Object and Rule Models
For
Pedestrian Evacuation Project[1]
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Object Models: In order to specify the motion and behavior of objects in the simulation tool, the objects and their attributes must first be identified. These can collectively be viewed as a time dependent state in the system. At a given point in time, the next state is derived from the current state. The objects include individuals (pedestrians), control agents, obstacles, geometric resources (features), groups, individual and group agendas, cells, cell characteristics, and hazards. In the next section, rules that specify the behavior the derivation of next state from a given state are outlined.

For each object type in the system, there are static and dynamic attributes. Static attributes are constant throughout the simulation. An example is the gender of an individual. Dynamic attributes can change in the course of the simulation. For example, an individual might become incapacitated and their mobility level might thus change.

Attributes are endowed to the pedestrians using a variety of techniques. For example, the user of the simulation tool will know what percentage of the pedestrians will be female or male adults, minors, or elderly. Once these percentages are gathered, the social science

Rules: The rules are used to specify the each state of the system from the previous state. The input to a rule is the current state of objects and hazards, including the agendas of objects such as individuals and the schedules of hazards and other pre-scheduled objects that might influence the behavior of individuals. The output is the next state.

OBJECTS: ***ObjectName*** (Attribute$_1$, Attribute$_{2, \dots,}$ Attribute$_{n)}$*

Individual (UniqueID, ColorTextureSignature, ***AgentType***/Type(ControlAgent PedAgent), GroupMembership, ***ActivityAgenda(***Origin, Intermediate Stops, Destination***)***, Position, Speed, Heading, GazeDirection, TimeBudget, PhysChar$_1$,

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PhysChar$_2$, … PhysChar$_n$, BehavChar$_1$, BehavChar$_2$, …., BehavChar$_n$, KeynoterMatrix (Multivalued))

Examples of Physical Characteristics, PhysChar$_i$

- Gender, Age, Physical Condition, Height, Width, Thickness
- Visual Acuity – derived from age, physical condition, etc.)
- Physical Harm – Extent to which a person has been harmed thus far in an event.
- Mobility – derived from age, gender, physical condition, and physical harm (captures "physical incapacity" parameter of Ben, as well as other)

ControlAgent Subclass of Individual (Type, TrainingLevel, Traditional/NonTraditional, ….)

Examples of Behavioral Characteristics for a PedAgent, BehavChar$_i$:

- Perception – Perception of current event.
- Responsiveness (time to and type of)
- Obstacle/Collision Avoidance Response (will be specified on a scale such as 1- avoid by all means using previous planning, 2- …., 3- follow course somewhat, but will deviate once close to obstacle, 4- … , 5- will follow course up to the point of collision)
- Integration with/into group (family versus dynamically formed group)
- Path deviation
- Physical Harm Response – Extent to which a person responds an event. Mobility can be partially derived from this.
- Activity – Captures the general activity of the individual. For example, if the individual is of type control agent, then there might be some activity that they are engaged in that can be described and will influence the behaviors of the groups and individuals. This will also be considered a geometric resource. So a rule will dictate the creation of a GeometricResource object.

`ASSUMPTION: VisualAcuity is a factor in perception level and responsiveness.`

Obstacles (UniqueID, ObsChar1, ObsChar$_2$, … ObsChar$_n$, Position(CellsOccupied) AvoidanceFactor, etc.)

Examples of Obstacle Characteristics, ObsChar

- Visual (camouflaged or not …
- Physical Characteristics other than Shape and Area (already captured by CellsOccupied) such as Height, etc.
- Impact on Pedestrians (physical harm induced, sensorial impact, etc.)
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GeometricResources (GRID, Location, Type, State…)

ASSUMPTION: Geometric Resources include such things as exit signs, exits, alarms, fire shelters, and lights that would assist in an evacuation. State is derived from such things as pedestrian density in the location, etc.

Group (UniqueID, GroupMembership, Size, Members(multivalued), Keynoter, Position, ActivityAgenda (see below)Speed, Heading, Agility, AvailResources, Integration, SubGroups (multivalued), Diversity ……..…)

ASSUMPTION: Size is derived from Members and is a factor in Agility (ability to adopt new behavior). So Agility is also a (partially?) derived attribute.

ASSUMPTION: AvailResources are derived from the attributes of the individuals in the group as well as the nearby geometric recources.

ASSUMPTION: Diversity – Level of contrary and conflicting group definitions.
The greater this is, the slower the group will respond to events and make decisions influencing behavior. So diversity is also a (partially?) derived attribute.

ASSUMPTION : In groups, the trust level of keynoters will influence the formation and re-formation of new groups. KeynoterMatrix is a list of possible keynoters within or near an individual's current group/location and an indication of the trust level (that is, how probably this person would be willing to follow a group formed around the keynoter). The longer an individual has followed a keynoter, the more likely he/she will continue with the keynoter (unless several incidents of obstacles and other events slowing their path to their destination). This is meant to consider the "social relations" parameter of Ben)

Assumption: Keynoter, and Integration are emergent behaviors based upon the characteristics of the members of the group. Integration covers the difference between a family group and an emergent group of pedestrians emerging from a plane to move together to the luggage and street transportation areas.

ASSUMPTION: Integration is related to such physical factors as distance among members. The more integrated a group, the more likely it will stay together.

ASSUMPTION: GroupMembership and SubGroups is meant to capture groups within groups.

ActivityAgenda (IndividualID, Origin, Destination, SubAgenda (multivalued), Purpose, TimeConstraints (multivalued), Importance)

GroupAgenda (GroupID, Origin, Destination, SubAgenda (multivalued, Purpose, TimeConstraints(multivalued))

GroupResources (Derived from the attributes of the members in the group as well as nearby geometric resources)

Queue (UniqueID, Head, Tail, Length, Members (multivalued), Rate, …..)

QueueServer (UID, ProcessingRate, ArrivalRate, …)

CellCharacteristic (CID, Visability, …)

ASSUMPTION: A cell has a visibility level (how well someone can see around them from that spot), and each individual has a VisualAcuity level (how well they see).

ASSUMPTION: Geometric and other visual effects (such as lighting, presence of smoke, etc.) will influence the perception of an individual of a state in the building.

Event (EID, Type, Level, Time, Location, Alarms (Multivalued), AgentsDeployed (MultivaluedIndividuals), …)

RULES: ***RuleName***: If antecedent then consequent. TBD. The rules will govern the emergent behaviors and movements of the pedestrians. In some cases, some attributes may be derivable from others. Rules will govern these derivations as well.

ASSUMPTION: Adoption of new behavior is the dependent variable for the rules.

QUESTIONS: Identify the independent and dependent params.

- Note: Some attributes are static (fixed for the object) and some dynamic (changing over time). Dynamic attributes are emergent and inferred from previous states of the object.

Pedestrian Motion Rules,

1) **Set Preliminary Heading and Travel Speed Based on Next Destination, and Interactions with Group Members**
    a. **Minimize Travel Time or Service Time to Next Activity Area/Server**
        i. Attempt Most Direct Heading to Destination (Regardless of how busy) at Preferred Speed (Possibly Constrained by Group Members' Speeds)
    b. **Adjust Travel Speed**
        i. Ensure Arrival Time to Destination Within Time Budget
        ii. Strive to Maintain an Equilibrium Distance to Other Group Members (Pick up Children if Necessary)
2) **Assess Trajectory Conflict with Obstacles/Pedestrians** –
    a. Project Obstacles/Pedestrians Locations (2 – 3 Steps ahead for Major Obstacles? One Step ahead for Pedestrians?): [Function of(Current Location, Current Speed)]
    b. Assess Observance of Safe (or Interpersonal) Distance to Obstacles/Pedestrians (Interpersonal Distance may Vary with Respective Flow Directions and Overall Flow Density?)
        i. If Observed, Keep Direct Heading and Adjusted Speed
        ii. If not Observed, Assess Obstacles/Pedestrians Visibility
3) **Assess Obstacle Visibility to Pedestrian:** [Function of (Obstacle Visibility Characteristics, Pedestrian to Obstacle Distance, Pedestrian Visual Acuity, Pedestrian Heading, Pedestrian Height, Pedestrian Cone of Vision, Familiarity with Environment)]
    a. If not Visible, Keep Direct Routing as Previously
    b. If Visible, assess Mandate for Immediate Obstacles/Pedestrians Avoidance
4) **Assess Perceived Mandate for Immediate Obstacles/Pedestrians Avoidance** [Function of (Pedestrian Distance to Obstacle, Obstacle Characteristics, Pedestrian Speed, Obstacle Speed), etc.]
    a. If Mandated Take Immediate Avoidance Actions
    b. Otherwise, Keep Direct Routing at Adjusted Speed
5) **Avoid Obstacles/Pedestrians**
    a. Deviate Away from Direct Path when Facing Fixed Obstacles/Pedestrians
    b. Establish Motion Priority Rules when Facing Mobile Obstacles/Pedestrians (Ex: Gender-Based /Age-Based/Survival of the Fittest Priority Rules …)
        i. If Higher Motion Priority, Continue on Direct Path at Adjusted Speed
        ii. If Lower Motion Priority, Deviate Away from Direct Path (Conceivably, Maintain Heading but Increase/Decrease Speed)
6) **Determine Hazard Presence**
    a. If Active Hazard (Simulation time between hazard start time and end time), Assess Hazard Awareness
    b. Otherwise, Keep Direct Routing at Preferred Speed
7) **Assess Hazard Awareness**

Hazard Awareness: [Function of (Hazard Visibility, Issuance Status of Visible Warnings or Guidelines from Management, Deployment Status of Control Agents, Extent of Keynoting, Distance to Keynoters, etc.)]

8) Assess Hazard Perception

Hazard Perception [Function of (Trust in Keynoters/Control Agents, Extent of Keynoting within and between Groups, Group dynamics (Groups Merging or Splitting), Clarity and Consistency of Messages/Warnings from Management]

9) Establish Activity Agenda Decisions

New Activity Agenda: [Function of (Hazard Perception, Guidelines from Management)]

10) Establish Activity Agenda Decisions

Establish Direct Heading and Speed to Next Activity Area/Server as Stated Above (Shall We Reset Time Budget?)