Developing an Aquaponics Interface

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ABSTRACT
Aquaponics is a method of farming which can be useful in an urban setting for sustainably producing food and increasing food security. This study pursued two goals related to the display of aquaponics system information: to extend the abilities of managers to operate such systems effectively and to provide environmentally conscious customers with relevant information about the sustainability of the system. By using value sensitive design, we produced an interface for monitoring an aquaponics system and provide suggestions for furnishing interested parties with sustainability information.

Author Keywords
Aquaponics; sustainability; value sensitive design;

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation: User Interfaces

INTRODUCTION
Aquaponics is a method of farming which produces fish and vegetables simultaneously in the same system (see Figure 1). It is particularly useful for increasing food security and producing food sustainably in urban settings. Aquaponics systems are very modular and easy to maintain once they have been set up and equipped with automated monitoring and control devices. With only a few parameters to check every day, even large systems can be managed well by a single person with the right tools.

The intent of this project is two-fold: to extend the abilities of managers to operate their aquaponics systems effectively and to provide environmentally conscious customers with relevant information about the sustainability of the system. To do this, the project will follow a value sensitive design approach.

RELATED WORK
Aquaponics
As Domingues et. al. demonstrate in [4], computer automation of the hydroponic growing process is very effective for increasing efficiency and reducing labor. The current project aims to implement this type of automation for aquaponics systems, which are somewhat similar to hydroponic systems. However, there appears to be a lack of research into the human factors of the design of such an automation system. Based on some initial interviews with experts in the field, urban aquaponics growers have specific needs for novel features of in an interface that would allow them to interact with their systems remotely. The current project has a direct goal of incorporating the values of these experts into the design of an effective online interface for aquaponics systems.

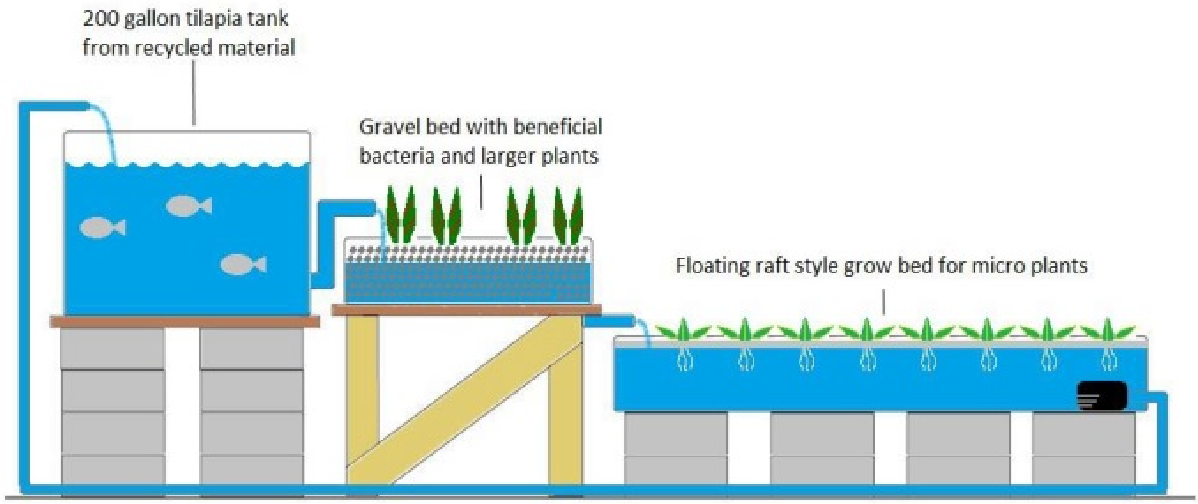
There is prior work [1, 2] in engaging consumers in thinking about the sustainability of their actions, and also in engaging companies in analyzing the sustainability of their operations [1, 7]. Salvá et. al. identify several key factors of sustainability that companies and consumers are interested in. Cornelissen et. al. have determined effective ways for engaging people positively in environmental behaviors. Bonanni et. al. have studied a specific tool which allows businesses to present information to customers about the amount of shipping used to produce their products. The current project will combine and expand on these three pieces of work. Specifically, there will be a customer interface showing real time sustainability information (based directly off of the sensor readings) about the operations of the aquaponics system. Customers will be able to see details about water, energy, waste, etc. and how the measures of these sustainability factors compare to the average American farm. The design of the customer interface for a positive experience with environmentally friendly behavior will be well informed by the values of consumers, as determined through surveys, interviews, and other studies.

In general there seems to be a lack of research into design of well integrated computing technologies for sustainable urban food production and consumption, so this project will be an important step in seeding this area of research in the HCI community. Furthermore, it should demonstrate a helpful addition to the farm-to-table movement by introducing real sustainability information that is available for the consumer to see how their specific actions, in their specific location, benefit the environment, as opposed to generalizing about the environmental benefits of farm-to-table, which can vary significantly from place to place.

Value Sensitive Design
Blah [5][6]

METHODS
Intro to methods

Identifying stakeholders



The Skales Prototype includes (from left to right): a 200 gallon tank where tilapia are raised, a grow bed with gravel media and microorganisms to process the fish waste into fertilizer, and a floating raft bed ideal for growing micro-greens and herbs. A recirculating pump will return the water to the fish tank.

Figure 1. Skales Cooperative aquaponics system

Direct Stakeholders	**Benefits/Harms**	**Values**	**Conflicts**
System managers	Benefits: Able to fix problems more quickly Benefit or harm: Less time doing maintenance and tending plants by hand Harm: Could be alerted of emergencies at any time	Human welfare Autonomy Calmness Free time away from work Interaction with nature Physical interaction with systems Awareness (of system functioning)	Physical interaction with systems and awareness may conflict with calmness and free time away from work
Indirect Stakeholders	**Benefits/Harms**	**Values**	**Conflicts**
Restaurants and restaurant customers	Benefits: Know about where their food comes from Provide feedbacks or improvements to owner Harms: Could be lied to if presented with false information	Trust Accountability Environmental sustainability Autonomy Ownership and property (restaurants)	Ownership and property (in the form of profitability) may compete with environmental sustainability

Table 1. Paired down list of stakeholders

Our first step was to create a list of potential stateholders. Although our list was initially quite extensive, we chose to focus on a few principle ones in our investigation (see Table 1). In particular, we chose system managers and restaurants owners/customers because we suspected their needs could be addressed using the system monitoring information available to us. Once we identified these two key groups, we began by constructing surveys in order to investigate the values of each. In response to feedback about our plan of investigation, the surveys were adapted into outlines for informal interviews. We had identified some values for each group in the initial step of identifying stakeholders, but needed to verify whether our intuitions were accurate. From this point, our investigations of the key groups diverged, and are addressed individually below.

Direct Stakeholders

The direct stakeholders, or system managers, can also be considered the "expert users" of our interface, whose needs and skills are specifically adapted to the system at hand. Our informal interviews allowed us to identify a few key parameters that needed to be monitorable using the interface: pH balance, water temperature, nitrogen levels, air temperature, and dissolved oxygen. Ideally the system managers would be able to add any type of parameter that could be monitored, allowing for extensible use. The system managers also stated a preference for all data to be visible on one graph, rather than a separate graph for each parameter. The interviews also confirmed the conflict between valuing calmness and free time away from the system versus physical interaction with and awareness of the system; system managers stated that an online interface would drastically improve maintenance, but that alerts would need to be immediate and disruptive if urgent.

Based on these preference statements, we outlined a few key features:

- An adustable timeline, which would allow system operators to not only see up-to-date data, but also arbitrary intervals of time in order to look for trends in the system's performance.
- Multiple visualizations of live system data. A line graph works well for data over time, but under-emphasizes the time frame a system manager will most often be concerned about when checking the site: the present moment. The system will also eventually be fitted with a camera to allow the system manager to monitor data that perhaps is not best represented by numbers, such as fish activity.
- Individual, customizable settings for each parameter. Each parameter has its own value range. Also true is that each parameter has a particular range that it should stay within for best performance of the system; the system manager should be able to set that range for each parameter.
- A normalized view of all parameters. Because each parameter has its own value range, the request that they all be displayed on one graph was at first conceptually daunting. Since each parameter also has a particular range that it should stay within, we therefore conceptualized this as an "optimal zone" by which to normalize.
- The ability to add parameters as more monitoring equipment becomes available.

Based on these features, we produced our first sketches (Figures 2 and 3). When our concept was solid enough, we

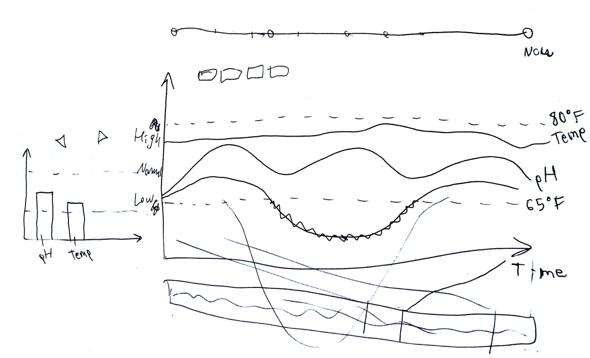


Figure 2. Initial sketch in response to system manager's desire to see all information at a glance.

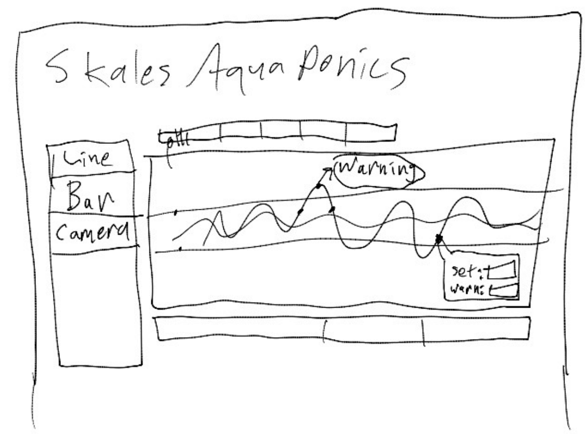


Figure 3. Refinement upon first sketch.

produced a color mockup in the style of D3.js in anticipation of utilizng the Javascript library to implement the interface prototype (Figure 4) [3]. Having a color mockup in the same aesthetic system proved useful for adapting to new suggestions as they occurred.

The next step was to implement a prototype on which we could conduct task-based testing. The prototype was populated with static, generated data, which meant that task performance could be compared a "correct" script. The tasks were constructed around ensuring that various features of the interface were easily interpretable (Table 2).

Due to lack of availability of "expert users" for testing, we adapted the tasks by adding the following scenario preamble.

"You are the manager of an aquaponics farming system. In order to ensure that it is in good working order, you need to monitor the following: pH balance, water temperature, nitrogen levels, air temperature, and dissolved oxygen. Each

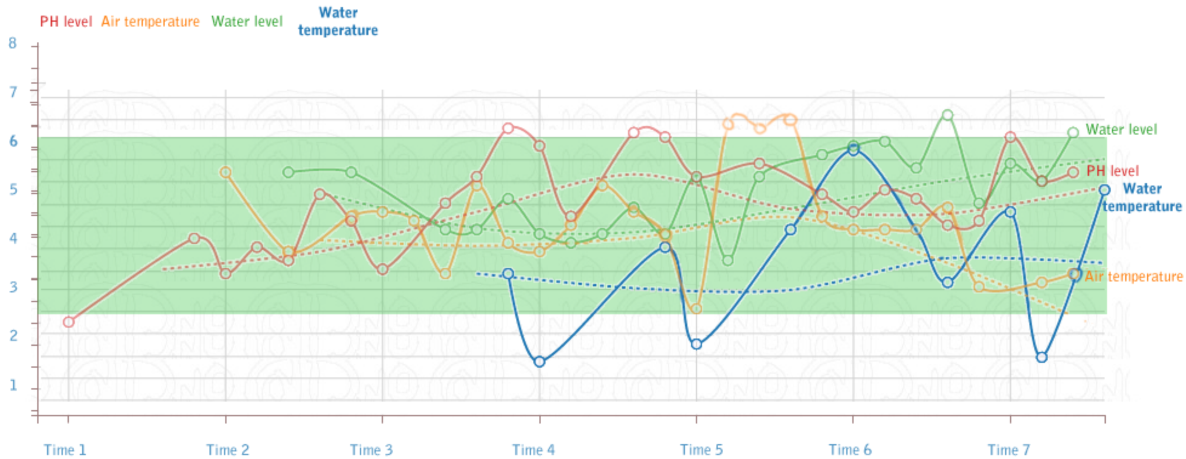


Figure 4. Color mockup based on D3.js aesthetics.

Task instruction	Feature tested
Identify whether any feeds are currently outside of optimal limits.	The default view of the chart, whether optimal settings zone is clear
Find how many times the feeds went outside optimal parameters in the last 3 months.	Whether brush (timeline) has correct affordances
Find out if/how many times each feed went outside optimal settings between March and February.	Whether people view all settings at once, or use the buttons to view them individually; requires additional use of brush

Table 2. Tasks used to test interface prototype

of these has boundaries it should stay between for best performance, for example, dissolved oxygen should remain between 30 and 60. If it goes above or below those measurements, the system will need in-person maintenance."

The feedback from the task-based user testing was then integrated into our final interface.

Indirect Stakeholders

The group of indirect stakeholders that we addressed, restaurant customers, constitute a much larger group than the direct stakeholders. Although we were only able to conduct interviews with a very small sample of this group, we were still able to elicit some useful information regarding values.

Initially, the intent of our investigation was to design an interface that addressed the needs of both direct and indirect stakeholders. The intuition was that the information used by system managers to monitor the operations of the aquaponics system could also be used to assess its sustainability. However, our informal interviews made it clear that the information needs of the indirect stakeholders were too different from those of the direct stakeholders to be addressed by the same interface. Instead of implementing another interface, we decided to present suggestions for how such data could be made available to non-experts interested in sustainability:

- The live data available to system managers is too much for non-experts to make sense of. Instead, certain system information should be available in summary, e.g., water used annually.

- In addition to presenting information in summary, data should also be contextualized. Even given data such as annual water use, non-experts are not able to compare to more conventional forms of farming. Suggested contextualization techniques include:

  – Resources consumed in system to create a plate of food.

  – Amount of food that could be produced if the aquaponics system filled a city block.

  – Direct comparison to conventional farming methods either inhabiting the same amount of space as the aquaponics system or generating the same amount of food.

- Ideally, information should be available to restaurant customers in-restaurant. Even restaurant customers who self-reported as being particularly interested in sustainability stated that they would not go out of their way (read, download an app or go to a website) to get sustainability information about food served in restaurants. In order to accomodate this, we suggest a system that generates a data sheet suitable for printing, for the restaurants to carry at their discretion.

RESULTS

Our design efforts resulted in a limited live prototype, a static version of which can be seen in Figure **??**. [1] The graph at the

[1]Accessible for the foreseeable future at **http://homes.cs.washington.edu/~samw11/510/**

top is the trend of the five parameters system managers indicated, i.e., pH value, water temperature, nitrogen, air temperature and dissolved oxygen. The x-axis represents the time and the y-axis represents the value of the those parameters. Color encoding is used in this visualization to represent the parameters. Users can select one of the five parameters at the top and the line of the selected parameter will be highlighted in the graph.

The green area in the graph represent the safe zone for the parameters. In ideal case, all values should be within the green area. If some of the parameter values went off the green area, a little alert box with an exclamation mark on top of the value will be appeared and also the system will alert the user by sending text message, email or even a phone call. In that case, user will able to take action on it. User can also mouse over the points on the line to see the actual value of the parameter at specific time. A tooltip box will pops up and the background of the tooltip will change to yellow if the value is out of the green area, indicating that user needs to pay attention on that.

There are more controls at the top right corner. Right now, only line graph is implemented. The bar graph and the live camera will be the future work. There is also a setting button which user can adjuct the suitable values for those parameters. For example, the water temperature needed to be adjusted depends on the weather.

There is an overall time graph at the bottom of the visualization. This graph represents all the value from the beginning until present. The main graph at the top shows the time line of the little grey box area at the bottom of the graph. When user brush the grey box, the top graph will changed showing the values over the brushed time. The width of the grey box can also be changed so that user will not only limited on a specific time region.

FUTURE WORK

Although the original list of stakeholders was thought to be extensive—including everyone who could conceivably be influenced by the aquaponics system or its interface—an interview with Batya Friedman revealed a particular bias: only humans were considered as stakeholders. The fish living in the aquaponics system, possibly the most direct stakeholder of all, had been overlooked.

Further development of the alert system would have benefited both the previously-identified stakeholders and the newly-considered ones. By creating a hierarchy of alerts, system managers could be consistently informed about the status of the system, and sufficiently disturbed by an alarm that denotes immediate dangers to the living inhabitants of the aquaponics system. Investigation into the creation and maintenance of such a hierarchy would be an invaluable next step for the success of this interface.

Our design currently makes strong use of color symbolism. From testing, it was clear that people immediately understood that green means "good." Additional use of color could be used on the graph to show the proximity of parameters to setting off the next tier of alarm, such as "yellow zones" and "red zones" denoting increasing severity as the parameter deviates farther from its optimal settings.

Another insight Friedman provided was the consideration of how to handle hardware aging. One idea to address aging is to allow system managers to set regularly-recurring maintenance reminders, but more work would need to be done on the form of alert appropriate for such reminders.

Other extensions to this interface include moving from a passive, monitoring role to being able to actively control certain functions in response to the incoming data, e.g., remotely activating. More visualization could be added such as the bar chat. The live camera could also be added once the hardware is in place. In terms of the alert feature, the system could be adjusted automatically if the value goes off in a small amount rather than keep sending alert to the user.

CONCLUSION

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