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— PROGRAM ABSTRACTS/ALGORITHMS —

FISH: A commons dilemma simulation

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A local-area-network-based commons dilemma (CD) simulation is described. The program uses fishing as its CD metaphor; research participants experience the metaphor through both graphics (fish may be seen in an ocean) and text (CD terms such as "resource regeneration" are translated to fishing terms such as "spawning"). Common CD parameters, such as the availability of the resource, payoff values, the number of harvesters, the rate of regeneration, knowledge about the state of the resource, and awareness of other harvesters' actions may be varied. Other CD parameters that are not yet widely studied may also be varied, such as variability in regeneration rate, uncertainty in the amount of the resource, operating costs necessary to harvest the resource, length of time for the resource to regenerate (spawn), and whether the resource is visible to harvesters. The program worked well in pilot testing and in a study in progress.

In a time of ecological concern, it is important to understand the social psychological processes involved in managing environmental resources. We extract, refine, use, and dispose of many natural resources. Individuals face resource management problems every day, although awareness of this is sometimes low. To varying degrees, we monitor our personal use of resources, observe the effects that our usage has on the environment, and are aware of the usage patterns of other individuals. The crucial aspect of individual-level resource management is that it sums, across millions of peoples' actions, to societal-level management in ways that are mysterious, partly irrational, but all-important.

The Commons

Originally, the *commons* referred to a central open space in the heart of a village or small town. Shares of the commons were owned by villagers, each of whom was welcome to use its grass and open space. Villagers grazed their animals on the commons.

As long as there is grass enough for all the shareholders, the commons is a tranquil place. In most commons, however, the day eventually arrives when someone develops a motive to use more grass—perhaps to feed another cow or to sell the grass to another village. Or, the number of shareholders in the commons grows and, even though no one takes more than before, more individuals are using grass. When villagers notice that someone is "getting ahead" or that the resource is shrinking faster than it can regenerate, use of the commons will be hotly debated. New arrivals will claim they have an equal right to the resource; those who have increased their take will defend their harvesting with the view that "it's a free country, isn't it?" The issue becomes freedom in the commons (Hardin, 1968).

Commons are established on the assumption that the supply of the resource can meet the demands of the community. Those who unquestioningly accept this assumption feel free to exploit the resource as much as possible, because in exploiting the resource for one's own benefit, the individual allegedly is guided (according to 18th century economists such as Adam Smith) by an "invisible hand" to benefit the whole community. For example, a whaler who becomes rich would employ people, buy equipment, donate to social, educational, and charitable causes, and generally aid the economy.

An early 19th century economist, William Lloyd (1837/1968) the first to see a problem with this logic: he recognized that many resources are limited. In a desirable but limited commons, individuals act in self-interest, according to Hardin (1968), who asserts that a process called the "tragedy of the commons" then begins: "Each man is locked into a system that compels him to increase his [harvesting] without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest..." (Hardin, 1968, p. 1244).

Many resources besides pasture lands are limited and essentially held in common: oil, whales, buffalo, water, and even fresh air. In general, a commons is any desirable resource jointly held by a group of individuals.

Commons Dilemmas

What is a commons *dilemma*? Some resources regenerate relatively quickly (e.g., grass for grazing, river water for electric power), others not so quickly (e.g., fish, trees used for lumber), and some very slowly or not at all (e.g., oil, endangered species). When resources regenerate more slowly than people can harvest them, the danger of resource exhaustion arises. We might paraphrase Hamlet: To get ahead quickly at the expense of the commons and other harvesters, or to restrain harvesting to preserve the commons and increase one's wealth slowly, that is the question.

When the resource is available in essentially unlimited quantities, this choice may be unnecessary and there is no real dilemma. However, when harvesters are able (through improved technology, previous overharvesting, or sheer personpower) to harvest the remaining resource

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faster than it can regenerate itself, this choice between rapid, resource-destructive, short-term, self-interested harvesting (''get 'em while there's still some left'') versus restrained, long-term, public- and resource-oriented harvesting is precisely the dilemma they face. The term *commons dilemma*, inspired by the thought of Lloyd and Hardin, was first used by Dawes (1973).

Are Commons Dilemmas Always Fatal?

Social scientists have not unquestioningly accepted Hardin's tragedy-of-the-commons argument that individuals will always act in short-term self-interest; they consider the issue of how individuals will behave in a limited commons to be an open question that will be resolved through empirical research. Psychologists and economists, in particular, have pursued the question and created sizable but, unfortunately, largely separate bodies of work on the question (cf. Gardner, Ostrom, & Walker, 1990; Hine, 1990).

From everyday experience, we know that individuals sometimes do act in the public interest rather than in self-interest. Many individuals will walk out of their way to deposit litter in a garbage can, voluntarily limit the number of children they have, or turn down their thermostats. Of course, experience also teaches us that sometimes individuals do act in pure self-interest. Laboratory studies (e.g., Edney & Bell, 1984) show that stealing from others in the commons is frequent.

The real question is: under *which conditions* will individuals act in self-interest? Often it is easier or more rewarding, at least in the short run, to engage in self-serving behavior than it is to behave in the public interest. In a limited commons, the public-spirited act is often more expensive, difficult, or time-consuming, and less immediately rewarding than the self-serving act.

In sum, we all manage a steady supply of natural resources that have been converted into products we use every day. Some of these resources come from limited sources called *commons*. A commons is a pool of desirable materials that may be harvested by a number of individuals or organizations that share access to it. Commons dilemmas occur when improved technology or increased person-power enables the harvesting of resources faster than the resource can regenerate. Harvesters then must decide whether to maximize their own gain in the short term or to help maximize the gain of the whole group or public, including themselves, over the longer term.

Simulating Commons Dilemmas

The original (noncomputerized) commons dilemma simulation was proposed by Julian Edney (1979), who called it ''the nuts game.'' In it, a number of participants sit around a large, shallow bowl. The bowl contains a dozen walnuts. The experimenter explains that participants may take as many walnuts out of the bowl as they wish at any time; there is no turn taking. The walnuts may be traded at the end for something valuable—money, concert tickets, or food. Before the participants knock each other over while grabbing the walnuts, the experimenter adds one more piece of information: ''If any walnuts remain in the bowl 10 seconds after the start, I will place that many more walnuts in the bowl.''

A number of computer-based commons dilemma simulations have been described in the literature (e.g., Cass & Edney, 1978; Chapman, Hu, & Mullen, 1986; Parker et al., 1983). Each appears to serve the experimenter's purposes well but may not be flexible enough to serve many different research purposes. None, to our knowledge, provides true networking, so that real harvest data can be shared immediately among the harvesters. Most do not appear to allow for the manipulation of more than a few parameters as part of the program.

FISH, a commons dilemma simulation, creates a context that includes many of the essential elements of any commons dilemma. The researcher selects from a menu of 19 different parameters (see Figure 1). These include the number of trials (seasons), the probability of harvest (catching a fish), various income and cost variables, resource availability (size of the remaining fish stock), degree of uncertainty about the resource's actual quantity and regeneration rate, and so on. The fishers are able, if they choose, to harvest the resource (catch fish) more quickly than the resource can regenerate itself (spawn). Multiple harvesters (in pilot studies, up to 17 simultaneous fishers have been accommodated successfully) have equal and full access to the resource. Their harvests and identities may (or may not) be displayed to other harvesters. Payoffs can be arranged so that a relatively large, quick profit may be made (which tends to exhaust the resource) or a larger, albeit slower growing profit may be made (when harvesters use restraint and allow the resource to regenerate).

In FISH, both text and graphics support the metaphor of fishing. Introductory screens describe the simulation so that FISH is essentially self-explanatory. The harvesters are fishers who operate fleets of boats—the resource is fish; fishers actively cast for fish, drift without casting or return to port, and regeneration occurs through the periodic spawning of any fish that remain after a season of fishing.

Figure 1 illustrates a typical setup template file in which the experimenter chooses options for each of FISH's parameters. Figure 2 depicts a typical opening scene in a FISH session. The dark fish are bright red and blue on the color VGA screen. The outlined fish (optional) are the same color as the background and represent uncertainty in fish stock size: they may or may not actually be in the ocean.

Each fishing season ends when all fishers choose to return to port (i.e., have caught as many fish as they wish). Fishers, therefore, are able to exhaust the resource within one season. However, if all of them return to port without harvesting all the fish, spawning will occur and they may return to fish for another season. In FISH lexicon, a career is all the seasons during which fish are available.

FISH is economically realistic. Fishers pay a start-up cost to leave port, which represents their capital costs (e.g., a loan payment on their boats). They pay operat-

Game Parameters
Mon Dec 10 12:48:28 1990

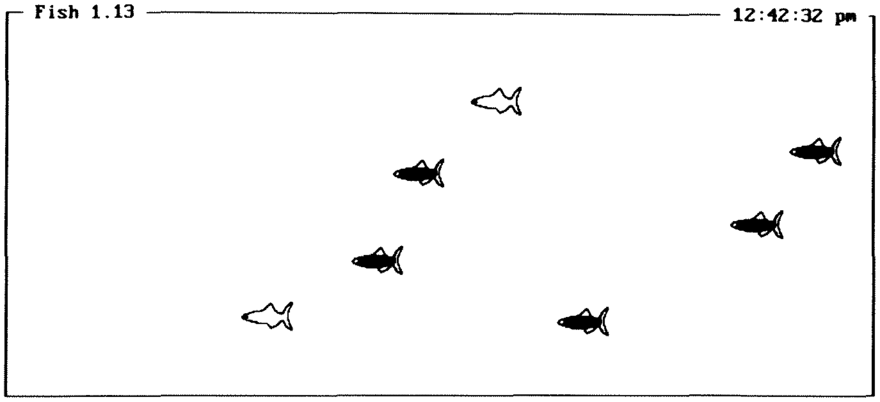
Number of Seasons:	5
Probability of Catch:	1.00
Income per Fish:	25.00 dollars
Fixed Cost:	10.00 dollars
Hourly Cost:	60.00 dollars/hour
Maximum Stock:	12 fish
Base Stock:	12 fish
Range of Uncertainty in Stock:	2 fish
Display Group Member Numbers?:	Y
Display Group Member Names?:	Y
Display # Group Member Fish?:	Y
Display Group Member Status?:	Y
Random Assignment to Groups?:	N
Number of Groups for Random Assignment:	1
Status Update Interval:	1 seconds
Fishing Turn Interval:	5 seconds
Number of Missed Turns to Quit:	2
Spawning Period (Wait):	5 seconds
Number of Players:	3
Number of Groups:	1

Season Parameters

Season	Spawning Factor	Random Number
1	2.00	0.528395
2	2.00	0.456377
3	2.00	0.903757
4	2.00	0.681280
5	2.00	0.635242

Figure 1. A FISH template file from a session in which Bob, Don, and Dee comprise a fleet of three fishers in a simulation governed by the parameters shown.

Fish 1.13 12:42:32 pm



Welcome to port! From here you can go fishing, or retire.
Retire:[Esc] Set out Fishing:[F]

	Season 2	Career
Fishing Time :	0:00:00	0:00:25
Number of Casts:	0	3
Fish Caught :	0	3
Fish Remaining :	5 - 7	
Your Income :	$ 0.00	$ 75.00
Your Expenses :	$ 0.00	$ 10.42
Your Profit :	$ 0.00	$ 64.58

Your Fleet: 1

Fisher Name	#Fish	Status
1 of 3 *** You ***	0	In Port
2 of 3 Don	3	Fishing
3 of 3 Dee	1	Fishing

Figure 2. Screen dump from Bob's monitor at the beginning of the second season of a FISH session.

ing costs (e.g., for labor and fuel). They receive payment for each fish caught.

Many aspects of the fishing experience that the commons dilemma literature suggests influence commons dilemma behavior (for a survey, see Gifford, 1987) may be varied within the program. These include the number of fishers in a fleet, the original size of the fish stock, the payoffs and costs, the spawning rate, and knowledge of other fishers' behavior. In addition, other parameters may be varied that either contribute to the realism of the simulation or someday may be shown to influence behavior in commons dilemmas. These include whether or not the number of fish remaining is known to the fishers (i.e., are visible on the screen or not), the degree of certainty about how many fish are present ("perhaps-real" fish may be displayed), variability in the spawn rate, length of time permitted for a cast, and the off-season time required for spawning. Obviously, other variables that do not depend on the simulation itself may also be varied, such as whether communication is permitted, whether persuasive attempts are made, and which personal and group characteristics of fishers are examined.

FISH is network-based. All, part, or none of the information on fishing activities may be distributed to fishers in a fleet. Data on time spent fishing, number of casts, fish caught, costs, and profits for each fisher and fleet are automatically collected and stored. Figure 3 shows typical results from a FISH session.

Hardware and Software

FISH is written in Microsoft C and runs under MS-DOS. It requires about 150K of memory. It depends in part on functions provided in two commercial C libraries (C Tools Plus and PCX Programmer's Toolkit). Each fisher requires an IBM-PC-compatible machine with at least VGA display capability. The PCs are normally linked in a local area network (LAN) that supports the MS-DOS SHARE facility, although the program will run, for demonstration purposes, on a stand-alone PC. Communication among fishers is through a single shared file,

Group Status
Mon Dec 10 12:48:29 1990

Group	Number of Players	Seasons Started	Current Stock
1	3	5	4

Player Results
Mon Dec 10 12:48:29 1990

Group:Name Season(s)	Turns Taken	Casts Made	Fish Taken	Costs	Income	Profit	Init. Stock	Final Stock
1:Bob								
Season 1	5	3	3	10.42	75.00	64.58	12	5
Season 2	0	0	0	0.00	0.00	0.00	10	6
Season 3	4	3	3	10.35	75.00	64.65	12	8
Season 4	7	5	5	10.65	125.00	114.35	12	4
Season 5	3	3	3	10.25	75.00	64.75	8	4
TOTAL	19	14	14	41.67	350.00	308.33		
1:Don								
Season 1	1	1	1	10.10	25.00	14.90	12	5
Season 2	6	3	3	10.52	75.00	64.48	10	6
Season 3	0	0	0	0.00	0.00	0.00	12	12
TOTAL	7	4	4	20.62	100.00	79.38		
1:Dee								
Season 1	4	3	3	10.37	75.00	64.63	12	5
Season 2	2	1	1	10.18	25.00	14.82	10	6
Season 3	2	1	1	10.23	25.00	14.77	12	8
Season 4	6	3	3	10.48	75.00	64.52	12	4
Season 5	1	1	1	10.08	25.00	14.92	8	4
TOTAL	15	9	9	51.34	225.00	173.66		

Figure 3. FISH results from the careers of Bob, Don, and Dee.

separate from the template file, which is accessible through the LAN. A separate program is used by the experimenter to convert the template file into the shared file used by the fishers and to extract the results of the fishing from the shared file.

FISH has been tested in our laboratory network of 20 IBM PS/2 Model 60 computers connected through an IBM Token Ring LAN that runs Novell Netware. Even with 17 fishers in a fleet, the most we have included at once, LAN performance was sufficient to allow screen updates on all machines at 1-sec intervals. FISH has run smoothly in pilot testing and numerous labs for classes. The first full-fledged experiment, which examines the influence of uncertainty in spawn rates and uncertainty about actual stock sizes, is nearly complete, also without any problem. In all, about 50 groups ranging from 3 to 17 in size, using variations on all the parameters, have been run successfully. Most current research programs on resource management that focus on the responses of small to medium groups to simulated dilemmas and vary any of the parameters mentioned earlier could use FISH. The program is very flexible in terms of allowing many combinations of conditions to be examined.

Availability. A copy of FISH may be obtained by writing to the senior author. Enclose $8 for shipping and handling, or $6 if you send a formatted diskette. Specify whether you prefer a 3.5-in. or a 5.25-in. diskette. A LAN is required for the program to run to its fullest potential (i.e., for information exchange among participants, etc.), but a demonstration copy that will run for one person on a single PC (FISH-DEMO) is available on the same terms as FISH.

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