A Hazard Situation During a Fire Evacuation

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Table of Contents

Executive Summary

As the fire alarm blares throughout the hallway of the High School dormitory at Santa Fe Indian School (SFIS), the residents begin to evacuate the building. Within the dormitory, there are three exits on the first and second floor, and two on the third floor. While the boys use all exits provided, the girls use one exit, which is a single back stairway/doorway. A total of 134 girls exist through the back entrance. The fire evacuation routes are inconsistent and endanger the lives of the residents. Evacuation drills are used to determine the safest exits out of the building, but it is difficult to determine a safe route out of the dormitory when all of the girls use the same exit a majority of the time.

With our model we will determine the quickest and safest route out of all dormitory residents, particularly the girls from for all three floors. From floor plans we have created an outline of the dormitory on the program, NetLogo. In our model, residents will determine the safest evacuation route depending on the distance from an exit and the congestion at any specific exit.

A Hazardous Situation

Originally established in Albuquerque, New Mexico the academic program was moved to Santa Fe, July 1979 when it became Santa Fe Indian School (SFIS). Since its establishment, SFIS has been an off-reservation boarding school. While the admission is open to Native American students across the country, a majority of the population is composed of students from the nineteen pueblos of New Mexico and from the Navajo and Apache Nations.

In 2004 SFIS opened the long waited new High School dormitory, which consisted of three stories. Unlike the previous dormitories, the new facility housed both boys and girls: boys residing on Wing A and girls residing on Wing B. Altogether the High School Dormitory houses 302 total of 134 of which are girls. The building is provided with three exits on the first and second floors and two on the third floor. It would seem that during fire drills, the 70 girls on first floor, on 43 second floor and the 21 girls on third floor would be able to exit quickly out of the building to a designated area. That is not so, however. During evacuation drills, a majority of the girls from all three floors exit through the single back stairway/doorway. The congestion of the girls in the back exit and the poor lighting in the exterior stairway lead to a longer amount of time needed to evacuate the building. As a result, the time it takes girls to exit the building upon hearing the alarm varies from six minutes to four minutes.

The hazardous situation simulation on our NetLogo agent-based model has agents representing the female residents of the dormitory under the scenario of a fire. Initially, agents are located in their rooms and start their egress at the sound of the fire alarm. Agents then move along gradients toward exits. When determining the next step, agents avoid walls and avoid moving to patches that have reached the maximum density of girls. While evacuating, an agent may temporarily move away from an exit due to the presence of a fire or of high congestion. In our model, congestion is reached when agent density exceeds four people per square meter. From the literature, pedestrian traffic jams are caused mainly by congestion densities, which depend upon the agent size, group cohesion constraints, and an agent's familiarity of a location. Using the literature as a guideline, the congestion threshold is four agents per meter square to reduce and avoid pedestrian traffic. To estimate the density within our simulation, girls from first floor were gathered into a section of the hallway measuring three meters square. A total of nine girls fit tightly into the section. The speed of agents was calculated by a series of exercises of walking at a normal pace, then walking quickly, then running down the hallway of the dormitory.

From floor plans, a layout of the girl's first, second and third floor was created on the programs Microsoft PhotoDraw and Adobe Photoshop. From the outline, colored pixels were used to distinguish the different features. The color, black, is used for walls, white for the floors, yellow for the interior doors, red for exterior exits, and different shades of green for portals. In our model, "magic portals" are used to allow agents from second and third floor to appear "magically" on the first floor—to transport agents to various floors of the dormitory. For an example if an agent touches a portal on the first floor, it is automatically transported to the corresponding portal on the second floor. Each stairway has different shades of green to distinguish movement from first floor to second floor and from second floors to third floor.

In our simulation the flood-fill algorithm is used to determine the shortest route out of the building. The algorithm starts at patches with exits and sets the patch variable to distance-to-exit to zero. Neighboring patches of the patches containing exit variable is set at distant-to-exit to one. For each patch the distance increases by increments of one, this is done until all patches have a distance-to-exit variable for each exit in the building.

Results

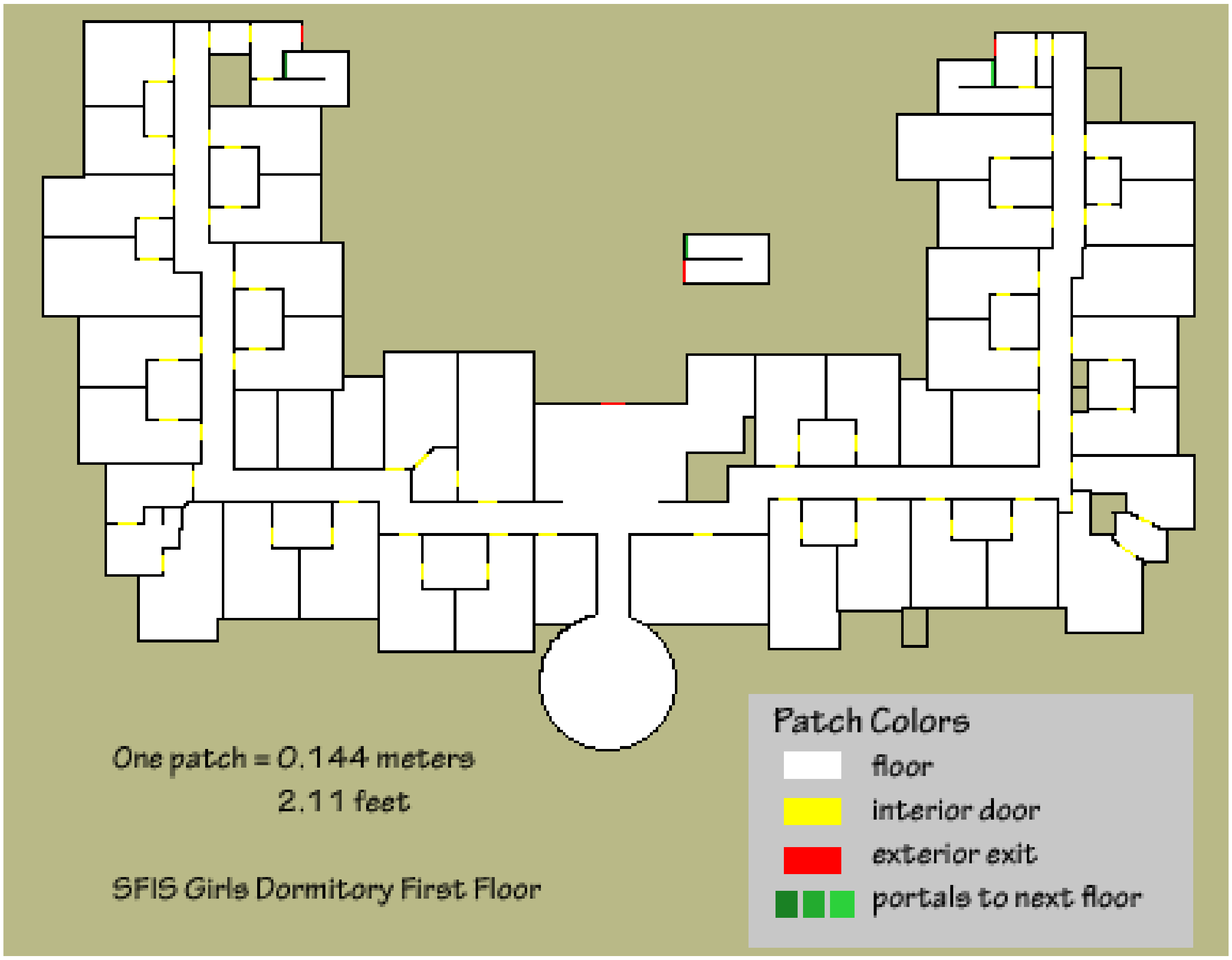
Currently we are in the process of obtaining results from our model. Using the flood-fill algorithm in our experiments, our initial experiment will use only one exit. In the following experiments all exits will be used with same initial conditions. The results of the runs will be presented at the 2007 Expo in Los Alamos. Until then we will be working hard on our model.

Appendix

Figure one

An aerial view of the SFIS High School Dormitories, the girls building is outlined in red.

Figure two



Floor plan of dormitory with patch coloring strategy for floors, doors, exits & “magic portals”

Table one is an example of the congestion in different areas.

Table one

Academic Source	**Country**	**free flow velocity (m/s)**	**traffic jam density (pedestrians/m^2)**
Oeding	Germany	1.50	3.98
Older	Britain	1.31	3.89
Navin & Wheeler	USA	1.63	2.70
Fruin	USA	1.36	3.99
Tanaboriboon et. Al	Singapore	1.23	4.83
Guyano	Thailand	1.21	5.55
Yu	China	1.26	5.10
Gerilla	Philippines	1.39	3.6
	average	**1.36**	**4.21**

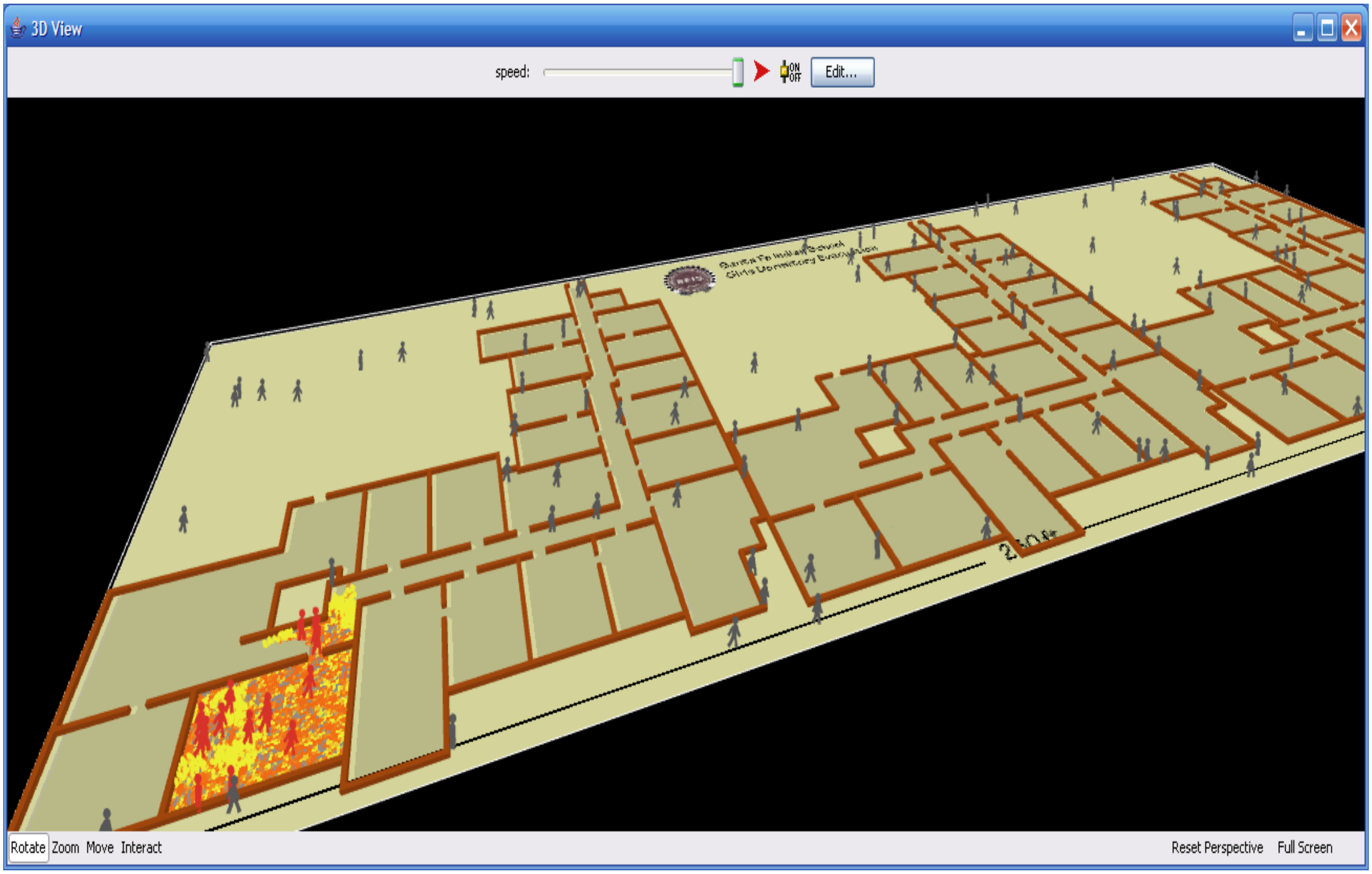
Table of Crowd Densities from Literature (Kardi, 2002)

Estimated Speed of Agents

Distance of hallway: 15.6 m

Pace	Time	Speed
walk	13.3	1.17
walk	12.03	1.3
walk	12.03	1.3
hurry	8.16	1.91
hurry	7.82	1.99
hurry	7.28	2.14
run	4.3	3.63
run	4.37	3.57
run	4.5	3.47

Figure three



Screenshot of NetLogo model with egress and fire scenario

NetLogo Code for Dormitory Evacuation

```
breed [agents agent]      ; girls exiting the dormitory
breed [dead-agents]       ; use a separate breed to persist dead/injured
pedestrians. The alternative of Stamping while using a drawing layer has some
bugs
breed [flames flame]      ; Fire agents. Flames are the advancing flame front

agents-own [frame]        ; used for animating the agents' walk cycle. person-1
thru person-9 are in the shapes editor. Borrowed from the Shapes Animation
Example.

flames-own [age]          ; the flames are colored and burn out according to
age
                          ; flame agents don't move. they have variable
headings and sprout new flames according to their heading
patches-own [wall?        ; boolean variable for obstacles
        fuel        ; patches have limited fuel for fire to burn
        pfeature    ; a list that holds distances to each exit. created in
the floodfill algorithm
        ptmp        ; a temporary variable needed for floodfill with
multiple layers
       ]
```

```
globals [init-fuel        ; all burnable areas have their "fuel" variable
initialized with init-fuel
         inside           ; agentset of all patches colored as inside in
"dormDrawing.png"
         wall-color       ; color of walls that are obstacles to egress
         feature-colors   ; colors used by the flood-fill algorithm as exit
points
         ignite-patches   ; possible ignition locations for fire. positions will
be changed during parameter sweeps
         ticks            ; keeps track of how many steps in the simulation
         v                ; preferred velocity of non-blocked agents. may make
this an agent property if we need heterogeneous agents
         patches-per-meter     ; scaling variable for the model
        ]

to setup
  clear-all
  set patches-per-meter 6.928
  set ticks 0
  set feature-colors [black yellow sky blue white gray red white]
  random-seed init-random-seed
  set wall-color orange - 2
```

```
  import-pcolors "dormDrawing.png"                    ; dormDrawing holds the
floorplan of the dormitory
  ask patches with [pcolor =  64.9][sprout-agents 1 [   ; create agents on
green patches marked in dormDrawing. Green patches are where the girls rooms are
    set color black + 3
    set size random-normal 1 .1
    set size 15
    set frame random 8 + 1
    set shape (word "person-" frame)
   ]]
  set ignite-patches patches with [pcolor = 64.9]
  set init-fuel 300
  ask patches [set fuel init-fuel set wall? (pcolor = 0)]
  ask patches with [pcolor = white][set pcolor white - 9]
  ; import-drawing "sfisDrawing.png"                    ; this graphic is for
display only. does not affect the model
  ; ignite
end

to go
 if ticks = 0 [reset-timer]
 move
 burn
```

```
    plot count flames
    set ticks ticks + 1
end

to move
   set v mean-velocity * patches-per-meter * delta-t
  ask agents [
    if any? flames-here [hatch-dead-agents 1 [set color red set shape shape-of
myself] die]
    ifelse (wall?-of patch-ahead v = true  or fuel-of patch-ahead v !=
init-fuel)
      [rt random 90 - 45]
      [set shape (word "person-" frame)
       rt random 20 - 10  fd v
       set frame frame + 1
       if frame > 9
         [ set frame 1 ]]
  ]
end

;to move2
;  let d item layer layers
;  ifelse pfeature = goal [die][
```

```
;    let p one-of neighbors with [(count turtles-here = 0) and (item layer-of
myself layers < d + frustration-of myself)]
;    ifelse p != nobody
;      [jump-to p set frustration 0]
;      [set frustration frustration-increment]
;  ]
;end

; pick one of the girl's rooms and start a fire there
to ignite
  ask one-of ignite-patches [sprout-flames 100 [set color one-of [red red red
orange yellow]
     if color != yellow [ht]
     pd set shape "pentagon" set size 1 ht]
  ]
end

to burn
    let flame-velocity 1
    let flame-mid flame-life / 2
    ask flames [
      set age age + 1
      ifelse age = flame-life [set color red  ht][ifelse age < flame-mid [set
```

```
color yellow st ][set color orange - 1 ht]]
      set fuel fuel - 1
      if fuel < 1 or age > flame-life [die]
      ifelse wall?-of patch-ahead flame-velocity
        [rt random 90 - 45]
        [if random(100 - flame-prob) = 1
          [if count flames < 7000 [hatch-flames 1 [set age 0 fd flame-velocity
rt random 50 - 25 ]
        ]]]
    ]
end



; floodfill algorithm
; patches keep a list of flood-features. A flood-feature is the calculated
distance to an exit.
; this model has 4 exterior exits so will have four elements its flood-feature
list
to floodfill [pset flood-feature] ; floodfill starting w/ the given patch or
patchset, adding the next layer to flood-feature.
  if is-patch? pset [set pset patches with [self = pset]]  ; lets the caller
pass in a patch or an agentset. Converts to agentset if a patch is sent in.
  ask patches [set ptmp 9999]
```

```
  let n pset
  ask n [set ptmp 0]
  while [count n > 0] [
    let nnext patches-from n [neighbors with [ptmp = 9999 and pfeature =
flood-feature]]
    ask nnext [set ptmp min values-from n [ptmp + distance myself]]
    ask nnext [set pcolor red + ptmp]
    set n nnext
  ]
  ask patches [set pcolor item pfeature feature-colors]
end

;to-report pushlayer
;  ask patches [set layers (lput ptmp layers)] report (length layers-of patch 0
0) - 1
;end
```

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