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Digi-Koi: A Game for Cell Phones

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1 Introduction

Cell phones offer game designers unique challenges and opportunities. The phone we have picked as our target platform, Mitsubishi Electric's J-D05 J-Phone, is typical of current second-generation (2G) phones. It shares their limitations in that it has limited memory capacity and restricted input capabilities (a phone keypad plus arrow keys). However, it has (relatively) strong output capabilities: a 132x162-pixel screen with 12-bit color; and the communication capabilities inherent in all cell phones, including Short Messaging Service (SMS). Most importantly, it is an existing product. J-Phone reports that they have sold over ten million cell phones with similar capabilities [1].

We do not yet know what types of games will be the most popular on platforms like the J-Phone. Will ports of existing PC or PDA games dominate [2] or will a new class of compelling games emerge that are tailored to cell phones? Also, we do not yet have an adequate repertoire of interface widgets for performing typical interactions on cell phones. What are the best ways to support browsing, selection, text entry, etc., on a device with a small screen and no dedicated pointing or scrolling device? In this paper we contribute to the ongoing debates on both of these questions.

First, we present a novel game that takes advantage of the 2G cell phone as a game platform. Our game is a simulation that is based on the popular Japanese pastime of breeding koi, or ornamental carp. It differs from other breeding-based games by attempting to emulate an existing real-world hobby: our digi-koi look like real koi and our simulated genetics exhibit many of the characteristics of real koi genetics (see Fig. 1). Because the goal is to breed attractive koi, the game is openended and can be played by a sole participant at any time and at irregular intervals, e.g., while commuting. However, the ability to trade koi with other players via SMS messages adds an important social element to the game.

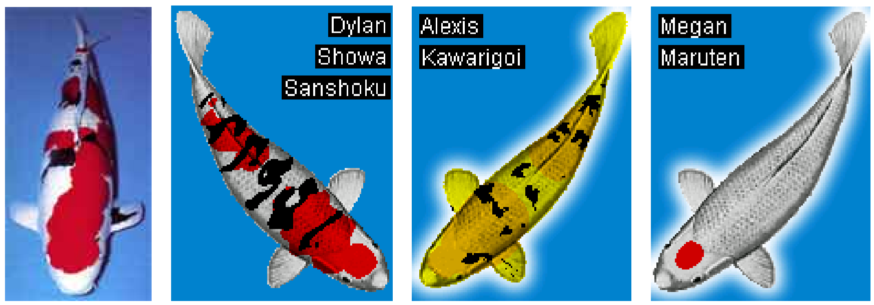

Fig. 1. Examples of real koi (left) and three digi-koi bred by test users of our game (right). The koi's name and classification are displayed in an upper corner of the screen.

Second, we describe two new interface widgets for supporting the selection and browsing tasks required for the game. Actions are selected using a *KeyPadPie menu*: the numeric keys map to menu commands on the screen that are located in the same relative positions as their corresponding keys. This design is superior to conventional menus in two ways. It leverages human procedural memory: common operations are performed via short number sequences that quickly become automatic with use. It also provides a natural mapping between function and control of that function. Browsing the virtual pond of digi-koi presents another problem. The virtual pond is arranged as a grid, in which each cell is either empty or occupied by a single digi-koi. A pan-and-zoom approach to browsing is not possible because the phone's CPU is not powerful enough to support continuous, animated navigation of the grid. A discrete version of panning, in which the grid is traversed one whole cell at a time, can leave the user disoriented because there are no visual cues for location within the grid. Our solution is a modification of the discrete-panning metaphor in which neighboring cells are partially visible. This metaphor of *discrete panning with partial context* gives the user a sense of location while browsing the grid (see Fig. 2).

In the following sections we describe in turn: related work; the game experience; the genetic simulation at the heart of the game; the user interface; the results of preliminary user studies; and our plans for future work and commercial deployment.

2 Related Work

While several groups have built genetic simulations that are similar to our work, no single project matches our combination of goals, platform, and audience.

The original inspiration for aesthetically oriented interactive-evolution systems was work by Karl Sims [3] and Todd and Latham [4] in the early 90's. Since then several games have been developed around the theme of interactive evolution. Alien Fish Exchange [6] is a multi-player game for WAP cell phones in which players compete against each other to breed the most exotic fish possible. Players then gain points by selling these fish to restaurants that pay based on the rarity of the breed.

The emphasis on the fiscal facets of the game and the fanciful representation of the fish separate Alien Fish Exchange from digi-koi. Perhaps the most successful example of this genre is CyberLife Technology's *Creatures* [7], a suite of breeding and nurturing software for the PC. Creatures is similar to digi-koi in that there are few set goals and they are both largely self-directed experiences. Both simulations include a large set of genes that result in a large number of physical variations. Unlike digi-koi, Creatures focuses largely on the nurturing of pets. Players direct the development of their creatures over time by interacting with them. Digi-koi places more weight on the breeding process, and employs a more realistic breeding simulation than does Creatures.

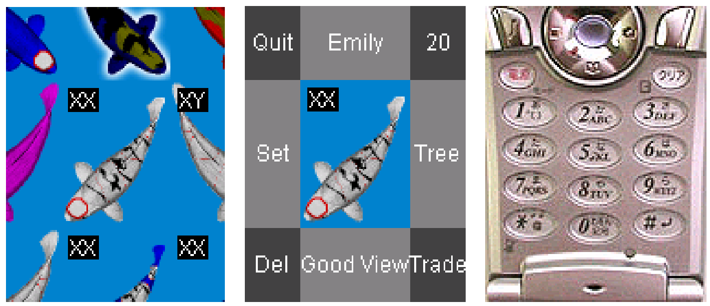

Fig. 2. Discrete panning with partial context (left), the KeyPadPie menu (middle), and the Mitsubishi Electric J-D05 J-Phone keypad (right).

The work most like ours was built by Danesh et al., who designed and built *Geney* [5], a collaborative problem-solving application that lets children explore genetics on the Palm™ platform. On the surface, *Geney* is similar to digi-koi in many ways: players breed and trade fish and participate in an experience with both single and multiplayer facets. Additionally, the Palm™ platform has some of the same physical constraints as the J-Phone (small screen, limited input and memory). The differences between these projects are in their audience and their goals. Geney is primarily an educational tool. A small number of genetic traits allow children to quickly grasp a few key concepts. Digi-koi has a much richer variety of genes, and was designed as an entertaining experience to be enjoyed over a long period of time. Because Geney is an educational tool, the physical representation of fish need only convey the genetic characteristics: a simple line-art image with textual description is appropriate to this goal. In digi-koi, an aesthetically pleasing representation is the goal, so a much richer visualization of the fish is needed.

3 The Game Experience

Unlike more conventional computer games, the digi-koi game does not have an intrinsic goal. Although we leave open the possibility of contests to breed digi-koi with certain characteristics, we think that the primary motivation for playing is likely to be aesthetic pleasure: a typical player will probably just want to breed beautiful digi-koi. In solo play, such a player will need to browse her pond of digi-koi to look for promising breeding stock. She will want to consider the parents, grandparents, and siblings of a candidate pair of digi-koi to determine if they have desirable and complementary genes. Even with well-chosen parents, the randomness of genetics may produce many offspring that do not exhibit the visual characteristics the user wants, but hopefully a few that do: just as in real koi breeding, skillful culling of unwanted koi is an important task [8]. For the offspring the player keeps, choosing an appropriate name is an important step in turning her creation into a pet [5].

Trading allows a player to augment her gene pool by acquiring digi-koi with genetic characteristics that are absent from her pond. The trading mechanism is very simple: a digi-koi can be sent from one player's pond to another by an SMS message. However, the trading process can be complex in a social sense and adds significant richness to the game, because the value of a digi-koi can be hard to assess. One factor is a digi-koi's "breeding age": to avoid traumatizing players, digi-koi do not die unless they are culled; but to avoid the proliferation of particular genes, digi-koi can only mate a prescribed number of times. The other main factor affecting value is a digi-koi's lineage: what genes does it have and how do they complement those already in her pond? Once two players have made their own evaluations of all the digi-koi in a potential trade, then the haggling can begin!

4 The Genetic Simulation

Digi-Koi includes a wide variety of gene pairs that adhere to basic diploid Mendelian genetics. These gene pairs are summarized in Table 1. Over 6 trillion unique genetic combinations (genotypes) are possible with over 100 billion unique appearances (phenotypes). The memory limitations of a cell phone preclude storing koi as images, so koi are stored internally as a 68-bit gene sequence. Images of the koi are rendered by compositing a small number of stored image templates in ways dictated by the gene sequence (see Fig. 3).

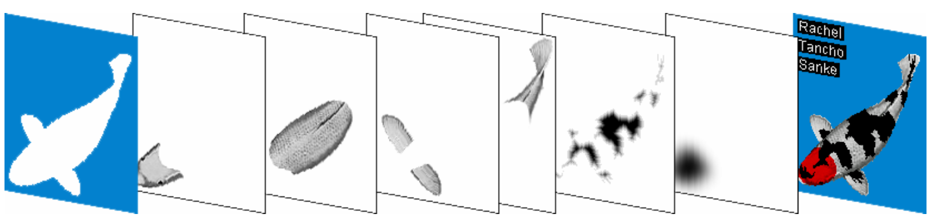

Fig. 3. A small number of stored image templates are composited together to create a large number of koi variations. The result of this composite is shown on the right.

While we do not claim to have an exact match with all the subtleties of koi breeding, we do simulate many of the Mendelian properties of real-world genetics. Digi-koi genes exist in allelic pairs, and the behavior of these pairs dictates the physical representation of the koi. For example, digi-koi have a gene pair for scale type. Each allele in this pair is either a recessive '*s*' (for shiny), or a dominant '*D*' (for dull), making three possible genotypes: '*ss*', '*sD*', and '*DD*' (order is not important). Because the '*D*' allele is dominant, koi with either a '*sD*' or '*DD*' genotype will have a dull appearance. Only koi with a '*ss*' genotype will appear shiny. When koi breed, each parent passes one allele from each pair to their child. In this way, it is possible for two parents with dull scales, each with a ‘*sD’* genotype, to produce offspring who are ‘*DD’* (dull), ‘*sD’* (dull), or ‘*ss’* (shiny).

Digi-koi include a variety of allele types. There are dominant alleles, such as those for a black secondary pattern, and recessive ones, such as those for shiny scales. Alleles for color exhibit co-dominance: a koi containing an allele for yellow scales and one for blue scales will exhibit green scales. Semi-dominant allele pairs, in which every unique genotype has its own phenotype, are present as well. For example, a koi with two alleles for large fins will have large fins, a koi with two alleles for small fins will have small fins, and a koi with an allele for large fins and an allele for small fins will have medium-sized fins. Genes for pattern density use a 7-bit polygenic approximation that exhibits typical breeding characteristics: a densely patterned father mating with a lightly patterned mother will produce medium patterned offspring. Finally, many allele pairs are epistatic to other pairs: one masks the other. For example, a black base color hides the appearance of black stripes.

Table 1. Summary of gene pairs. C-D, D/r, S-D, and P denote Co-Dominant, Dominant/Recessive, Semi-Dominant, and Polygenic respectively.

Gene Pair	Number of Phenotypes	Number of Genotypes	Allele Types
The base color of the koi.	12	15	C-D
The color of the primary pattern.	12	15	C-D
The primary pattern’s edge style.	2	3	D/r
The primary pattern’s edge color.	12	15	C-D
The shape of the head markings.	3	3	S-D
The shape of the primary pattern.	3	3	S-D
A lightning-like primary pattern.	2	3	D/r
The primary pattern’s density.	127	127	P
The secondary pattern’s density.	127	127	P
The sex of the koi.	2	2	D/r
Whether or not the koi is shiny.	2	3	D/r
The size of the koi’s head.	3	3	S-D
The size of the koi’s body.	3	3	S-D
The size of the koi’s tail.	3	3	S-D
Existence of a black secondary pattern.	2	3	D/r

Because players cannot view genes directly, digi-koi includes a lineage tool for viewing a koi’s ancestors. In the example presented in Fig. 4, the selected koi exhibits a phenotype for a recessive trait: lustrous shiny scales (indicated by its glow). Looking at this koi’s parents, one sees that neither of them exhibited this trait; both parents must be carriers of this recessive gene. But both of this koi’s grandfathers have shiny scales. The grandfathers passed on this gene to their offspring, who both passed it on to this koi. By examining the appearance of a koi, its ancestors, and offspring, a player gains an understanding of its genetics, and can then better select koi for breeding. For a more detailed understanding of Mendelian genetics, the reader should consult any introductory biology textbook. However, only a vague understanding of genetics is enough to enjoy digi-koi, as shown by our preliminary user study (see Section 6).

5 The User Interface

As described briefly in the introduction, the user interface has two modes: action selection and pond browsing.

5.1 Action Selection via the KeyPadPie Menu

Many cell phone applications utilize linear menus to issue commands. The items in a menu are presented vertically, as they would be in a pull-down menu on a desktop computer. Pull-down menus were originally designed to be used with a mouse or similar pointing device, an input mechanism these cell phones lack. Menu items are either selected by scrolling up and down or by hitting the key on the keypad that corresponds to the number in the menu entry. Because the keys on the keypad are not laid out in a vertical fashion, a user must translate menu items from linear menu space into two-dimensional keypad space before making a selection.

We present a new interface widget for supporting menu selection and browsing tasks, *KeyPadPie*, shown in Fig. 2. These actions are summarized in Table 2. Pressing a button on the actual keypad triggers the menu commands on the screen that is located in the same relative position as its corresponding key.

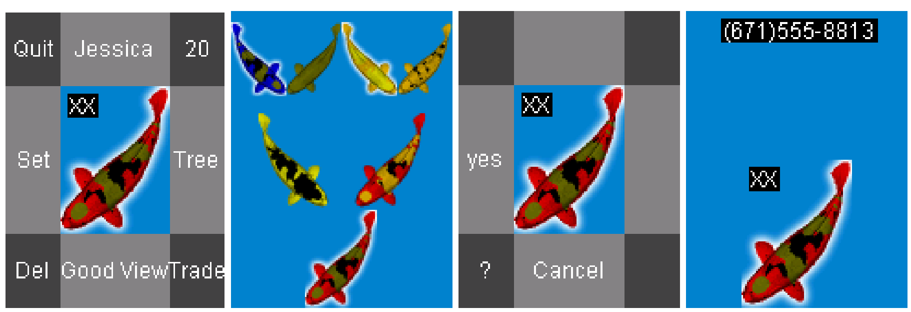

Fig. 4. The KeyPadPie menu (left), the lineage view (middle left), the deletion-confirmation menu (middle right), and the trading screen (right).

For menus that contain more than nine commands, *KeyPadPie* uses hierarchical menus, such as the deletion-confirmation menu shown in Fig. 4. A menu item's sub-commands fill the remaining eight regions upon selection of the parent. The user issues commands nested deeply within a menu by using a sequence of keystrokes.

As mentioned previously, one of the benefits of the *KeyPadPie* technique is that common operations are performed via short, easy-to-remember number sequences. For example, from the pond-browsing mode the number sequence 5-7-4 transitions to the action-selection menu, chooses the deletion action, confirms the deletion and returns to the pond-browsing menu. The sequence 5-4-5 transitions from pond browsing, selects a parent, and transitions back to pond browsing. Tasks such as these that require more than one step exploit the player's procedural memory:

common operations become second nature. One potential drawback of this automation is that issuing a delete command and confirming it are grouped into a single number sequence – confirmation becomes inadequate to prevent the accidental deletion of a koi. We implemented an undo command on deletion so that a player can revive "deleted" koi for a short time by revisiting the koi's location in the pond.

Table 2. Summary of actions in the action-selection menu. Location 3 shows data. All other locations are used to trigger actions.

Location in keypad coordinates	Description
1	Quits the digi-koi application. Confirmation is required.
2	Produces a new name for the digi-koi.
3	Shows how many more matings are possible. When the number reaches zero the digi-koi can no longer be selected as a parent.
4	Sets the digi-koi as the father or mother for mating, depending on its gender. Once parents have been selected, the user can populate empty cells in the pond-browsing view with the parents' offspring.
5	Switches back to pond-browsing mode. Button 5 is used for all mode-changing actions in the digi-koi application.
6	Causes the digi-koi's lineage to be displayed. Parents and grandparents are shown – see Fig. 4.
7	Removes the digi-koi from the pond permanently. Confirmation is required and the deletion can be undone – see Fig. 4 and section 5.1. The vacated cell can be reused to house another digi-koi.
8	Switches to a full-screen view of the digi-koi. Button 5 is used to return from full-screen view to the action menu.
9	Initiates a dialogue for trading the digi-koi, requiring the user to input the phone number of the intended recipient – see Fig. 4.

5.2 Browsing the Virtual Pond via Discrete Panning with Partial Context

Panning the virtual pond is achieved via a similar keypad metaphor, e.g., Button 2 moves to the cell directly above, and Button 3 moves diagonally up and to the right. Button 5 is used to switch to the action-selection menu. As shown in Fig. 2, portions of neighboring cells are shown to provide some context within the pond.

6 Playtesting

To direct digi-koi's development, we conducted a series of playtesting sessions using a PC prototype of our game. In general, people have enjoyed the game (several were surprised that an hour had passed) and have quickly picked up on the controls and at least some of the rules that govern koi genetics (most of the koi in this paper were bred by novices within the first hour of play). While all players have been able to quickly learn how to navigate around their pond, several people have reported trouble returning to a particular koi. One solution might be to insert landmarks (such as islands and fountains) into the pond to aid in wayfinding. Within an hour, all players reported that they felt able to direct the development of their koi. However, the confidence that they could quickly breed a desired koi varied among players. Players varied greatly in terms of the genetic traits they found most desirable. Trading was almost always reciprocal, with players often eyeing each other's ponds.

7 Future Plans

Stringer and Ward [9] describe a new class of "Games that Go in the Gaps": games that fit in-between the events and activities of our daily lives and are easily stopped and restarted. They point to SMS as an example of a technology that succeeds because of its unobtrusiveness and conclude, "this unobtrusive, interstitial nature of SMS may be a feature which many ubiquitous computing applications would do well to mimic." Any mobile game that will continue of days, months, or even years will have to fit into the gaps in our lives.

While this observation directed our design, we have yet to conduct a study to answer the questions, "Where and for how long do people play games like digi-koi?" and "Does digi-koi fit in the gaps of player's lives?" Beyond this issue, we plan to ask, "Is there any educational value to our game?" and "Do users gain a deeper understanding of genetics through playing digi-koi?" Additionally, we plan to generalize our KeyPadPie menu and compare it with traditional menus across a variety of measures. As we continue to make improvements to the experience, we are exploring the commercial deployment of digi-koi with several game companies.

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