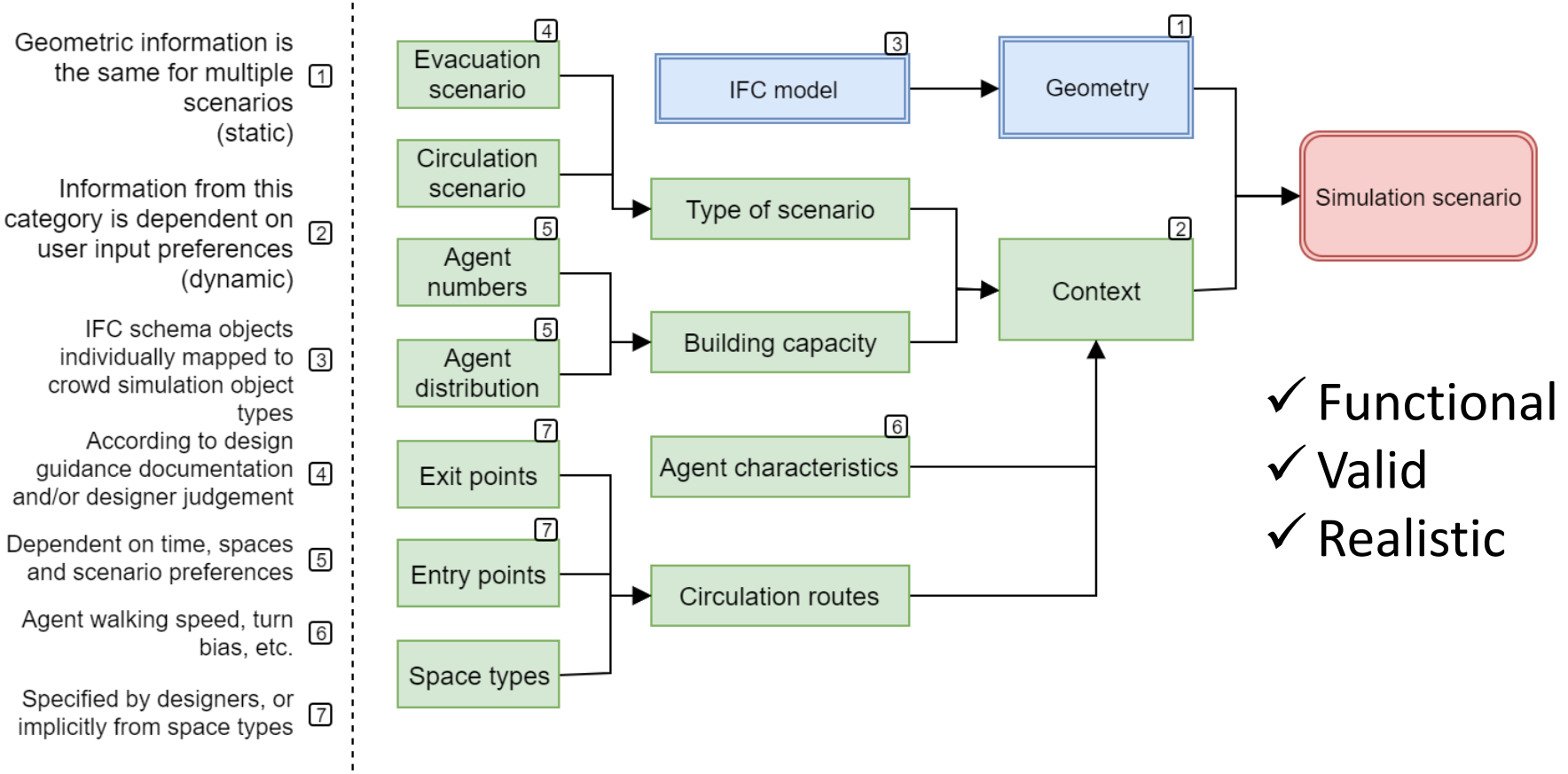
Scale

(Zhou et al. 2010),

Degree of realism

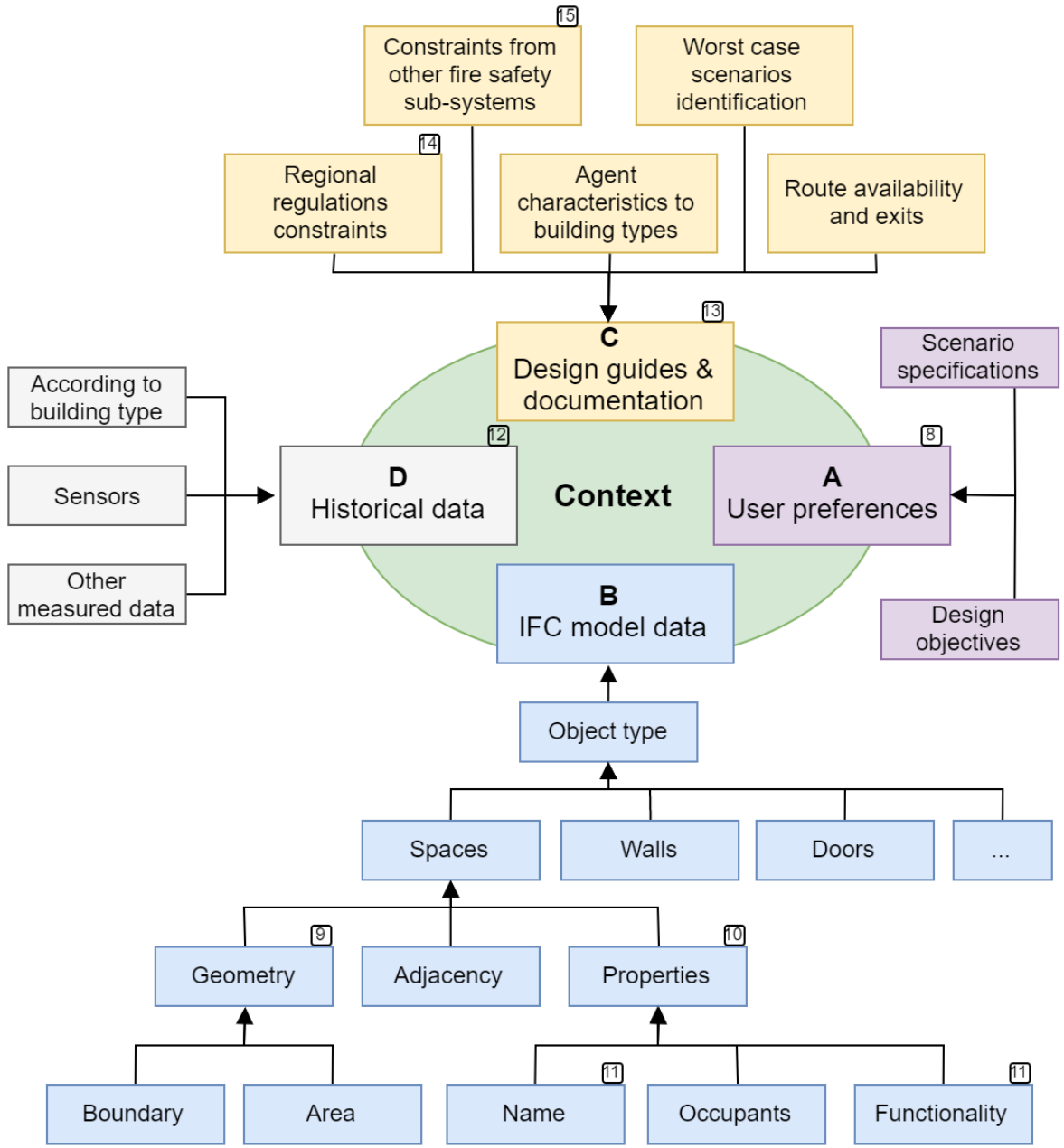
(Duives et al. 2013)

STAGE I – scenario generation (automation)



Simulation scenario input information types

Identified sources of data and information



8 User input can affect all other categories in B, C and D, which differ from one scenario to another

9 Object geometry can provide contextual information implicitly or is conjunction with other data

10 Properties specific to building occupancy are not defined in the IFC schema, but custom ones can be used to provide explicit data

11 Names of specified functionality of a space can be used to decide route selection, entry and exit points with the correct rules and reasoning

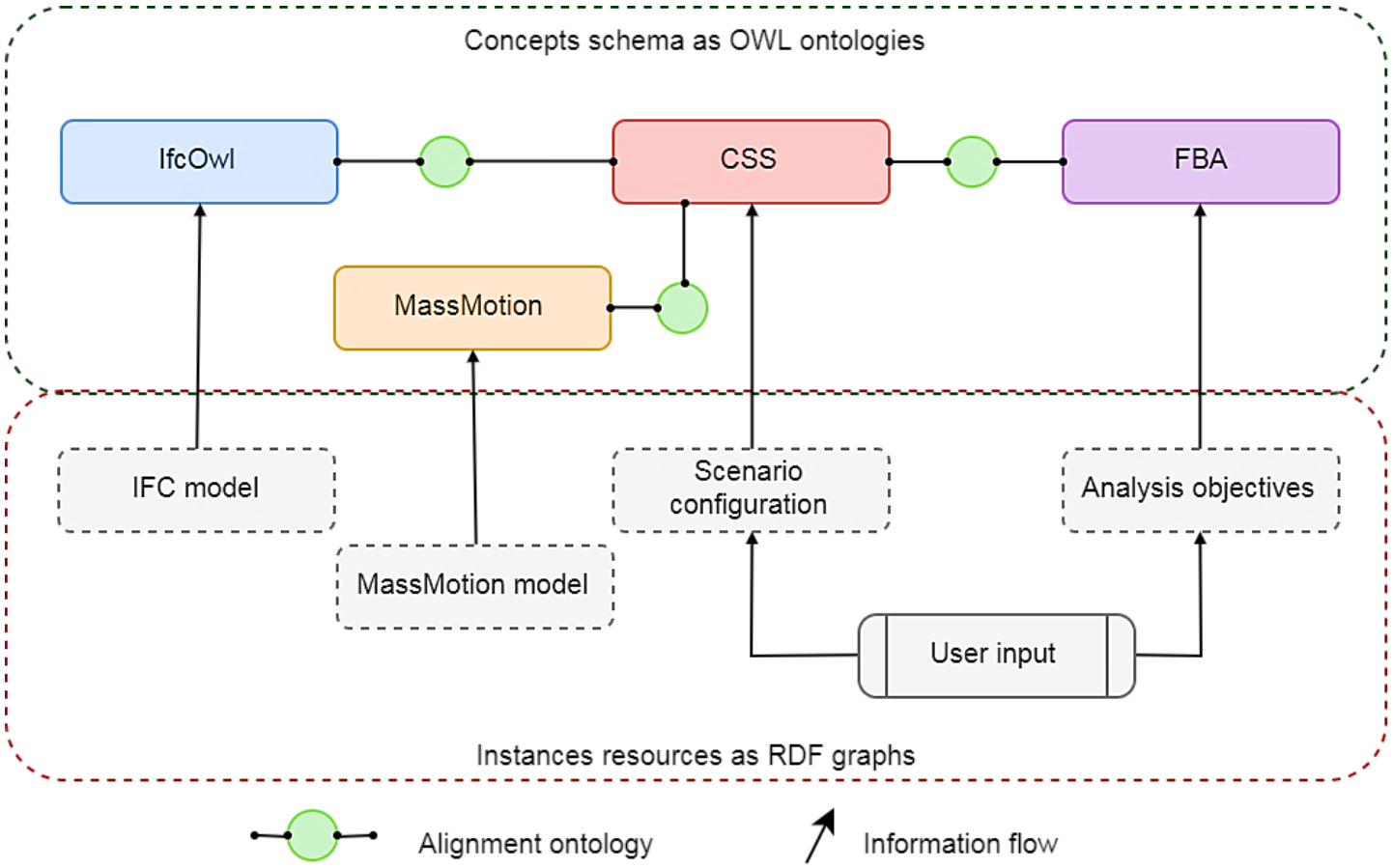
12 Where available, historical data about the building in operation stage, or similar buildings in the past can provide relevant data

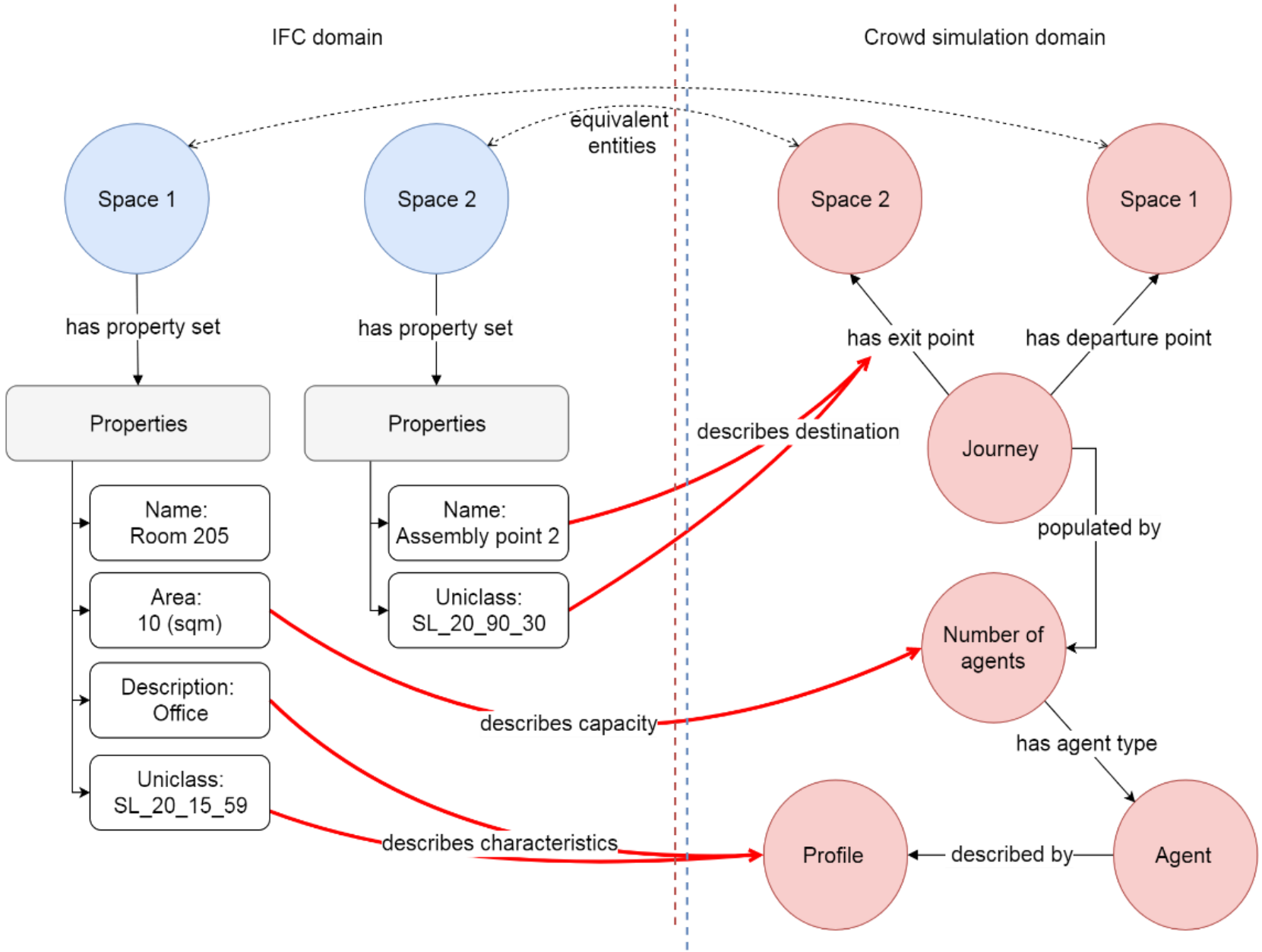
13 Due to the indicative nature of design guides, many assumptions are flexible, vague and subject to designer personal judgement

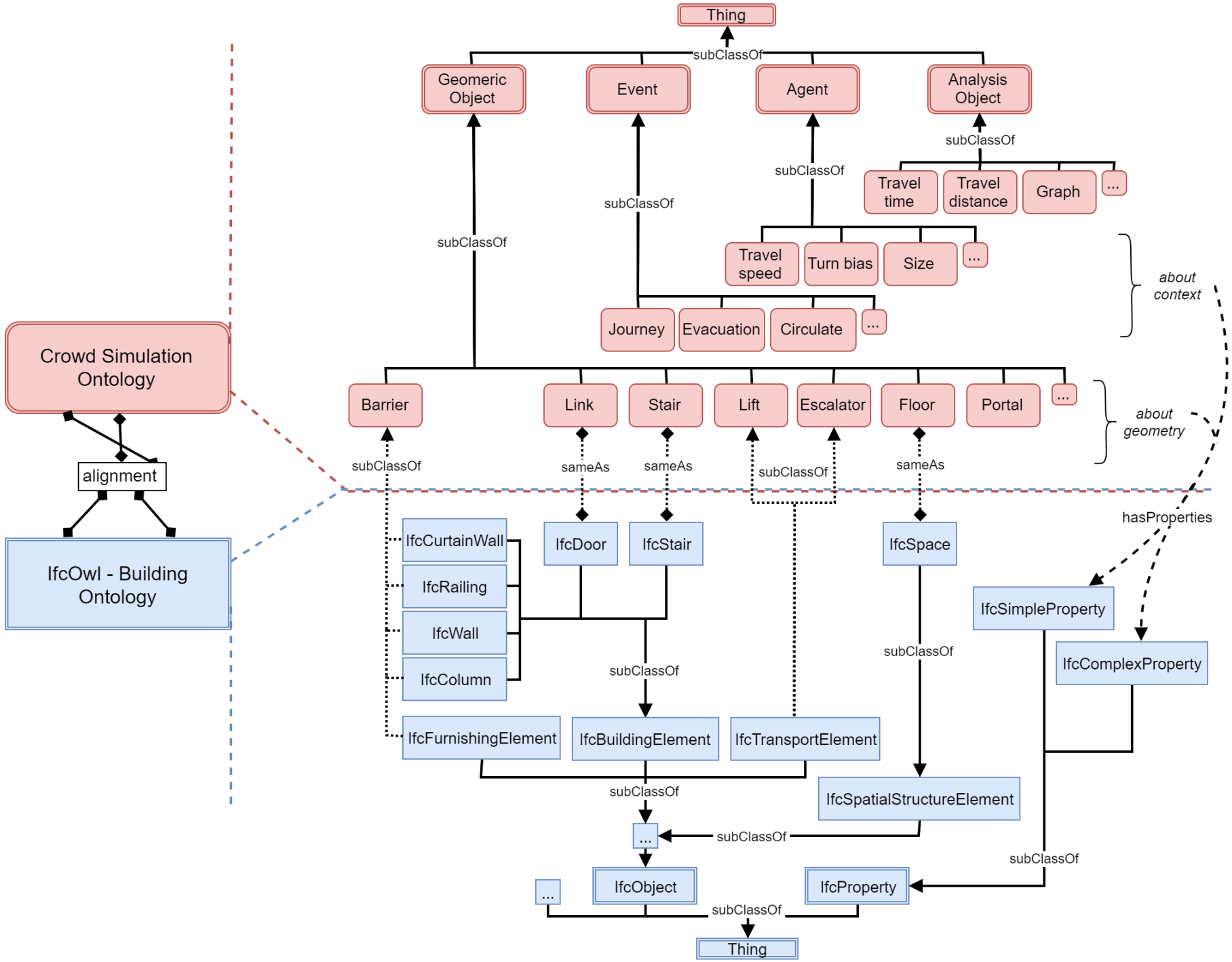
14 certain regulations vary with region, such as occupancy loads per space type

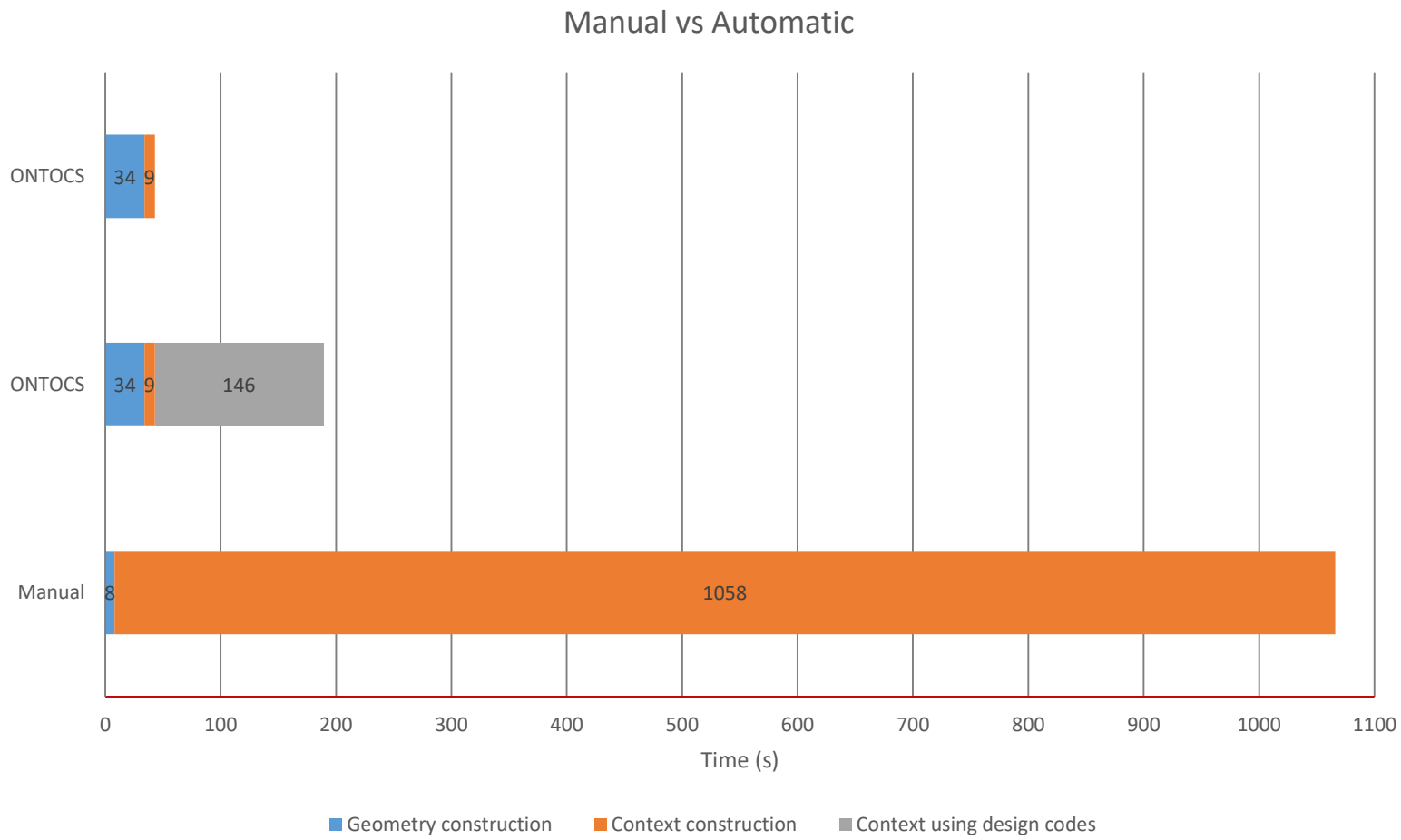
15 due to the fire safety design complexity, other sub-systems can reflect the assumptions for crowd simulation scenarios

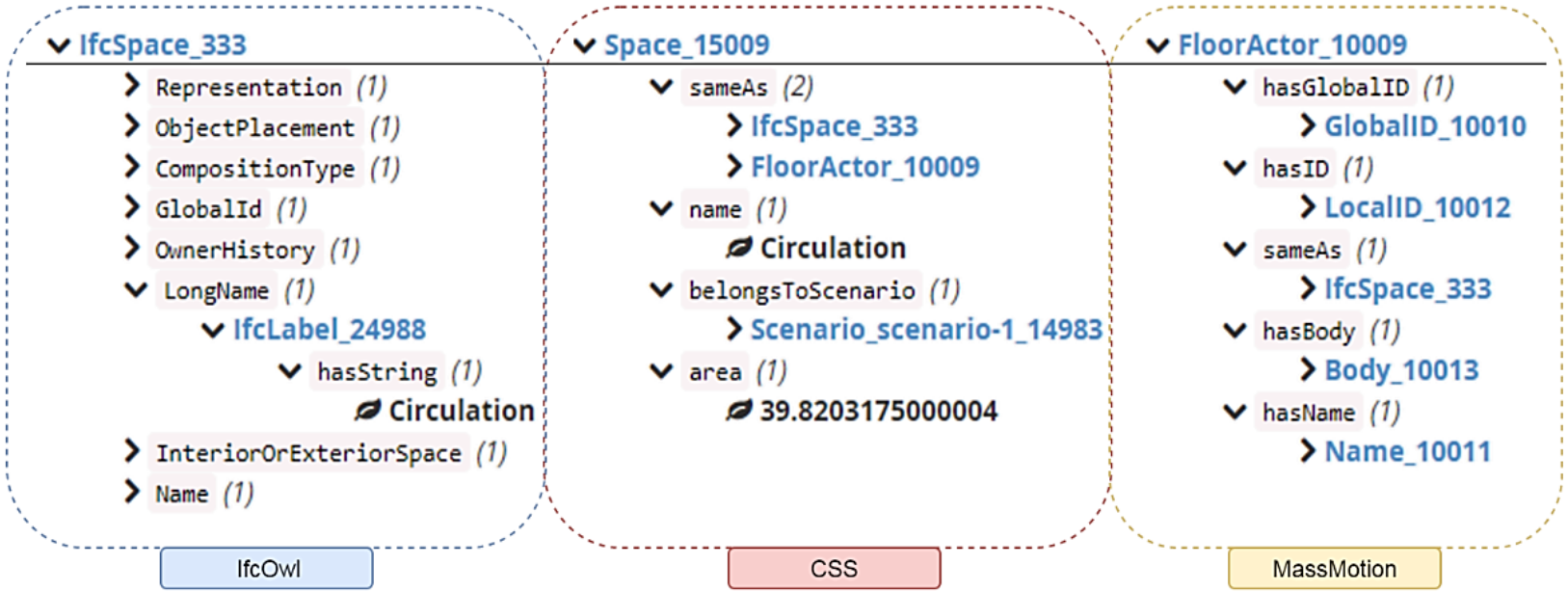
Storing knowledge, interaction of RDF resources




IFC domain
Crowd simulation domain
equivalent entities
Space 1
Space 2
Space 2
Space 1
has property set
has property set
has exit point
has departure point
Properties
Properties
describes destination
Journey
Name: Room 205
Area: 10 (sqm)
Description: Office
Uniclass: SL_20_15_59
Name: Assembly point 2
Uniclass: SL_20_90_30
populated by
Number of agents
describes capacity
has agent type
describes characteristics
Profile
described by
Agent

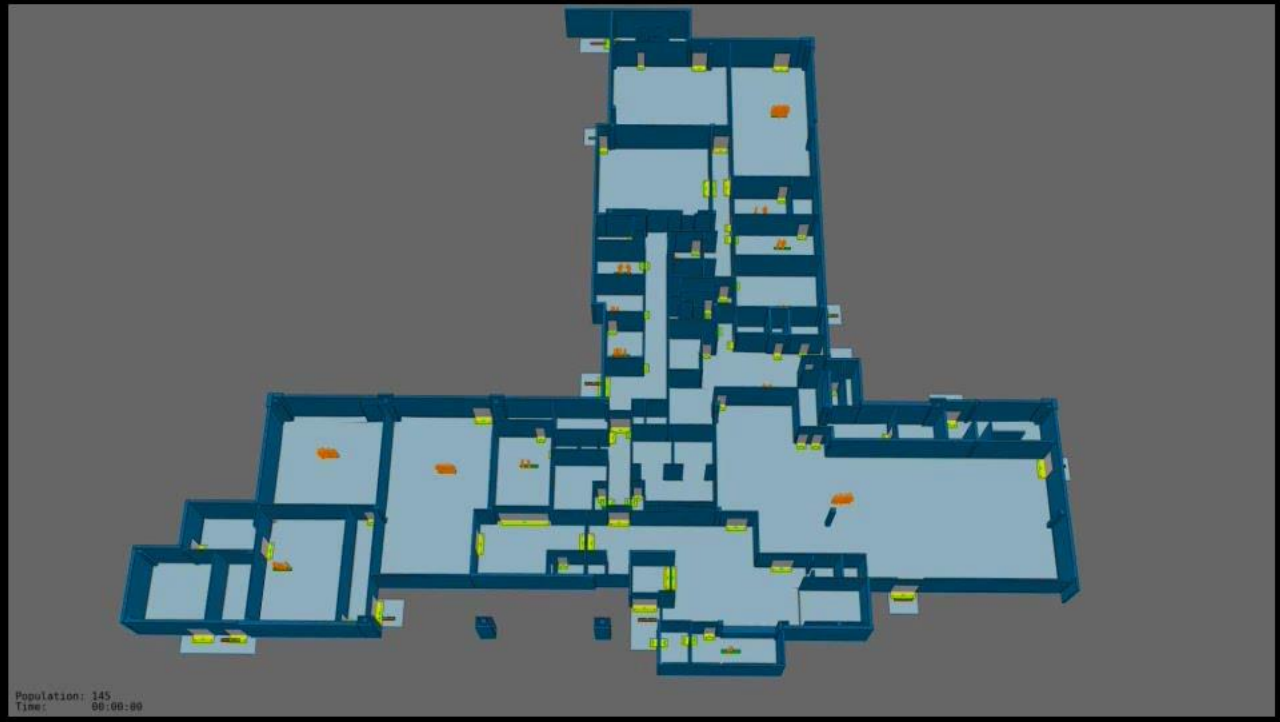

Crowd Simulation Ontology
alignment
IfcOwl - Building Ontology
Thing
subClassOf
Geomeric Object
Event
Agent
Analysis Object
Travel time
Travel distance
Graph
...
Travel speed
Turn bias
Size
Journey
Evacuation
Circulate
about context
about geometry
Barrier
Link
Stair
Lift
Escalator
Floor
Portal
sameAs
hasProperties
IfcCurtainWall
IfcRailing
IfcWall
IfcColumn
IfcDoor
IfcStair
IfcSpace
IfcSimpleProperty
IfcComplexProperty
IfcFurnishingElement
IfcBuildingElement
IfcTransportElement
IfcSpatialStructureElement
IfcObject
IfcProperty

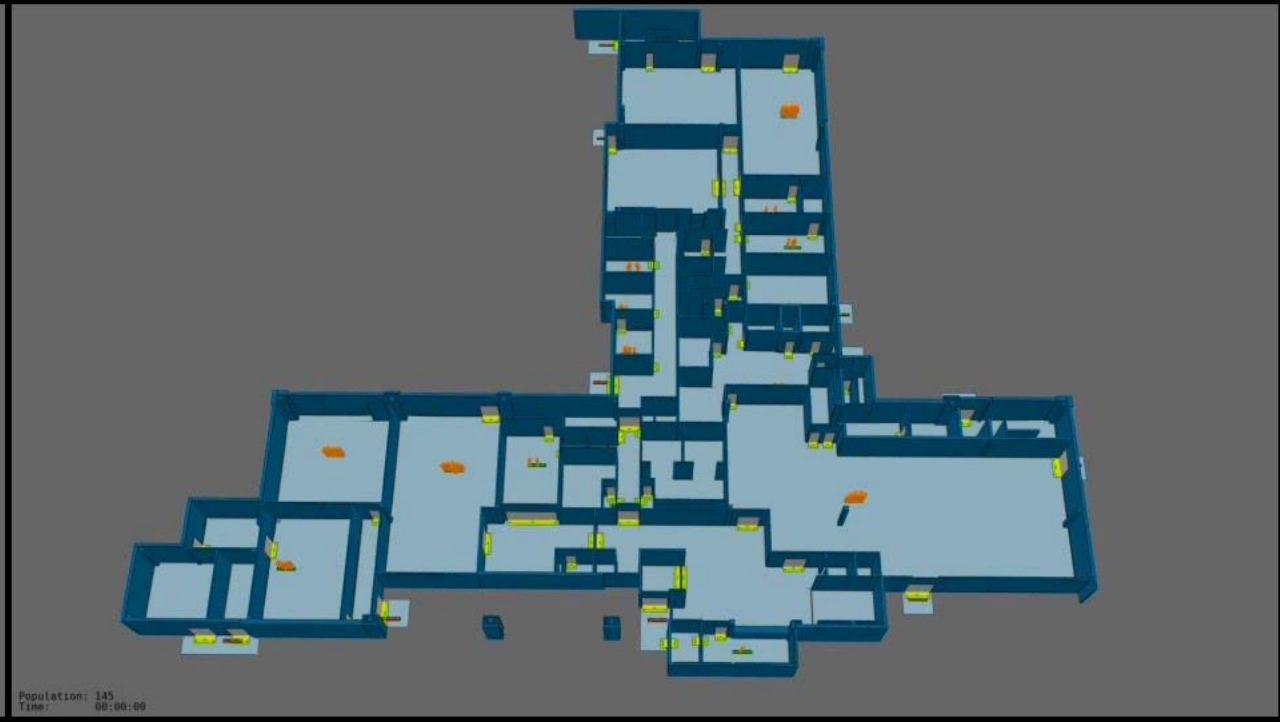

Manual vs Automatic
ONTOCS
34
9
ONTOCS
34
9
146
Manual
8
1058
0
100
200
300
400
500
600
700
800
900
1000
1100
Time (s)
Geometry construction
Context construction
Context using design codes

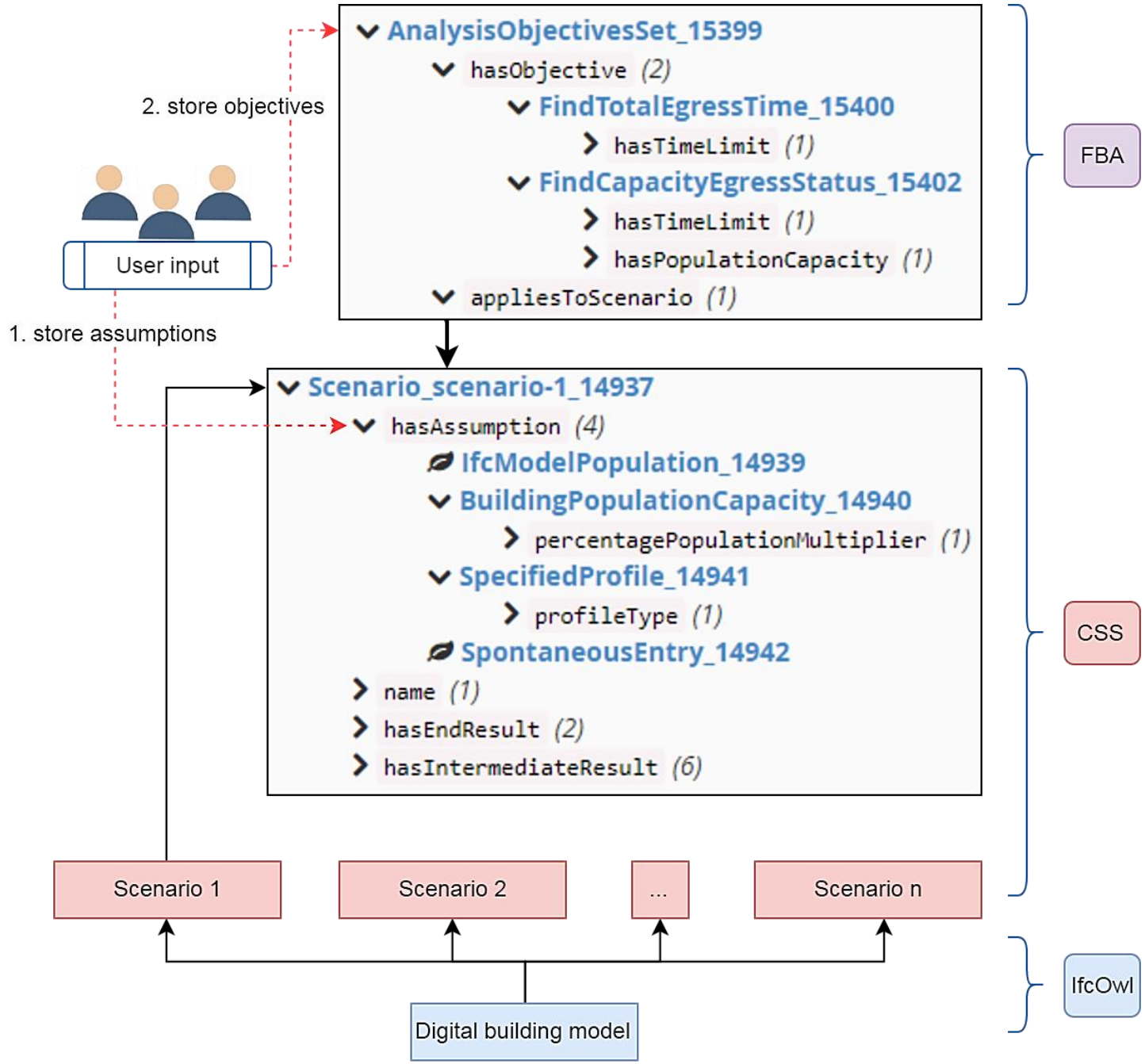

IfcSpace_333
Representation (1)
ObjectPlacement (1)
CompositionType (1)
GlobalId (1)
OwnerHistory (1)
LongName (1)
IfcLabel_24988
hasString (1)
Circulation
InteriorOrExteriorSpace (1)
Name (1)
IfcOwl
Space_15009
sameAs (2)
IfcSpace_333
FloorActor_10009
name (1)
Circulation
belongsToScenario (1)
Scenario_scenario-1_14983
area (1)
39.8203175000004
CSS
FloorActor_10009
hasGlobalID (1)
GlobalID_10010
hasID (1)
LocalID_10012
sameAs (1)
IfcSpace_333
hasBody (1)
Body_10013
hasName (1)
Name_10011
MassMotion


Population: 362
Time: 00:00:00


Population: 72
Time: 00:00:00

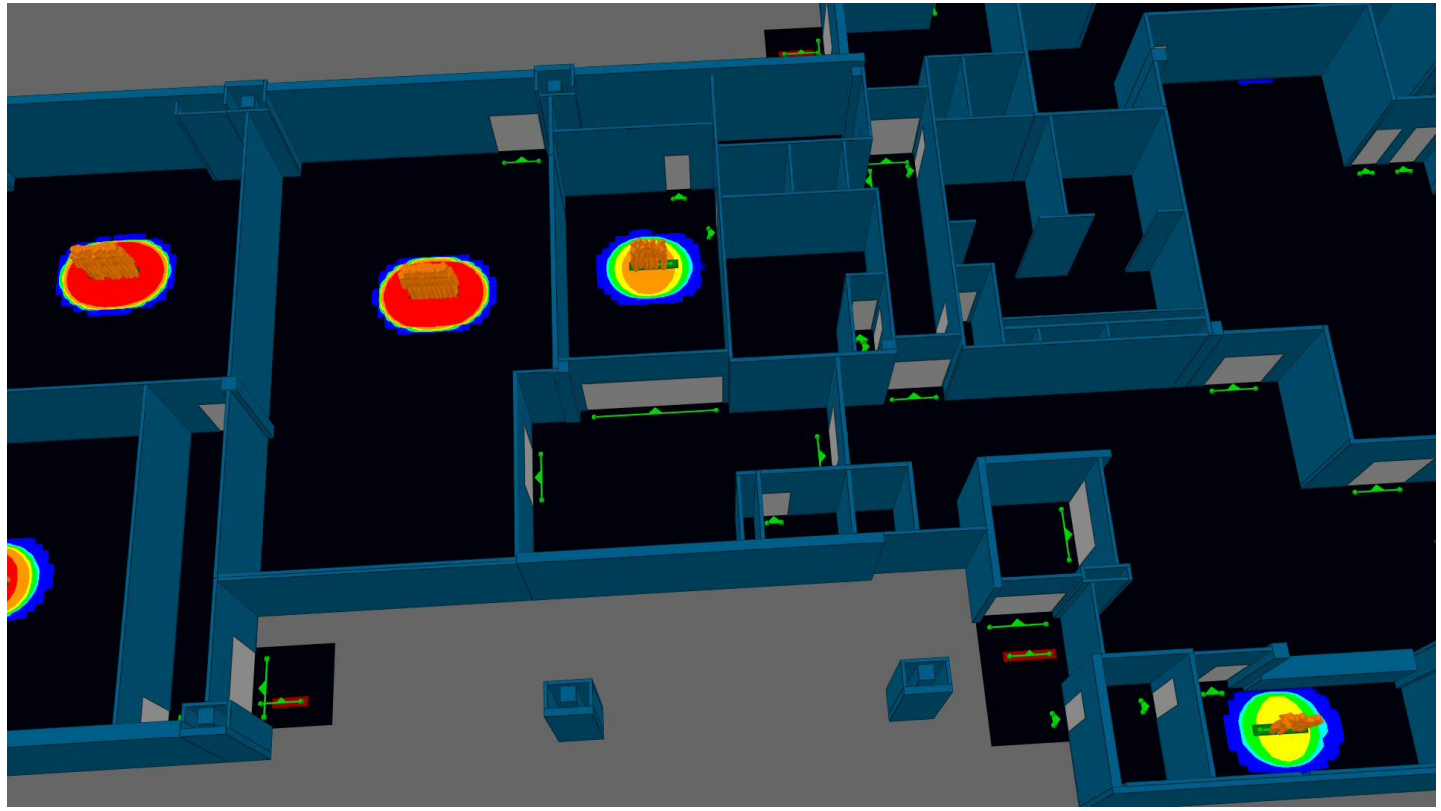

Population: 145
Time: 00:00:00


Population: 145
Time: 00:00:00


AnalysisObjectivesSet_15399
hasObjective (2)
FindTotalEgressTime_15400
hasTimeLimit (1)
FindCapacityEgressStatus_15402
hasTimeLimit (1)
hasPopulationCapacity (1)
appliesToScenario (1)
2. store objectives
User input
1. store assumptions
FBA
Scenario_scenario-1_14937
hasAssumption (4)
IfcModelPopulation_14939
BuildingPopulationCapacity_14940
percentagePopulationMultiplier (1)
SpecifiedProfile_14941
profileType (1)
SpontaneousEntry_14942
name (1)
hasEndResult (2)
hasIntermediateResult (6)
CSS
Scenario 1
Scenario 2
...
Scenario n
Digital building model
IfcOwl

Design feedback – object level

		Agents		Travel distances (m)		
Spaces	Agent profile	IN	OUT	MIN	MAX	AVG
▾ Common Room						
scenario-1	FruinCommuter	90	0	6.60	44.78	17.08



Publications

- "A framework for ontology-based design assessment for human behaviour during fire evacuation" Calin Boje & Haijiang Li
  - EG-ICE July 2017, conference
- "Crowd simulation-based knowledge mining supporting building evacuation design" Calin Boje, Haijiang Li
  - ADVEI May 2018, journal
- "Knowledge representation, storage and retrieval for BIM supported building evacuation design" Calin Boje
  - Thesis July 2018, at http://orca.cf.ac.uk/112966/

What is the future potential?

- Sensor data integration -> building operation stage
- Digital Twins –> human occupancy safety & comfort
- A common crowd simulation interoperability layer?

References

- Malsane, S. et al. 2015. Development of an object model for automated compliance checking. *Automation in Construction* 49(PA), pp. 51–58. Available at: http://dx.doi.org/10.1016/j.autcon.2014.10.004.
- PD 7974 2004. *The application of fire safety engineering principles to fire safety design of buildings. Human factors. Life safety strategies. Occupant evacuation, behaviour and condition (Sub-system 6)*. British Standards Institution Group London UK.
- Ronchi, E. and Nilsson, D. 2013. Fire evacuation in high-rise buildings: a review of human behaviour and modelling research. *Fire Science Reviews* 2(1), p. 7. Available at: http://firesciencereviews.springeropen.com/articles/10.1186/2193-0414-2-7.
- Wang, S. and Wainer, G. 2015. A simulation as a service methodology with application for crowd modeling, simulation and visualization. *SIMULATION* 91(1), pp. 71–95. Available at: http://sim.sagepub.com/cgi/doi/10.1177/0037549714562994.