CROWD
A simulation of crowd behavior

ORIGINAL DOS PROGRAM

This program simulates up to 255 individuals moving around on a field, moving toward a destination, following another individual at a specific distance and maintaining a specific direction, and avoiding collisions with each other and with stationary obstacles. Each person contains up to six simple control systems. There are preconfigured setups showing, among other things, a "guru" being followed by several "disciples," a "man" and a "dog" at heel, a rabble converging on the same destination and competing to occupy the center, a "mother goose" followed by a train of "goslings", and other examples of people moving in relation to other people and things. The user can create new setups and save them in named files.

CROWD is a program that simulates the movements of a crowd of up to 255 persons, in an area as large as 600 feet long by 400 feet wide. Each person's motion is guided by six control systems. Two of the systems are concerned with avoiding collisions with other persons; two are concerned with seeking a goal position; two are concerned with seeking proximity to another person.

Two parameters of each individual's control systems are adjustable by the user. A "reference level" value can be set for each controlled variable, determining the level of that variable that the person seeks, and a "gain" value can be set, determining how energetic the reaction will be if the variable departs from its reference level. Each individual can be assigned a starting point on the field. Each person can be set up to seek a goal- position that can be specified somewhere else on the field, or the position of another person (or both). Each individual avoids collisions with other people by sensing their proximity and direction, according to the reference level and gain that is set (the avoidance systems are one-way: they react only to proximities greater than the assigned reference level). By experimenting with these numbers you can give the individuals different characteristics. As a result the mass behavior of the active persons on the screen will take on recognizably different forms.

Individuals move only when they are designated "active," inactive persons being assigned to positions at random and remaining stationary there. The total number of persons can be changed at any time, the maximum being 255 or a smaller number automatically set to accommodate computers with limited memory. By varying the total number you can change the number of inactive (stationary) persons that the active ones must move around on their way to their goal positions. The scale of the field can be changed in length; the width (vertical dimension on the screen) adjusts itself to the proportions of the screen.

All operations are done from the keyboard; no special equipment is required. Hercules graphics or CGA graphics screens are automatically detected, scaling being adjusted appropriately. The program apparently also works with EGA and VGA graphics boards, and also with ATT graphics. The author cannot easily test any but Hercules and EGA compatibility.

This program is a way of starting to apply the method of modeling to social behavior. The behavior of the whole mass of people arises strictly from the properties of the individuals. By varying the properties of the individuals, one can see how interactions among people with these properties lead to emergent phenomena of interaction. By setting up different situations, one can see whether the simple model used for each person is sufficient to explain a social phenomenon as it is actually observed. Where the model proves insufficient, one can begin to see what needs to be added to it to make the results more realistic. In an iterative process the model is set up, its behavior noted, and its behavior is compared with reality to set the stage for the next generation of the model. This, in a nutshell, is the method of modeling.

Preparing to use CROWD.

Put the distribution disk in a floppy drive, transfer to that drive, and type README for startup directions. Several crowd setups are already stored; you can create new setups yourself.

To start the program be sure you are in the proper subdirectory and type CROWD (enter).

Operating the program

When the program is started, it shows a directory of any files that already exist in the directory. You can type in the name of any file or enter a new file name. If you enter a new file name the program will start running with a single active person with default characteristics, and 49 inactive persons on the field. If you choose an existing file name you will see another setup already created.

THE ONLY EXIT FROM THE PROGRAM occurs at this point. If you answer the request for a file name with just the Enter key, the program will exit back to the operating system; you then have to type CROWD to restart it.

At any time you can type Q or q and abort a run. At this point you can abandon the program, save the parameters under the old file name, or save them under a new name. Thus you can start with a previous setup, modify it, and save it under a new name for later use. If you start by creating a new name, the program will start running with the default settings; you can then stop it to modify the parameters, by typing p or P.

During a run you can type r or R to restart the run, space to pause the action and then to continue it, t or T to turn trails on and off, or, as mentioned, q or Q to abort the run. A legend across the top of the screen reminds you of these options. See the end of this discussion for printing out graphics screens and lists of parameters ("Whistles and Bells," below).

Parameters can be adjusted at any time during or after a run, by typing p or P to bring up the parameter menu. There are two groups of parameters, general and individual/group. Use the arrow keys to move the highlight up and down (only the up/down arrow keys work). To change any entry, simply type in the new entry. Backspace deletes it and allows retyping it. The entry can be terminated with a return (i.e., enter), Escape, End Key, Up arrow, or Down arrow. If you leave this menu and later return to it, the highlight will be where it was, so you can quickly make successive changes to the same parameter and see the effects.

At any time while entering parameters, you can exit back to the active program (restarting the run) by pressing the End or Esc key. These keys are legitimate terminators for an entry. If you use the End key, you are asked a question (discussed below under "Groups"). If you're exploring the effect of changing one parameter, exit with the Esc key to see the results immediately. When you re-enter the parameter screen with p or P, the highlight will be where it was, so you can just enter another value and hit Escape.

General Adjustable Parameters

In the top part of the parameters screen there are parameters that apply generally. The first two should be the measured height and width of the display screen in millimeters for scaling purposes. You can leave these as is. Next is the length of the field in inches; the default is 1200 inches, or 100 feet. The width (vertical dimension) of the field is calculated automatically to fit the screen proportions.

Then comes the total number of persons, the maximum being 255. If your computer has limited memory and you specify too many persons, the number will be reduced to the maximum possible. The total number of persons can be changed at any time. If it is less than the number of active persons, the specifications for persons not shown ARE NOT lost, even if you store the setup. Inactive persons are placed randomly around the field. The field is scaled to 2/3 of the dimensions of the screen.

Next is the "proximity factor." This number is the distance in inches between persons (center to center) at which the sensed proximity falls to 1/4 of the maximum proximity, 255 arbitrary units. The proximity function's value is proportional to the area covered by the visual image of a person at a given distance. It gets smaller as the person is farther away. This function is used by all persons to convert distance to another person into a perception of proximity, which is the controlled quantity for all persons' avoidance systems.

The last entry in the upper part of the screen is the Seek Proximity Factor. This effectively creates another proximity function (usually broader) that is used in seeking the position of another person. If the Seek Proximity Factor is 1, the proximity curve for seeking is the same as for avoiding. If it is larger than 1, the curve is broadened, so that perceived proximity falls off more slowly with distance (for seeking only). Both proximity curves are plotted in the corner of the screen during a run.

Between the upper and lower parts of the screen is a legend showing the index number of one person and the group to which that person belongs. The PgUp and PgDn keys cycle the person number, the data below always being for the person shown in the legend. The index number "wraps around" the limits set by the total number of persons entered above. Remember that the lowest person number is 0, not 1. Person numbers run consecutively; they do not re-start at zero when the group changes.

Now we consider the parameters in the lower part, which specify the characteristics of each individual.

Individual Characteristics

The first two entries the left column specify the person's initial X and Y positions, IN INCHES. Zero is in the center of the screen, so to start the person on the left, enter a NEGATIVE X-position. Negative Y positions are below center.

The next entry is the initial direction of movement of the person, in positive or negative degrees -- zero is the direction to the right (or east, if you think of this as a map). Zero is the normal setting. You can go as far as +179 and -180 degrees.

The next two entries specify the X and Y position of the goal that this person is seeking, IN INCHES, measured from the center of the field.

The next entry is SEEK DEST/PER. If this entry is P, the person will seek the position of another person as well as seeking the destination position. You can stop seeking of the destination by setting the Destination gain parameters to zero (below). If the setting is D, the person seeks only Destination, not a Person.

Inactive persons are shown as circles. Persons seeking a destination are shown as the capital letter D, and persons seeking another person's position are shown as the capital letter P.

When the setting is D, a goal circle is drawn for that person at the location of Dest X and Dest Y. When the setting is P, no circle is drawn if the Dest X and Dest Y positions are both exactly zero. It is possible to have a person seek both another person and a goal position, creating conflict, so you may want the goal circle to show. Just don't put it exactly at 0,0.

The next entry is meaningful only if the SEEK DEST/PER entry is set to "P". It designates which person (by number) will be sought. This person can be a member of any group and can be either active or inactive. If the setting is "D", this person number is ignored.

Next the active/inactive status of the person is specified by typing Y for yes (active) or N for no (not active). Only active persons move. Inactive persons are assigned positions at random, by the program, and remain there. All parameters for inactive persons are ignored.

The last entry in the left column designates the group, A to E, to which the person belongs. More will be said about groups later.

In the right-hand column we have the control parameters. These must be understood in some detail to understand their effects.

Control Parameters

In the right-hand column, the first four entries concern avoidance.

Avoidance is based on a sensing the sum of proximities of all other persons on the field. The individual contributions to the sum are weighted according to the cosine of half the angle away from the direction of travel -- the weighting drops to zero for the exact reverse direction. Each person perceives the weighted sum of proximities to the left, and, separately, the weighted sum of proximities to the right. The difference between these summed proximities is used to steer around other people, and the sum is used to adjust speed of approach to other people. Even persons whose position is being sought are avoided according to these parameters.

The "Avoid Dir" entries determine how soon and how rapidly a person turns when proximity to others rises. The reference level sets a lower limit on proximity: proximities lower than this limit have no effect on direction. The maximum proximity is 255 arbitrary units. A reference level setting should be lower than that amount, or there will never be any turns to avoid collisions with an isolated individual. The sense of proximity, however, is summed over many other persons, so even if a single individual might be overrun when a reference setting of 255 is used, a group of individuals close together will lead to a summed proximity much greater than 255, and will cause a turn. So you can make a person into a cowardly bully who picks on loners but avoids groups. When the direction of travel is exactly toward another person, the Avoidance Direction perception is "dithered;" varied randomly within a small range of angles, to prevent an impasse.

The "Avoid Dir Gain Pct." entry determines the error sensitivity -- how fast the person will turn for a given excess of proximity over the reference level.

The number 100 is a sort of nominal setting; you can enter any number from 0 to 1000. Think of it as a percentage of the nominal setting. The higher the number, the more abrupt will be the turns. Setting the gain to zero removes the control system from action. A normal setting is about 200.

The "Avoid Prox" entries have similar meanings, but the effect is to slow rather than turn the person. When summed proximity exceeds the reference setting, the speed of the person lessens. The "Avoid Prox Gain Pct" entry determines how much slowing there will be for a given excess over the reference proximity. The speed can go negative, so the person backs away from a close approach by another active person. Use a rather small number (4 to 10) or the speed may go to zero and stop the moving person next to a stationary one. When that happens the person is stuck, because you can't turn at zero speed.

The next entry is the "Dest Dir Gain Pct," nominally 100 but normally set to a much lower number, like 20. The direction reference level is always set to zero, meaning that the person always tries to make the difference between the direction of travel and the direction to the goal be zero. That just means that the person heads toward the goal instead of to the left or right of it. The gain setting, which you can adjust, determines how energetically the person will turn when the direction of travel is not toward the goal. A useful setting is about 18.

To see the significance of this, you have to remember that the avoidance control systems also act by altering the person's direction of travel. Doing that disturbs the goal-seeking system. If the goal-seeking system has too high a gain, it will fight the avoidance system and collisions will occur. So you have to balance the avoidance direction gain and the destination direction gain to get progress toward the destination but also allow for avoiding collisions with other people.

The next two entries determine the speed of goal-seeking motion. The "Dest Prox Ref Level" specifies the amount of proximity to the goal that the person will seek. To make the person go all the way to the middle of the goal, set this number at 255. It can normally remain there.

The next entry, "Dest Prox Gain Pct," determines how rapidly the person will head toward the goal. The initial proximity of the goal will usually be close to zero, if the goal is across the field. That means that a proximity reference level of 255, as recommended, will lead to a proximity error of 255 -- a big error. You want only a small percent of that error to appear as speed unless you want the person to get to the goal in a few swift jumps (bowling over everyone in between). Reasonable numbers are 5 to 25, meaning 5 to 25 per cent of the "nominal" setting of 100.

Finally we have four entries concerned with seeking the position of another person. The meanings are the same as for the "Avoid" entries above, except that (1) the person moves toward rather than away from the position of another person, and (2) control is bidirectional. Bidirectional control means that the perception of proximity (taken from the broader proximity curve established by Seek Proximity Factor) is controlled relative to a specific reference level, being reduced if it is too high and increased if it is too low. Thus persons seek a specific amount of proximity to the designated other person. Remember that the maximum proximity is 255. If the reference level is 100 and the target person is stationary, the moving person will head toward the target person and stop when the sensed proximity is near 100. A lower reference level means less proximity is wanted; the person will stop farther away.

Knowing this much, you should be able to try different values of the parameters to see and understand their effects. The default setup, with only one person active, is a good way to do this. You will get this setup if you start with a new file name.

Groups

One of the entries for each individual is the "Member of group A..E" entry, to be filled in with a letter from A to E. What makes a group-membership useful is that you can set the parameters for the first (lowest-numbered) individual in a group, and then cycle upward through persons setting all of them to be members of the same group (the cursor won't move). When you hit the End Key (instead of the Escape key) to exit from setting parameters, you'll be asked for a list of the group letters for groups whose characteristics are to be copied from those of the first member of each group. Just type the letters one after another, ending with the Enter key. Typing AEB means that the parameters of the lowest-numbered member of group A get copied into the rest of group A, and so on for groups E and B (sequence makes no difference). If you change your mind about copying, just hit the Enter key before typing any letters, or after deleting them all with the backspace key. The groups containing at least one active member are shown at the lower left on the parameter screen.

All persons, even inactive persons, belong to some group. Group E can be reserved for inactive persons (as it is in the default settings). Groups may contain both active and inactive persons.

Having set all members of a group to have identical characteristics, you can re-enter the parameter menu with p or P and set individuals in that group to have different characteristics -- for example, you may not want them all to start from exactly the same position. You may want to introduce a scatter in their speeds or error sensitivities (gains). After you have made such individual changes, exit with the Escape key so that the group characteristics will not be copied from the first member. If you accidentally hit the End key, you can still leave the parameters as they are by typing Enter without entering any letters.

When making a whole group follow a single leader, it is useful first to set the whole group to have identical characteristics, including designating the same person number as the person whose position is to be sought by everyone in the group. Exit with the End key to allow copying parameters, then re-enter the parameters menu and set the group leader (the one whose number appears in all the other Person Number entries in the group) to seek only the destination (Seek Dest/Per set to "D").

You cannot use stored setups from Version 1 or 2.0. The data records are of a different size. If you try to use old setups, the program will exit with an error message.

Whistles and Bells

Version 2.1 will not create a new file or update an old one until you elect to save it after typing q or Q (entering the old name or a new name). Thus typing errors don't show up as new but unwanted setups. If you misspell a file name and type Enter before you notice it, let the run start, end it with q or Q, then answer the question about saving the file with N or n for No.

You will also notice that whether you save a file or not, a new question appears, asking if you want to print out the parameters. If you answer Y or y, the general parameters will be printed, followed by the parameters for each person, by group, and then a list of the positions of all inactive persons using x and y coordinates. This allows setting up real experimental conditions to reproduce the conditions in a given setup. Note that inactive persons are assigned positions AT RANDOM. This means you must photograph (using space to pause the action) or print out the behavior on the screen BEFORE doing a real experiment, because the positions of inactive persons will be different on the next run of the same setup. But see below for a way of repeating all person positions.

The parameter printout requires a wide-carriage (132 column) printer. It issues a command that will set an Epson printer to condensed printing, so 8-1/2 x 11 paper will do. If you have another brand of narrow-carriage printer you must manually set it for condensed printing (17 characters per inch) to use 8-1/2 x 11 paper.

You can freeze the positions of inactive persons by making them active, then setting all their Gain and Ref Level values to zero so they won't move. You must then set the initial positions of these persons one at a time (Init X pos and Init Y pos). If you assign these persons to Group E, you can set parameters for the first person in that group and exit with End, then duplicate parameters for group E. Then re-enter the parameter menu with p or P and adjust the individual initial positions. Exit with Esc, type q or Q, and select the option (Y or y) that saves the setup. This allows you to repeat runs for a given setup that contains stationary persons.