Chapter 5
Representing Pedestrian Behaviors

The generic framework is based on the requirement that the dynamics of the interactions of individuals and many components in environment are primary determinants of the complexity behavior emerging in the system. Chapter 4 explained how the objects in simulation system relate to one another. In this chapter we put more emphasis on an individual Mouse, explaining how the agent (mouse) perceives its environment, how the agent (mouse) acts upon it, and how the agent (mouse) selects which action to perform. The latter part presents the computable forms and implemented models of general behaviors found in pedestrian movement.

5.1 Structure of an Agent “Mouse”

Object Mouse in this context is an autonomous agent. An agent is a distinct object that has a task to perform and it is situated in an environment that it shares with other entities, perceiving and acting on these other entities. This Mouse is said to be autonomous because it is reactive, instinctively driven by stimulus. Each agent perceives its environment and has its own physical mobility to move about because of its internal structure. The internal structure of an "agent mouse" can be described in terms of three basic components: the external perception, the internal state, and the behavior production system.

5.1.1 External Perception

Each agent has an ability to see objects and recognize stimuli in the environment. In this context, each agent's field of vision while walking is 360°. The perceptual system eliminates the objects and stimuli hidden behind the obstacle, as shown in Figure 5.1. Therefore, the non-shaded area in the figure determines the perceived scene and the perceived objects for an individual. The radius of perception has no limit because we assume that size of the environment is relatively small. Thus if there is no obstruction the individual can see through the whole space.
This field of vision model is based on the concept of isovists (Benedikt, 1979) and Gibson's approach of visual perception (1979). An isovist, or viewshed, is the area in a spatial environment directly visible from a location within the space. Isovists are an intuitively attractive way of thinking about a spatial environment because they provide a description of space from inside, from the point of view of individuals as they perceive it, interact with it, and move through it. As such, isovists have particular relevance to architectural analysis. Benedikt introduced a set of analytic measurements of isovist properties to quantify space by considering the volume visible from a location. He then simplifies this representation by taking a horizontal slice, resulting in an isovist polygon that describes the visible area from a given location. Later he formulated an 'isovist field' by recording a single isovist property for all locations in a configuration by using contours to plot the way those features vary through space.

Gibson argued that people see the environment while moving, not just in pauses between movements. That is, vision should be considered in terms of this broader awareness, which involves movements of the eyes, the head, and the body. As we take into account the fact that people experience space over time, looking in different directions, so that they are ultimately aware of their complete surroundings, we endow the agent with 360 degrees vision. However, in this simulation, the agents only have a short term memory, meaning they can only see and register the objects – obstacles and attractions – in the scene to the behavior production system but their abilities do not involve a high level of cognitive behavior. Thus they cannot construct a model or understanding of the environment based on their experience over time.
5.1.2 Internal States

Each agent has an internal state that informs its individual internal motivation. The internal state is affected by its external perception, received from the behavior production system. So, the behavior production system modifies the internal state as a result of perception, giving a signal or drive to an agent. The signal indicates any of those motivations needed to be satisfied so that the agent will be in a 'comfort zone'. The internal signal is sent back to the behavior production system for the action-selection process to determine an appropriate behavior.

The internal state is defined by a set of variables that can take values between zero and three (*Figure 5.2, 5.3*). They represent state of hunger, and hurriedness. The degree of hunger increases over time, and can also be decreased if a proper behavior (eating) is executed. There is a significant different between the hunger scale and the hurriedness scale. A lower hunger value indicates a neutral state while a lower rush value becomes a higher value of relax, which may require a proper action to satisfy that need. Relax and rush are on the same scale because both relate to a period of time spent in the environment but in the opposite way. A 'relax' state allows an individual to spend more time, thus more activities, in the space but 'rush' degree is likely to discourage an individual's activity. The values will increase when an individual spends some time in space and they affect the speed (a rushed mouse will walk faster) and moving direction (a rushed mouse will use the shortest path).

*Figure 5.2: A scale of motivation degree of Hunger*
*Left: a state of very hungry, Right: a neutral state*

*Figure 5.3: A scale of motivation degree of hurriedness*
*Left: high degree indicates rush, Right: low degree indicates relax*
5.1.3 Behavior Production System

Each agent Mouse has a set of behaviors (Table 5.1) registered in the behavior production system. It is a set of behaviors from which the system selects for an agent to perform the action, according to its internal state and the external perceptions at any time step.

**Wander** is a default behavior for aimless agents and **pass-through** is a default behavior for purposive walkers. When there are no external signals – no station and moving obstacles – from the external perception system, and no signal from the internal state, agents use their default behaviors to drive themselves through the environment. These two behaviors are determined as **reflex behaviors** because this level of behavior requires no input for movement.

**Avoid obstacle** and **avoid collision** are at the **reactive behavior** level because this level of behavior depends largely on the external signal – stationary and moving obstacles –, taking it as an input to determine the next direction and speed.

The other behaviors -- **approach goal**, **get food**, and **get rest** -- are **motivated behaviors** because each of these behaviors needs both signals from external perception and internal state to drive them to move around and react to their environment.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>External Perception</th>
<th>Internal State</th>
<th>Type of Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wander</td>
<td>None</td>
<td>None</td>
<td>Default for a pink mouse (reflex)</td>
</tr>
<tr>
<td>Pass through</td>
<td>None</td>
<td>None</td>
<td>Default for a blue mouse (reflex)</td>
</tr>
<tr>
<td>Avoid obstacle</td>
<td>Obstacle at range</td>
<td>None</td>
<td>Reactive</td>
</tr>
<tr>
<td>Avoid collision</td>
<td>Moving obstacle in neighborhood field</td>
<td>None</td>
<td>Reactive</td>
</tr>
<tr>
<td>Approach goal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gate</td>
<td>-Gate perceived</td>
<td>Rush</td>
<td>Motivated</td>
</tr>
<tr>
<td>- Cheese</td>
<td>-Cheese perceived</td>
<td>Hunger</td>
<td>Motivated</td>
</tr>
<tr>
<td>- Green</td>
<td>-Green perceived</td>
<td>Relax</td>
<td>Motivated</td>
</tr>
<tr>
<td>Get food (eat)</td>
<td>Cheese at range</td>
<td>Hunger</td>
<td>Motivated</td>
</tr>
<tr>
<td>Get rest (sit)</td>
<td>Green at range</td>
<td>Relax</td>
<td>Motivated</td>
</tr>
</tbody>
</table>

*Table 5.1: Behavior repertoire of an agent mouse to perform the movement in the simulation*
We define the **behavior production system** as a system that produces behaviors to control an autonomous agent. The system implements principles and properties present in pedestrian behavior following the bottom-up approach – simple to more complex – and it is structured so as to allow an experiment to incorporate new behavior over the existing behavioral rules. Therefore, we first build the system to model reflex behavior, which constitutes an initial layer. Then we add a second layer to model reactive behavior on the previous layer. Next, we add another layer dealing with the problem of the motivated behaviors as the third layer over the previous ones. We construct the behavior production system connecting to the **external perception** and the **internal perceptual system** seen in Figure 5.4.

![Figure 5.4: Behavior production system showing connections with external perception and internal system. The feedback loops (red arrows) of internal drive and external perception are important in determining an appropriate behavior.](image)

The **external perception** system sends information about the perceived scene to the behavior production system at every time step. If there is no signal from external perception, a default action, wander or pass-through, (see detail in 5.3.1) is executed at the level of reflex behavior which, in this system, acts as a motor system.
After the behavior production system receives the external signal from external perception system, it will separate the objects that have been motivated explicitly from the explicit obstacles, sending those objects to the second step, motivated stimuli.

Whenever the signal 'obstacle at range' is sent to the system, the reactive behavior will respond (detail in 5.3.2). At the level of reactive or path determination, it sets an intermediate goal to avoid that object and passes a set of signals such as 'heading 50°', 'go forward 30 steps' to the reflex level to execute the actions. An agent must perform an avoidance action every time an obstacle is perceived in its path because the reactive behavior has not involved the process of action selection.

As soon as the behavior production system records the motivated stimuli in the motivated scene, it passes the signal to the internal perceptual system to make an agreement of external perception and its internal state. As we can see from the diagram, an agent has an internal state of hunger and relax but the external perception is the cheese whose attribute corresponds to the state of hunger, not relax. Hunger becomes the internal drive. The drive is sent to the feedback loop signaling the behavior production system which internal need should be satisfied. Then the system selects appropriate actions from the set of behaviors, producing the potential actions. An agent, finally, makes a performance of 'do it' or 'not do it'. In this example, it chooses to approach cheese and eat, then its degree of hunger is decreased. Next time it perceives cheese it would prefer 'not to eat'. Once there is no internal drive and external signal, that means it switches its behavior back to a default behavior again.

5.2 Goal Structure

We develop two kinds of agents (mice): purposive walkers (represented by blue mice) and aimless walkers (represented by pink mice). We realize that local movement can range from movements that are well-defined, exhibited by people who completely know or are familiar with the environment, to those that are more random and exploratory, exhibited by tourists or visitors who are unfamiliar with the environment. Therefore, we set 'pass-through' as a default behavior for the purposive walker and 'wander' as a default behavior for the aimless walker. Other than the default behavior, basically, these two agent mice have the same set of behaviors, and we distinguish these two walkers by goal.
There are four levels of goal:

1) **Final goal**: A final goal is an exit point where people finally get out of the area to some place else. The purposive walkers always have a final goal while the wander walkers do not. The wander walkers only make local decisions about the direction of their next step.

2) **Motivated goal**: every walker can have a motivated goal, according to their internal signal and the presence of stimuli in the space.

3) **Temporary (or intermediate) goal**: is a point along the path that is picked to avoid a stationary obstacle.

4) **Immediate goal**: is a temporary goal for avoiding moving obstacles such as other individuals.

Every walker operates with this structure of goals from the lower to higher level. For example, in order to get from one entry to one exit (final goal), one may need to stop at a food station (motivated goal) because of its hunger (motivated internal signal). While it walks to the food station, it needs to avoid obstacles (thereby setting an intermediate goal) if any object is in its way. And while it walks towards the intermediate goal, it may need to make a maneuver (making an immediate goal) if an oncoming walker seems to interrupt its moving direction, then quickly get back to pursuing the next goal.
5.3 Modeling Individual Behaviors

We, next, present the individual behaviors and rules modeled in the simulation. Some of these are derived from our casual knowledge supported by the findings from observations and the scientific literature as well as some selected from the theoretical studies of pedestrian behavior. In order to apply these behavioral rules to each autonomous agent in the models, they must be converted into a computable form, algorithm.

5.3.1 Reflex Behavior

“Since you do not want to keep changing direction while you walk and do not want to spend your whole time re-calculating your best direction of travel, you arrange your walking process in such the way that you pick a temporary ‘goal’ which is more or less in the direction you want to take and then walk in a straight line toward it for a hundred yards, then, as you get close, pick another new goal, once more a hundred yard further on, and walk toward it…..You do this so that in between you can talk, think, daydream, smell the spring, without having to think about your walking direction every minute.”

(Alexander, Ishikawa, and Silverstein, 1977)

1) Wander: This is the default behavior for an individual to move about the environment with no final goal. The rule tells an agent to go forward by picking any point in front and at any distance to be a temporary goal and proceed to that position. Then pick the next temporary goal and proceed … Do it over and over again. From observation we learn that people will usually make a smooth turn at the point of changing direction. This knowledge has been borne out by Kovacs and Galle in their study of "The logic of walking in urban plaza" (1993). They propose a computational model based on the concept of smooth walking lines to avoid pedestrians being annoyed or tempted to walk where it is not intended. Starting from their observation that people tend to make shortcuts (cutting off the corners of lawn, for instance, Figure 5.7), it seemed to them that the tendency to make shortcut between point A and B from a path can be measured. They developed the concept of smooth walking lines, finding that a minimum acceptable angle between any two consecutive segments of paths is 120° (Figure 5.6).
Based on the angle-based smoothness concept, we define **Area X** as a smooth walking area. Choosing any point within that area as the next immediate goal will smoothen the path because the next walking line will always form an angle with the current line larger than 120° (*Figure 5.8*). From the sketch, **distance D** refers to Alexander's suggestion that goals should never be more than a few hundred feet apart. With this rule, all pink mice move aimlessly about the environment (*Figure 5.10*).
2) **Pass-through**: This is a default behavior for purposive agents who move through the environment with a goal. In this default stage, with no external and internal signal, a goal is, in fact, a final goal which means a *gate*, a point on the boundary where the agent mouse will leave the space. Assume that each blue mouse (a purposive walker) who enters the environment, “intends” to use the space for passing through other space. At its first step inside this environment, it will automatically pick a *destination* at random, that is any gate, except its *origin*, as its final goal, then proceed to the goal. Therefore, the rule for pass-through behavior is that if the goal is in sight, steer directly toward it (*Figure 5.11, 12*).

![Figure 5.10: From a simulation scene: Pink mice - wander walkers - following their temporary goals (end points of each gray lines)](image1)

![Figure 5.11: Sketch diagram of blue’s default behavior, Pass-Through](image2)

![Figure 5.12: Flow chart of Pass-Through process](image3)
5.3.2 Reactive Behavior

In reactive behavior, an action is taken when a particular external stimulus is perceived. This level of behavior does not involve the process of action selection: whenever a stimulus signal is perceived, the corresponding or action will always be executed. Two behavioral models govern the reactive behavior: obstacle avoidance and collision avoidance. The external stimulus for the first model is a stationary obstacle such as a building block; the external stimulus for the second model is a moving obstacle such as other people in real environment and other mice in this simulated model. We construct both models so that every external signal received from the perceptual system (by seeing) will be sent to the behavior production system. In the behavior production system, so far, we already have a reflex level as a motor system waiting for an action execution signal that will be sent from the reactive level, which acts as a path and speed determination system. In short, the action execution signal that results in motor action behavior is created at this level of reactive behavior and it has a direct relationship to the perception of the external stimuli.

1) Obstacle Avoidance: When a stationary object is perceived in range of the current moving direction, an individual will perform the action of avoiding the obstacle by diverting its movement to another path. The avoidance process will be different between a wandering walker and a walker who has a final goal.

- Wandering Walker (pink mouse): Referring to area-X (the smooth walking area), when an individual perceives an object inside its area-X (Figure 5.13), the possible walking area will be reduced to include only the shaded area. This area is defined by the intersection of area-X and the individual’s field of vision or perceived scene at the time it pursues the current goal. An individual will pick the next temporary goal from this area, then proceed to the goal. However, sometimes an agent may randomly pick a next goal that is too close to the object (Figure 5.14), once it reaches that position the agent will realize that the possible smooth walking area is too small so it cannot proceed. This situation will cause an agent to change the current orientation to turn either left or right, parallel to the object. Then, it obtains a new possible smooth walking area, picks a goal, and proceeds.
Figure 5.13: Sketch diagram of pink's avoiding obstacle case 2

Figure 5.14: Sketch diagram of pink's avoiding obstacle case 3

Figure 5.15: Flow chart of pink's Avoid Obstacle process
- **Purposive Walker (blue mouse):** This type of walker uses the space (plaza) as a shortcut or a walking-though space. When an individual knows a goal, he tends to go towards it but once an obstacle gets in his way, he will pick the shortest possible path to avoid the obstacle. Once the goal is in sight again, he will divert the path and steer towards his final goal. We adapt Alexander’s concept of the proper arrangements of paths by using intermediate goal for the model of purposive walker’s avoiding obstacle.

In the diagram below (*Figure 5.16*), a person begins at A and heads for point E. Along the way, his intermediate goals are points B, C, and D. Since he is trying to walk in a roughly straight line towards E, his intermediate goal changes from B to C, as soon as C is visible, from C to D as soon as D is visible, and finally to E.

![Figure 5.16: The actual path: using a series of intermediate goal to arrange the path towards the destination (Alexander, 1977)](image)

In our obstacle avoidance model, when an agent (mouse) enters the space at A and its destination is B, immediately it draws the line linking its origin and destination. The line AB is actually the shortest path towards its final goal if there is no object X in the way, as shown in *Figure 5.17*. Once object X is perceived, the external signal is sent to the behavior production system (at the reactive level) to determine the new possible (shortest) path to "avoid object X" as an intermediate task while "going to B" remains the final task. First pick a temporary goal; next proceed to it. As soon as B, a final goal, is in sight, steer toward it. Otherwise, pick the next temporary goal and repeat this process until reaching a final goal (*Figure 5.18*). This set of action is determined by the reactive level and executed by the reflex level.

Now we explain in detail how to get a temporary goal (*Figure 5.17*). As soon as an agent sees object X in its way (intersecting line AB), it will first (randomly) pick one corner from the set of visible corners – x1, x2, and x3. In the illustration, after it picks corner x1, it then inserts
an invisible box, containing a set of points that represent its individual preference about distance from obstructions, at the selected corner. Then pick one position from that box and proceed to it. Keep repeating this process until a final goal is in range. The task of each autonomous individual ends when it reaches its final goal, that is, when it leaves the space.

![Figure 5.17: Sketch diagram of blue's avoiding obstacle](image1)

![Figure 5.18: Flow chart diagram of blue's Avoid Obstacle process](image2)
2) **Collision Avoidance**

One important determinant of avoiding action, is that, each individual tries to maintain its personal sphere. According to Edward T. Hall, "**Personal distance**" is the term originally used by animal psychologist, Hediger (1961) to designate the distance consistently maintained by members of non-contact species. It might be thought of as a small protective sphere or personal “bubble” (Sommer, 1969) that effectively maintains distance between an individual and others. These distances are not universal, they can differ from one culture to another, place to place, time to time, and even among various situations.

<table>
<thead>
<tr>
<th>Distance, face to face</th>
<th>Area required per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft</td>
<td>near(cm)</td>
</tr>
<tr>
<td>Intimate</td>
<td>Less than 1.5</td>
</tr>
<tr>
<td>Personal</td>
<td>1.5-4</td>
</tr>
<tr>
<td>Social</td>
<td>4-12</td>
</tr>
<tr>
<td>Public</td>
<td>More than 12</td>
</tr>
</tbody>
</table>

*Table 5.2: Interpersonal Distance based on the North American experience and suggested by Edward T. Hall, The Hidden Dimension*
Each individual has a personal sphere and a neighborhood field (Figure 5.20, 21). The former represents a protective distance from other individuals, the latter represents the distance of awareness, knowing that other individuals are around. In this model, the distance of a neighborhood field is influenced by pedestrian evasive distance. Pushkarev and Zupan (1975) found out that because of the angle the human eyes encompasses, another person must be at least 7 ft (2.1 m) away to be seen from head to toe so that his speed and direction of movement can be accurately judged. Therefore, pedestrians have been found to take evasive action anywhere from 2-17 ft (0.6 to 5.2m) ahead of a moving obstacle. The longer the distance, the less violent the maneuver necessary, and the less likely the possibility of a collision.

In this model we only concentrate on how individuals interact with other individuals so we do not incorporate any other object in the environment. Each agent starts to be aware of its neighbor only if the other individual is sharing its neighborhood field. As a consequence, its perception of the other agent's direction and speed (if more than one agent is in the field, then the nearest one is used) will be sent together to the behavior production system at the reactive level to calculate the future positions of both itself and the other. In the case that the anticipation of the future position turns out in the way that its personal sphere will be influenced by the other's, the evasive action starts to take place (Figure 5.22).
Figure 5.22: Two situations in neighborhood field (evasive distance). Situation A: no moving object in range and situation B: moving object is in range, preparing to take evasion to avoid collision.

Figure 5.23: Sketch diagram of collision avoidance.

Figure 5.23 illustrates the nearest approach between two individuals. We use the concept of "action force" (Reynolds, 1999) to modify the direction of an agent in order to avoid possible collisions. The direction of action force between individuals A and B will affect their new directions. The extended direction of action force from B to A becomes Force-A and will applies to individual-A. Force-B has the direction from A to B and will affect individual B's choice of path. If the action force points to the Left (in case of individual-A) of its current direction, an immediate goal is set a little to the left of the current direction. If the force points right, the current direction of movement is adjusted by setting an immediate goal to the right. The direction of the action force also affects each individual's speed. So we will see in Figure 5.23 Force A makes individual A move about the same speed or a bit faster to the right, and Force B makes individual B move
slower to a little right off the current direction (Figure 5.24). And the set of sub-goals will be signaled to the reflex level for execution.

**Figure 5.24: Flow chart diagram of collision avoidance**

- **Any mouse in N-field?**
  - **T**
    - (Get neighbors’ motions)
      - Draw its own motion and other mice’s (motion = a current direction line lining from center of each mouse in range to the edge of Neighborhood field or N-field)
      - The circle area defines range of evasive collision
    - (Get ImmediateGoal)
      - Choose a mouse that makes the nearest crossed line, then anticipate future position (where and when the two will make nearest approach), respectively to their private spheres.
      - (Get Reaction)
        - From the position of nearest approach, draw a line between those two and extend the direction of new force in the both sides so the one on the left get the left force and the right get right force.
  - **F**
    - (make Avoidance)
      - If the direction of new force points: right, then shift direction to the right left, then shift to the left forward, accelerate current speed backward, slow down the speed.
      - Then make ImmediateGoal, a shifting position from an expected collision position, regarding the given force.

- **Any line crossing?**
  - **T**
The process of path determination is different from the action selection process because the actions in range of reactive behaviors such avoiding obstacle and avoiding collision are always needed to be executed. Otherwise, an individual will run into the building or collide with another moving agent.

5.3.3 Motivated Behavior

Motivated behaviors are the level of behaviors that by necessity require an internal state to signal the behavior production system to select the behavior that responds to individual's needs. That is to say, unlike reactive behavior that strictly depends on the external stimuli, motivated behaviors are controlled mainly by the internal state of an individual. For example, we execute the behavior 'eat food' depending not only on the presence of external stimulus, 'food', but also the internal need, 'hungry'. The absence of a stimulus might also itself be an external stimulus capable of stimulating a motivated behavior. For example, the motivated behavior, search for food, is exhibited when the external stimulus, food, is not present in the surrounding environment. Motivation is thus a process that can produce changes in behavior (McFarland, 1981).

There are two states of motivated behaviors (Table 5.1), a desire state such as approach goal, and a completed state, eat and sit for instance. These two indicate sequencing of component

Figure 5.25: From a simulation scene: blues and pinks perform obstacle avoidance if others are in their neighborhood fields and their directions get crossed
behaviors in time. The **desire state** is an initial state of motivated behavior occurring when an internal drive indicates which internal need should be satisfied. This internal drive, if successful, alters an agent's new direction towards a motivated goal. The second behavior occurs when the motivated goal is at range (next to or under an agent), an agent then performs the second behavior which, technically, is to stop at the goal position – at cheese or on green space – for a length of time. This act expresses the **complete state** of motivated behavior and effects a change of the **motivation degree**.

In the simulation we provide two states expressing internal needs or motivation in each agent (*table 5.3,4*). The table expresses which external stimulus corresponds to which internal signal, a set of potential actions that an agent can use to satisfy the signal, and the **adjustment of motivation degree** after the appropriate need is already satisfied.

![Table 5.3: The internal states, Motivation degree and possible actions](image)

*Table 5.3: The internal states, Motivation degree and possible actions*
The internal signal is, in fact, a result from the combination of both scales. The stronger motivation is likely to be fulfilled before the weaker one. The adjustment (increase and decrease) of degree in the model allows changes in an agent's behavior. For example (see combination of two internal signals in Table 5.4) one agent obeying its hunger goes and gets cheese in order to fulfil its need. That means it has to spend some time in the space. After it has finished the cheese, its hunger decreases to 'one', indicating it might not want any more cheese. The amount of food it eats has reduced its degree of hunger. And at the same time his rush degree has increased to two, indicating it may not have enough time to find some place to relax and its speed of moving may also be affected. The increase of rush is caused simply by the amount of time elapsed.

Motivated behaviors are modeled as a third layer over the previous two (reflex and reactive) behaviors. A behavior at this motivated level can be seen as an agreement process of external perception and internal state (internal drive). The essence of the motivated behavior is to set a motivated goal, which can be the same as a final goal, and to select actions that are appropriate to the needs in sequence. This goal and the selected action are passed to the reactive level, as an input, to decompose the goal into a series of sub-goals. For example, in order to achieve the goal, an agent might need to avoid the obstacle if there is one, or to avoid running into other agents. All those actions are executed at the level of reflex behavior.

At the motivated behavior, we can clearly distinguish between the movements of the two types of walker, a wander walker (pink) and a purposive walker (blue).

<table>
<thead>
<tr>
<th>Internal state (before)</th>
<th>+ External Stimuli</th>
<th>= (potential)Action</th>
<th>Internal State (after)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hunger</td>
<td></td>
<td></td>
<td>Hunger</td>
</tr>
<tr>
<td>0 1 2 3</td>
<td></td>
<td>- search for food</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- search for green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- get food first</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>then sit and eat</td>
<td></td>
</tr>
<tr>
<td>and Relax - Rush</td>
<td></td>
<td></td>
<td>and Relax - Rush</td>
</tr>
<tr>
<td>0 1 2 3</td>
<td></td>
<td></td>
<td>0 1 2 3</td>
</tr>
</tbody>
</table>

Table 5.4: The combination of two internal states and adjustment of motivation degree
1) **A wander walker:** This walker only makes a local decision about its movement. As soon as it perceives a motivated stimulus (in this simulation, cheese and green space) its behavior production system, first, finds a balance between the perceived external stimulus and its internal signal. Then the agent makes a decision on the action, as seen in Figure 5.26. This decision is made in every time step (looping) until it chooses to approach a stimulus so the motivated goal is set or a stimulus is no longer in its perception, or it leaves the space.

![Flow chart diagram](image)

*Figure 5.26: Flow chart diagram shows local decision 'action selection' process of pinks*
2) **A purposive walker**: The nature of this walker is that it always has a goal. Its internal state makes it define a motivation goal when entering a space. (Figure 5.27) For example, if the internal drive is "very rushed" and "not hungry", its motivated goal is likely to be a 'gate' in order to get out of the space as fast as possible. If it is "hungry" and "not rushed", its motivated goal might be "cheese" or "green space". In the case where it sets cheese to be its goal but there is no cheese in space, it then changes its mind to get out of space, assuming that it goes and find cheese some place else.

![Figure 5.27: Flow chart diagram shows local decision 'action selection' process of blues](image)

### 5.4 Modeling Social behaviors

*The sidewalks are important not because they provide an environmentally sound alternative to freeways, but because they are the primary conduits for the flow of information between city residents.*

*Neighbors learn from each other because they pass each other, each other's stores and dwellings, on the sidewalk. Sidewalks allow relatively high range communication between total strangers, and they mix large numbers of individuals in random configurations. Without the sidewalks, cities would be like ants without a sense of smell. Sidewalks provide both the right kind and the right number of local interactions. They are the gap junctions of city life. (Jacobs, 1961)*

We propose two models of pedestrian social behavior to explain some dynamic movement characteristics in urban space, mainly to explore complex social behavior, such flow of
information, which emerges from simple social actions. Therefore, our models for social behavior are quite simple. They are based on the ideas of imitation and induction of behavior. The first model, the flow sensitive, emphasizes an imitation of behavior at the level of reactive behavior. The second model, the flow of information, emphasizes imitation and induction of behavior at the level of motivated behavior.

The external perception plays an important role in these models because induction and imitation of behavior requires some forms of message or information to be communicated. An inductor is an individual who sends out a message, perhaps in form of a gesture of movement or different appearance, to other individuals. And that message, a social action, would be strong enough to induce another to execute the same behavior that it is executing. The induction behavior is not necessarily by intention. On the other hand, while the inductor is a sender, an imitator is a receiver who receives a message and executes its action following the sender. Castelfranchi (1998) called an imitation a weak social action, and induction a strong social action. Figure 5.28 illustrates this idea. An individual who has a strong social action (as a higher value of sociality) will have a higher possibility to induce its behavior in others. However, in many examples of imitation behavior such as in crowd behavior, there is no requirement for a particular leader, or any specific inductor; the individual just imitates the movements of others that appear to be its local neighborhood.

![Figure 5.28: Graphics describes imitation and induction of behavior](image)

5.4.1 Imitation of Behavior

The flow sensitive: The presence of other people is important and the social environment may influence an individual’s behavior. Our model of imitation of behavior is based on the finding, from empirical studies by many researchers, that people are sensitive to pedestrian flows and will tend to follow others (Whyte, 1980; Pushkarev and Zupan, 1975; Schoggen, 1989; Zacharias, 1997). In this model we apply one more rule adding to the reactive behavior model. The rule is that if there is more than one other individual in its neighborhood field (the same field used in collision
avoidance model), the individual will imitate its neighbor's direction by adjusting its orientation to be coherent with the others' direction of movement (*Figure 5.29*).

*Figure 5.29: Imitation of neighbors' directions*

### 5.4.2 Induction of Behavior

**The flow of information:** We realize that good urban spaces, from a street corner to a city plaza, are the places that provide the possibility for people who may or may not know each other to socialize through some forms of communication. Thus, a city life depends partly on the interaction between strangers that changes one individual's behavior.

We model this imitation and induction overlaying the motivated behavior. This model does not directly represent real phenomena in urban environments but rather it conceptualizes the idea of the flow of information as people learn from other people when they pass by. We develop the *blue-cheese* story (*Figure 5.30, 31*) to help explain how motivated behavior can be induced by other individuals. It is assumed that the internal state of every agent mouse, either blue or pink, carries 2 scales of motivation, hunger and hurriedness.
Scene 1: Blue, a purposive walker, gets into the space with the degree of hunger as high as 3 and relax degree of 1. The internal signal tells him to **search for cheese**.

Scene 2,3,4: He keeps looking for cheese and eventually he finds one. He turns towards the cheese (**approach cheese**) and gets a big bite of it (**get cheese**). He seems to get the first task, which is driven from the hunger signal, done because he already reached the first goal, cheese. However, he has not completed a sequence of behavior yet since he decides to not **eat in** but to **take out** a piece of cheese to **eat** (a completed sequence of behavior) somewhere else. His second decision is caused by the signal of relax and the second task is, therefore, **search for green** space.
Scene 5: He carefully carries the cheese and goes about to find a nice place to sit and enjoy the piece of cheese in his hand.

Scene 6: At that time, Pink, who has been wandering in the space, sees the blue mouse with cheese. Suddenly his degree of hunger rises up from 1 to 3, indicating that he wants some cheese, too. This has to do with his external perception system, making equivalent the perceived behavior (of blue carrying cheese) to the motivated stimulus (cheese). And the external perception increases his degree of hunger to the point that the internal and external agreement is made, motivating pink's behavior to 'search for food' and 'eat'.

Scene 7: While Blue enjoys his cheese, Pink sets up his goal and begins to search for cheese to fulfil his need.

Scene 8: After Blue has finished the cheese, his degree of hunger turns back to 0 but his rush level increases to 3, indicating he has to go.

Figure 5.31: Blue-cheese story 5-8
From this story, Blue with cheese is an inductor and the motivation of Pink is induced when he passes by and perceives the cheese in Blue's hands. The induction of behavior has an effect on Pink's direction of movement by altering his wander action to search for cheese. The diagram (Figure 5.32) shows the change in color (indicating internal state of hunger), thus direction of movement when an individual is induced by one another. Distance 'd' refers to the social distance, suggested by Edward T Hall (Table 5.2). This distance extends from 4-12 feet (1.25 to 3.5 m) as a zone that acceptable for normal contacts --not an overly intimate or intense way; beyond this distance, people lose the ability to visually communicate with one another (Hall, 1966; Altman and Vinsel, 1977).

Figure 5.32: Sketch diagram of induction of behavior

All the individual and social behaviors presenting in this chapter allow a variety of possibilities in producing interesting experiments and simulations. Beside these autonomous agents, there are some other important components, already explained in Chapter 4, with which the agents interact in the simulated environment. Next chapter before we bring together agent mice and other elements representing environment into the simulation —experiments— in Chapter 6.