



## Simulating arcs and rings in gatherings

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A theory of collective behavior must be able to account for simple and common collective phenomena such as arcs and rings. Using a computer simulator designed according to the principles of Perceptual Control Theory, based on a model how a human being, as a living control system, engages in movement alone and with others in temporary gatherings we produced a highly symmetrical ring that remotely corresponds to the non-simulated world because it is made up exclusively of individuals. When we simulated the pairs that compared to non-simulated gatherings, the outcome was an arc but was still unlike those we have observed in many temporary gatherings. When we introduced disturbances into the gatherings in the form of other simulated actors they more closely represented what we have observed in the non-simulated world of parks, plazas, states fairs and school yards as well as those at political, religious and rallies. We offer several proposals for future research.

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### 1. Introduction

In public places like London's Hyde Park or New York City's Washington Square, it is common to see persons arrayed in arcs or rings around entertainers, political and religious speakers, or other points of common focus. Of these arrangements, Milgram and Toch write (1969, p. 518):

If individuals are randomly distributed over a flat surface in the starting situation, a point of common interest in the same plane creates a crowd tending toward circularity. The circular arrangement is not accidental but seems an important function. It permits the most efficient arrangement of individuals around a point of common focus.

A theory of collective behavior must be able to account for simple and common collective phenomena such as arcs and rings. Elsewhere we have examined arcs, rings and clusters, collective locomotion and other simple forms using field observation (McPhail, 1991, 1994b; McPhail & Wohlstein, 1986), experiments (McPhail & Wohlstein, 1986) and computer simulations (McPhail, Powers & Tucker, 1992; Schweingruber, 1993). We have argued that Perceptual Control Theory (PCT) (Powers, 1973, 1989) is the best existing theory for accounting for purposive individual behavior and have proposed an explanation for collective behavior based on this theory (McPhail & Tucker, 1990; McPhail,

1991, 1994b). Specifically, we argue that collective behavior is a result of individuals controlling for similar or related reference signals.

Here we use a computer simulation based on PCT to examine in greater detail arcs and rings as specific forms of collective action. By setting reference signals which are similar or related we are able to produce arcs and rings. By making the details of the simulation correspond more closely to what we know about gatherings in the non-simulated world, we are able to create rings and arcs which are more like those we have observed in temporary gatherings.

We argue that this is possible because the model upon which the simulation is built is an approximation of the model upon which non-simulated actions operate. Further refinements of this simulation which are consistent with this model can provide insight into non-simulated collective behavior which we observe in the field and in experiments.

After reviewing the theoretical model for our computer simulation (Powers, 1973, 1989) and briefly describing the program derived from this theoretical model (McPhail *et al.*, 1992), we present a number of arcs and rings generated from the simulation program and suggest several avenues for future research.

## 2. Perceptual control theory

In the hundreds of temporary gatherings that we have observed (McPhail, 1991) there is always an alternation between collective and individual action. Formulations which attempt to account for these actions by considering individuals as either internally command driven OR externally stimulated fail empirically to account for collective action (McPhail, 1991). What is required is a formulation which explains purposive action (McPhail & Tucker, 1990). The explanation of purposive action that we find most useful is a cybernetic (i.e. self-governing) model. Shibusaki (1968) points out that long before Weiner (1948) used the name, both Dewey (1896) and Mead (1938) had put forth some of the features of a cybernetic model of individual action. Rather than being controlled by consequences or action outcomes, problem-solving individuals select consequences on the basis of their potential for solving a problem. A person is not controlled by a stimulus; rather an individual selects or controls stimuli relevant to that person's interests.

A newer and more sophisticated formulation of these notions is presented by Powers (1973, 1989) as PCT. PCT claims that individuals are living control systems which act to achieve and maintain internally constructed intentions, purposes or goals. These intentions (which Powers calls "reference signals" using the language of engineering control theory) are electrochemical signals in the central nervous system (Stewart, 1981).

Each reference signal is part of a negative feedback loop which acts to keep a perception at a desired state. This control system contains an input function, which converts a perception from the environment into an electrochemical signal, which is compared to the reference signal. If there is a difference between the input and reference signals, an output function produces output in the form of muscle movements into the environment to alter the variable being perceived. Since this variable is also affected by disturbances, the system may have to constantly adjust its output to achieve and maintain the desired perception. Thus, the behavior of the system is not caused by internal signals or external

stimuli, but is the product of an individual controlling a perception in a changing, often uncooperative, environment.

Each human being, as a living control system, actually has thousands of “negative feedback control systems” arranged hierarchically and operating in a parallel and simultaneous manner. In most of the systems, the output consists of signals passed down to other control systems, where these signals become new reference signals. At the same time that electrochemical signals are being passed down to other systems, perceptions are being sent up and are combined by other input functions to create other, and more complicated perceptions. By these processes individuals are able to accomplish multiple intentions simultaneously. PCT (Powers, 1973, 1989) incorporates memory, cognition, learning and consciousness as part of the hierarchical arrangement of control systems.

### 3. Powers’s gathering simulator

In Powers’s Gathering Simulator each “simulated actor” (SA) is programmed according to the principles of the PCT model (McPhail *et al.*, 1992, Schweingruber, 1994). Each SA can be assigned one or more of three reference signals: (1) avoiding collisions with disturbances (including other SAs), and/or (2) moving to a particular  $X/Y$  coordinate and/or (3) seeking and maintaining a specified physical distance from another SA. There is also a setting for the amount of sensitivity to error (i.e. speed of reaction) for each of the reference signals. As many as 255 SAs can be located at specific coordinates on the field or they can be randomly distributed throughout the field. Each SA programmed to control for another SA or an  $X/Y$  coordinate may take a different path depending on the disturbances encountered during a particular “run”. A “run” begins when an SA begins its movement and ends when it has reached its destination. By programming these settings for a number of actors we are able to simulate purposive collective action.

### 4. Simulating arcs and rings

PCT explains how individual’s pursue their goals. Elsewhere (McPhail & Tucker, 1990; McPhail *et al.*, 1992) we argue that collective behavior is the result of individuals who are controlling for reference signals which are similar or related.† We consider other SAs in the actors’ environment and it is the interaction of purposive output with other SAs that yields collective behavior. The Gathering Simulator allows us to explore the question of what interaction of similar or related reference signals and other SAs produce arcs and rings.

In Panel A of Figure 1 we simulate the formulation of a ring by giving 14 simulated actors (here designated as  $P$ ) two identical goals. The first is to avoid collisions with anything in their paths, a goal accomplished by slowing movement or changing direction to circumvent the disturbance. The second identical goal is the pursuit of a target person (here designated as  $P^T$ ). The  $P$ ’s will pursue the  $P^T$  until the latter stops but will maintain sufficient distance from  $P^T$ , and from one another, to avoid collisions with any of those

†Human actors can only have “similar”, not “identical”, reference signals since each person’s perceptual organization is different. The SAs can have “identical” reference signals since their design is identical and their reference signals can be set by an investigator.

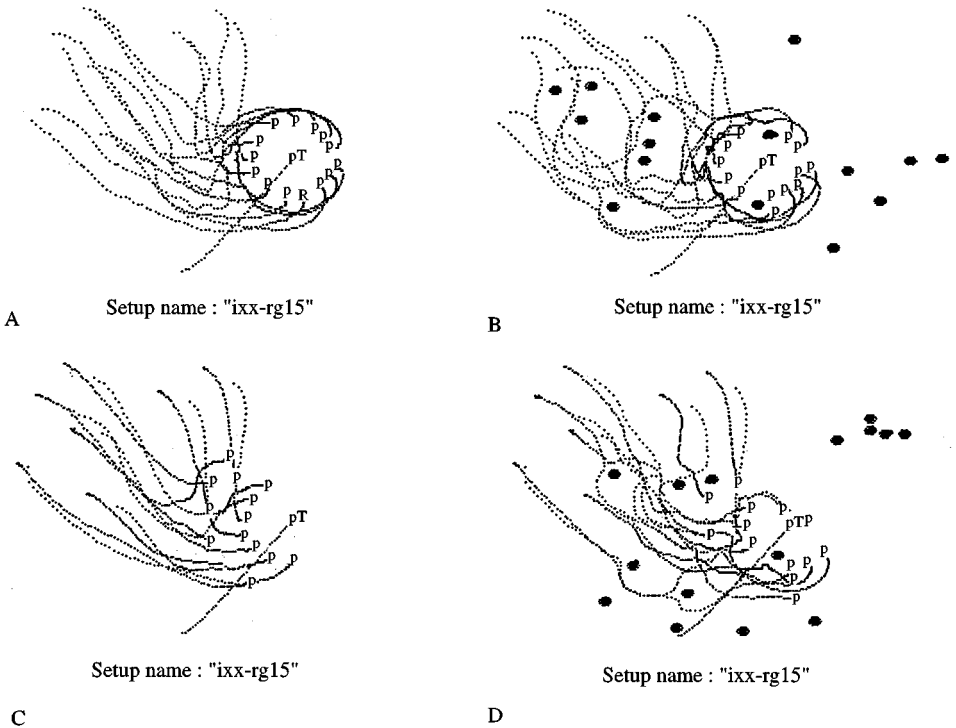


FIGURE 1. Simulations of arcs and rings.

possible obstacles. The coordinates of origin for the 14  $P$ 's are located in the upper left corner of the field; the coordinates of origin for  $P^T$  are in the lower right corner. Like the 14  $P$ 's,  $P^T$  is given a goal of avoiding collisions with anything in its path; but, in addition,  $P^T$  is given coordinates of a destination toward the center of the field. As  $P^T$  moves toward that destination the 14  $P$ 's move toward  $P^T$ , avoiding collisions with one another. When  $P^T$  stops at its destination, the 14  $P$ 's position themselves in relation to  $P^T$  but also position themselves so as to avoid a collision with  $P^T$  or other  $P$ 's.

The outcome of these individual goals is a ring formation of 14  $P$ 's around  $P^T$ , a social form not unlike those described by Milgram and Toch (1969) and similar to those we have observed in the field on many occasions. The first 14 simulated actors were not programmed to form a ring; rather, they were programmed to pursue identical goals. These resulting social forms are an epiphenomenal outcome of those individual's similar goals and their negotiation of the other SAs encountered in the course of pursuing those goals.

These simulated actors were not programmed to follow a particular route to a specified destination; they were programmed to seek and find a target person. In Panel A their paths do not show much deviation in route to their target because they encounter few obstacles. In Panel B of Figure 1, we introduce 14 stationary simulated actors in the field through which the original 14 simulated actors ( $P$ 's) move. These stationary  $P$ 's are randomly distributed and appear here as black dots. Nothing else was changed in the

previous program which produced the outcome in Panel A; however in Panel B the path traces of the 14 original  $P$ 's indicate their movements varied considerably as they negotiated the various obstacle(s) they encountered in their pursuit of  $P^T$ , and once again the outcome is a ring around the target person. Nevertheless, the symmetry of the rings in Panels A and B are atypical in the non-simulated world.

The rings in Panels A and B are atypical for two reasons. First, without considerable practice and rehearsal it is very unlikely that any collection of actors in non-simulated gatherings will position themselves in such a symmetrical fashion in relation to their point of common interest or in relation to one another. Second, most gatherings are not composed of solitary and disparate individuals; rather, they consist of some individuals and some small companion clusters of family members, friends or acquaintances ranging in size from 2 to 6 members (McPhail, 1994b). When this feature is introduced into the Gathering Simulator, the outcome in rings which take on a slightly different but more authentic form.

In Panel C of Figure 1, all SAs with one exception ( $P^T$ ) are programmed to simulate asymmetrical pairs, that is, one of the SAs is pursuing a second SA but the latter member of each pair is pursuing  $P^T$ . Thus,  $SA1 \rightarrow SA2 \rightarrow P^T$ ;  $SA3 \rightarrow SA4 \rightarrow P^T$  through  $SA13 \rightarrow SA14 \rightarrow P^T$ . The traces indicate that the SAs are asymmetrical pairs with one SA "following" a second. At the end of the run, the outcome is, once again, a symmetrical double-arc form. Even this symmetrical arrangement is rarely observed in public places since it requires each person to maintain exact and matching distances from others; this is difficult to accomplish without considerable practice.

In Panel D of Figure 1, 15 stationary SAs are introduced to illustrate what happens when obstacles are present. The traces reveal that the pairs of SAs are separated from each other as they move across the field because of other SAs. Finally, it should be noted that the arcs are not as symmetrical as in Panel C due to the disturbances which the SAs encounter. By having the SAs assemble in asymmetrical pairs that encounter other SAs, we have simulated a social form which better approximates those we have observed in the non-simulated world.

Eventhough it is quite common to observe people assembled around another person or set of persons it is just as common to see people assemble next to, by or around physical objects, structures of a "place". Some students at USC-Columbia are told to "meet me at the top of the horseshoe"; students at the UIUC say "meet me at Alma Mater" which is a large sculpture near the center of the main campus. At the annual State South Carolina Fair in Columbia, South Carolina, one can hear over the speakers a statement like "Sally, met your Mother at the rocket!" which most understand to mean "go to a forty foot silver metal rocket located by the front gate of the State Fair grounds." Every evening during the State Fair one can observe as many as 50 people gathered in the vicinity of that rocket. Thus, we are interested in simulating a gathering for a "location" as we have done for a "target simulated actor".

In Panel A of Figure 2 we simulate the formation of a ring by giving 14  $P$ 's the same goal of arriving at a location (denoted as " $X$ "). The coordinates of origin are located in the upper left corner of the field while the coordinates for "location" are in the center of the field. The resulting form is shaped more like a "3/4 ring" than the "ring" form evident in Panel A of Figure 1. The form in Panel B is similar to the form in Panel A except the

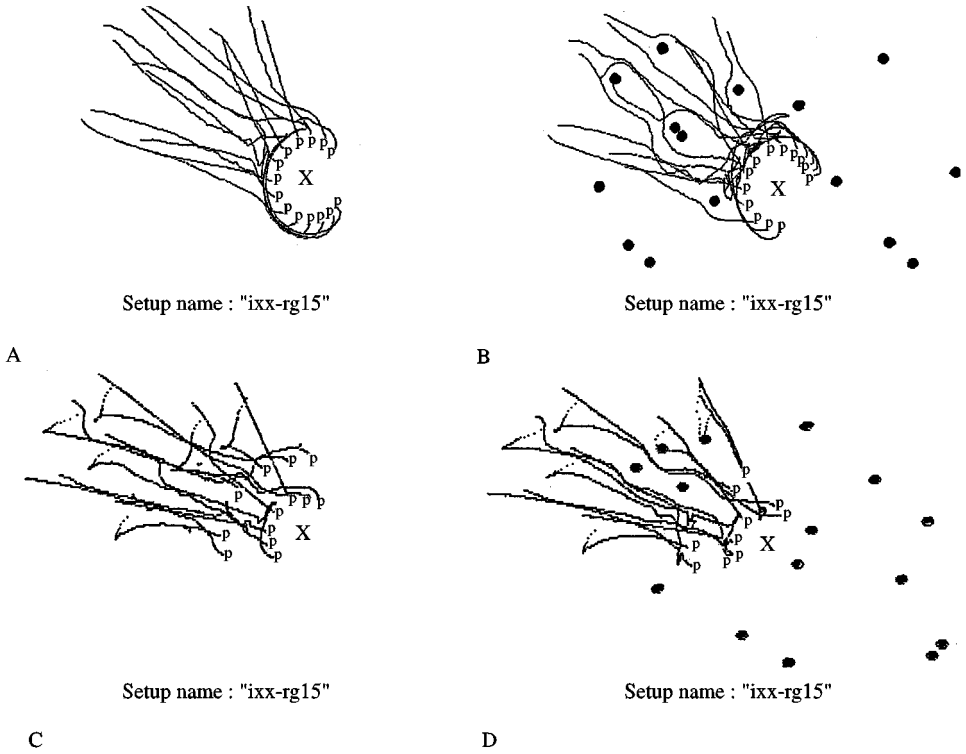


FIGURE 2. Simulations of arcs and rings with destination.

traces or paths of movement are not as “direct” to the location. The symmetry of the “ring” is still atypical in comparison with those we observe in a non-simulated world.

In Panel C all 14 SAs are simulated to form seven pairs with one SA of the pair pursuing the other member of the pair with the latter pursuing allocation (i.e. “X”). Thus, SA1 → SA2 → X; SA3 → SA4 → X through SA13 → SA14 → X. The traces show that the SAs move together as asymmetrical pairs and quite similar to Panel C in Figure 1 we see a very symmetrical, atypical double-arc form.

In Panel D, 15 additional SAs are introduced as obstacles and one can see from the traces that those “pairs” are separated as by the other SAs as they move through the field and then rejoin in pairs. Finally, we note that the arcs formed in Panel D are not as evident here due to the obstacles negotiated by the pair. The form in Panel D is quite similar to those we have observed in the non-simulated world.

## 5. Summary

We have demonstrated a computer simulation program for representing temporary gatherings. The Gathering Simulator is designed according to the principles of PCT (Powers, 1973, 1989) which is based on a model how a human being, as a living control

system, engages in movement alone and with others in temporary gatherings (McPhail, 1991, 1994b). We produced a highly symmetrical ring that remotely corresponds to the non-simulated world because it is made up exclusively of individuals. When we simulated the pairs that compared to non-simulated gatherings, the outcome was an arc but was still unlike those we have observed in many temporary gatherings. When we introduced disturbances into the gatherings in the form of other simulated actors they more closely represented what we have observed in the non-simulated world of parks, plazas, states fairs and school yards as well as those at political, religious and sport rallies.

## 6. Future research

Many improvements must be made in the GATHERING program to make it better represent what we observe in non-simulated gatherings. In most gatherings people negotiate disturbances by making adjustments and alterations more complicated than the SAs simple changes in direction or speed. People change goals in mid-course, moving from one pedestrian cluster to another or changing queues when one is moving faster. People can follow social conventions, such walking on the right side of the sidewalk and not treading on the grass. People can walk to one station, wait in a queue, then walk to another station, as during university registration. All such movements we observe in temporary gatherings we would hope to simulate with a more advanced version of the GATHERING program.

In order for the SAs to approach the complexity of human actors, they will need more control systems and these control systems need to be arranged hierarchically. This will allow higher-level control systems to change lower-level goals in order to negotiate disturbances or because one goal is achieved and another one is required. This will also allow the SAs to perceive more complicated perceptions as lower-level perceptions are combined.

A second feature needed for more complicated simulations is the ability for SAs to communicate with each other. Communication is certainly present in non-simulated gatherings in the form of talking, shouting, chanting, gesturing, etc. The addition of communication processes is also necessary to test our contention that complicated behavior-in-concert most often results from similar or related reference signals which are adopted from a third-party (McPhail, 1991). If this is true, the addition of a communication process—the ability of one SA to suggest a reference signal to another—should allow for much more complicated simulated behavior.

A third feature needed by the GATHERING program is the ability to add physical barriers, which we have observed influencing the development of simple forms, such as arcs and rings. These include the fountains, steps and fences in the parks and plazas where we have observed people gather and form arcs and rings. The program should also include structures which are not physical barriers, but which have socially constructed meanings, like sidewalks, signs and stoplights. SAs could then control for relationships to these structures as well.

By creating a more sophisticated and powerful simulation program, we hope to simulate more complicated forms of social behavior we have observed in the world of human actors. In this way, we can test and further refine our theoretical understanding of this world.

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