Plant Guild Composer: A Software System for Sustainability

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***Abstract*—This paper presents the design concept for a software application to aid users in the development of a sustainable backyard food and resource system[1]. It presents how we gathered and analyzed the requirements for an application that achieves a balance of user convenience, awareness, and sustainability in the context of creating a domestic plant guild. A plant guild is a community of plants that sustains itself and provides for people's essential needs.**

Based on a field study, the authors present requirements for building a *Plant Guild Composer* as one approach for addressing the aforementioned challenge. The requirements have been generalized because future applications that aide in the construction of a sustainable human system, which supports some human need without compromising the ability to satisfy this and other human needs in the future nor contributing to environmental degradation, may encounter similar design challenges.

***Index Terms*—requirements engineering; sustainability; plant guilds; permaculture; human-computer interaction**

I. Introduction

Complexity characterizes many of our lifestyles. Empirically speaking, it is a side effect of our options for nearly every aspect of life, from which career to pursue to what to eat for dinner. The use and development of technology is often intended to alleviate some of life's complexity via convenience, e.g., finding the exact doll your daughter wants for her birthday online is simpler than calling and driving to local toy stores. However, in effort to make life simpler, technology and the information provided by it has given us more choices and options than ever before. In sorting through these complexities, the need and ability to act sustainably is unnoticed or forgotten. In her visit to Change Islands, Phoebe Sengers discovered a lifestyle characterized by simplicity due to the severely limited access to technology and exotic resources, and the necessity to work for subsistence [13]. In many ways this simplicity rendered a more sustainable society and arguably improved their quality of life. As observed in the first authors ongoing ethnography of transition movements in Central Florida and Southern California, there are communities with an abundance of resources strive to achieve a similar simplicity, but are inclined to use technology to achieve it.

[1]Portions adapted from a previous workshop paper [8].

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A. Ties to RE4SuSy and Related Work in HCI

One of the objectives for the RE4SuSy workshop series is to develop Requirements Engineering (RE) techniques that help us design software systems that support sustainable lifestyles. Last year's contributions looked at how to improve existing RE techniques for green software [1]. Past HCI research has primarily approached the problem of unsustainable practices by outlining improper resource usage and its implications [3]. The issues associated with transitioning to a simple, sustainable lifestyle remain scarce amongst HCI publications, as it is established as a field of research in [2], and not explicitly mentioned in [3]. In contrast to both RE and HCI existing research, this paper provides an example system that supports a sustainable lifestyle and may be used as a case study in the future.

B. Sustainability and Permaculture

From our understanding, sustainable living can be achieved by managing consumption of extraneous materials, i.e., things we replace and dispose of without regard, and increasing self-sufficiency, i.e., providing for yourself. While Pierce approaches the topic of extraneous materials by encouraging reflection of how they are used [11], we are interested in enabling people to live independently of these extraneous materials by providing themselves with materials they need. Practices like permaculture (the eco-, human-sustainable design for permanence) advocate for similar ideologies, e.g., apply self-regulation and accept feedback [5]. Although independently ensured food and resource security is an innate step in becoming self-sufficient, this transition poses rather intensive, short-term complications. Namely, a great time investment is required to learn these methodologies and their implementation.

In permaculture, a domestic plant guild can foster human independence from extraneous materials. A domestic plant guild, as for example depicted in Figure 1, is a family of plants that can sustain itself and provide people with many of their essential needs (e.g., food, building materials, etc.) [7]. It

is an enabler of simple, sustainable living, i.e., reduces cost of living, ecological footprint, and the need for consumer goods.

C. Example Domestic Plant Guild Scenario

Picture yourself stepping out into a quiet backyard; your property is fenced in with an assortment of sugarcane and bamboo, protecting your privacy, and your other plants from wind. This same bamboo plant was used to build the bench you just sat down on. You gently stir your morning tea with a sweet cutting of sugarcane, yet another function of your privacy fence.

A brigade of bees and butterflies hover busily around your native goldenrod, gaillardia, coreopsis, milkweed, and sunflower. Where you would normally have grass, the native and hardy Gopher Apple gladly covers the ground; you even occasionally see a Gopher tortoise creep into your yard and lazily munch on his favorite snack.

A large persimmon tree provides shade for your bench as well as a nice little treat for you and the local wildlife. A passionflower entangles the persimmon tree, while its flower bobs happily around in your tea.

You begin to search for salad ingredients, your lunch, occasionally picking a few blackberries and sparkleberries; they taste quite like a blueberry, but half the maintenance. You pull a couple of leaves off the French Sorrel, the Moringa, and fennel. To top it off, you snag an avocado and some rosemary. You don't have to water or prune, you just have to eat your harvest. This is an ideal domestic plant guild.

D. Challenges in Plant Guild Design - A Need for good RE

The design and construction of a plant guild requires time and expert knowledge, two factors that prevent many from incorporating one. Therefore, if we can provide support tools to make it easier for people to develop and establish domestic plant guilds, then the gap between the idea of sustainable environments and their realization can be reduced. We believe that utilizing adequate RE techniques [9], [14] in the development of these software tools is essential in providing easy to use yet powerful interfaces to support domestic plant guild construction.

Outline

This position paper discusses, in the context of the Plant Guild Composer (PGC), the challenges of designing a software application with the intended use of supporting a sustainable lifestyle. Its focus is to mask the complexities of domestic plant guild creation through simple interfaces utilizing common and easily observable information about the environment.

We believe our topic is suitable for the RE4SuSy Workshop because (i) it focuses on gathering requirements at the intersection between human and environmental sustainability, and (ii) provides an example system in a new application domain for supporting the facilitation of sustainable lifestyles while masking complexity.

II. Plants Guilds

In the natural environment, plants exist in complex mutualistic communities. Within these communities, or plant guilds, each plant has a unique impact on the surrounding environment. Their impact may make one nutrient or resource more available or remove harmful constituents for neighboring plants. When considering an assessment of plant guilds, we assume that each plant has needs (i.e., inputs), products and behaviors (i.e., outputs), and intrinsic characteristics (i.e., physical traits); all are components of the plant's functional analysis. Once these plant characteristics are understood, a plant guild could be created to act as a semi-closed system, the only external inputs coming in from the natural environment. When this plant guild is used to provide outputs for human consumers, it becomes a domestic plant guild.

A. Central Objective of a Plant Guild

A domestic plant guild is one that is designed to insert a human component into this naturally closed system. Extraneous products from the plants provide edible, medicinal, and useable parts. Thus plant selection requires consideration of both fulfillment of the guild's and human's needs. The plants used in a guild are predominantly perennial (living more than 2 years) or self-seeding annuals, and if at all possible, native to the region. If the plant guild is designed and established properly, the human role is reduced to harvesting what is needed.

B. Principles for Designing Plant Guilds

To achieve a balanced domestic plant guild, experts initially model natural system dynamics (i.e., plant community functional analysis), then fit it to domestic constraints. The guild is designed to be convenient for humans (e.g., co-location of similar plant types and navigable paths) while still encouraging natural states of action between species (e.g., coaction, interaction, and inaction) [7], and features plants that support the humans' desired lifestyle (e.g., berries for jam production). The design of a plant guild is also dependent on implementation constraints (work, financial, and material resources). In general, the higher the human demand, the more initial energy required for the guild to reach establishment. In context of each constraint, plants are placed in appropriate geographic locations and functional arrangement. If designed correctly, the plant guild should not require human support past its establishment (i.e., when the trees reach maturity), though minor manipulation may increase its robustness (e.g., seasonal pruning of nutrient rich plants for mulch and fertilizer). However, due to a variety of variables, success is not guaranteed. It is possible that further consultation may be required, especially for complex, high-yield guilds. The basic design principles that permaculture designers follow are lined out in Figure 2.

Due to the intensive process of creating domestic plant guilds, the knowledge required to properly design and establish one is currently only possible by experts. As such, we've conceptualized the PGC, a tool to support the development of

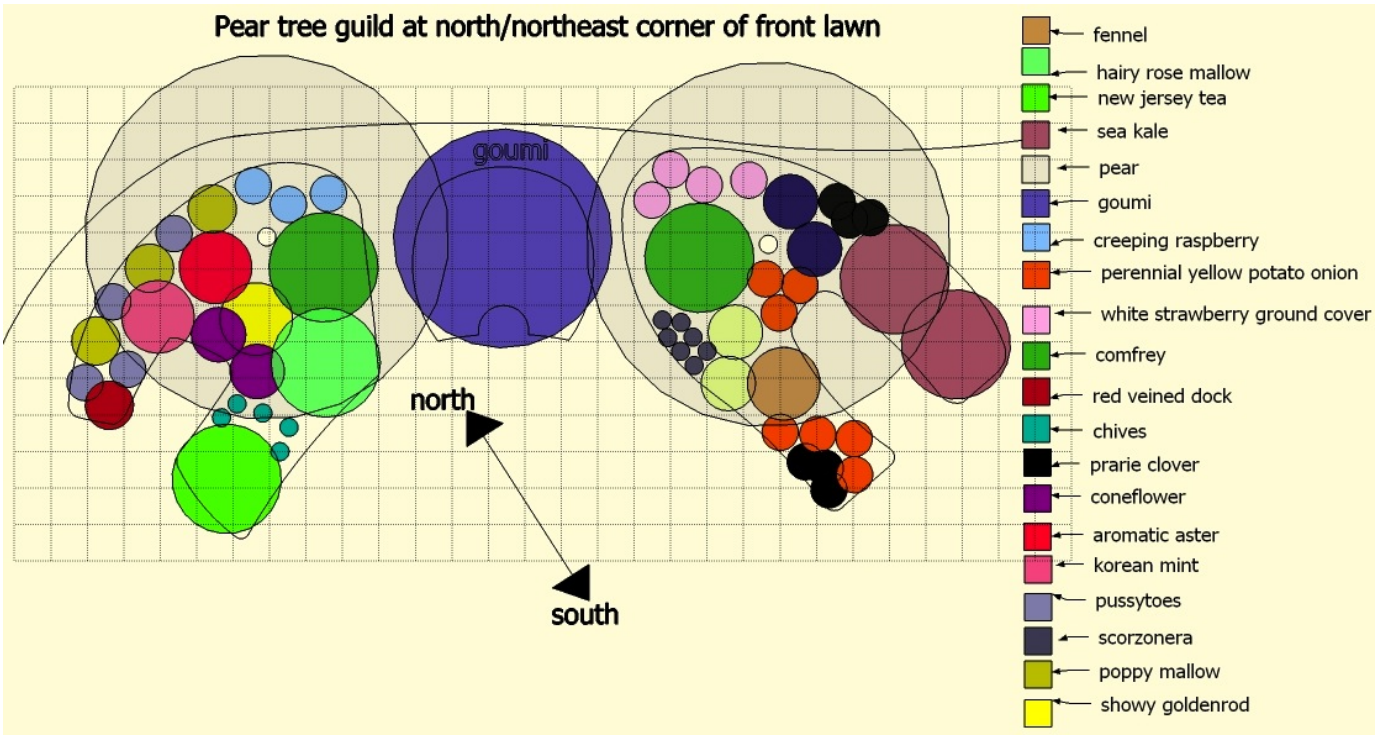

Fig. 1. An example plant guild by Michaelann Velicky. Source: http://elkinsparkfarm.wordpress.com/2011/09/20/pear-tree-guild-debut/ The key species is the pear tree, of which there are two. Mint, chives, strawberry, raspberry, goumi, kale, and fennel are used culinarily. Various parts of strawberry, clover, mint, scorzonera, fennel, New Jersey tea, and purple coneflower can be used for teas. Plants that provide nutrients to the guild include comfrey, clovers, chives, New Jersey tea, goumi, and wild strawberry. Fennel, chives, and mint are used as pest deterrents. New jersey tea, goumi, raspberry, and strawberry attract wildlife, where these in addition to aster and purple coneflower attract pollinators of fruiting plants.

domestic plant guilds which, in turn, will empower a simple, sustainable lifestyle.

III. Requirements Gathering in the Field

The first author is actively engaging in a longterm ethnography of transition networks, specifically those that practice permaculture. During the fall of 2011, the first author began her participant observation by completing a 9 week, 72 hour Permaculture Design Course (PDC) certified by the Green Education Center[2] and Simple Living Institute[3]. It was in discussions of learning curves and hardships of transitioning to sustainable living that the concept of the PGC came to light. Through the spring of 2012, she continued her observation at the Econ Farm in Orlando, Florida, sharpening her knowledge of plant guilds and other sustainable human systems. For designing the PGC, she consulted the Education Director and then Garden Manager (second author) at the University of Central Florida Arboretum [4], and three community permaculture experts, all of whom are well versed in plant guilds and the cultivation of plants for food, medicine, and other materials. In Fall 2012 the first and second authors continued the field research at a private residence in Winter Park, FL, installing a plant guild of tropical fruit trees, shrubs, and ground covers. In the Winter of 2013, the first author relocated to Southern California to compare and contrast plant guild design between the two drastically different locations.

A. Interview Series

From expert interviews in Florida, five in total, we have come to the conclusion that the user experience design of the PGC dictates the tool's ability to effectively model and assist the design of a plant guild. Identifying and placing plants in a functional arrangement is difficult for non-experts. They also do not have the skills necessary to acquire environmental information (e.g., soil type, sun patterns, points of erosion, etc.) or the means to implement such a complex design. Due to plant guild implementation constraints (e.g., budget and time), the experience of creating it, beyond the interaction with the PGC, must be considered in the tool's user experience design and how it models and simulates a domestic plant guild.

B. Central Requirements by Permaculture Designers

From the results of our ongoing field study, we've established the following set of requirements for the design of the PGC. We have generalized these requirements because we feel future applications that aide in the construction of a sustainable human system (i.e., an environmentally beneficial system established with the intent to support some human need) may encounter similar design challenges.

[2]http://www.greeneducationcenter.com/
[3]http://www.simplelivinginstitute.org/
[4]http://arboretum.ucf.edu/

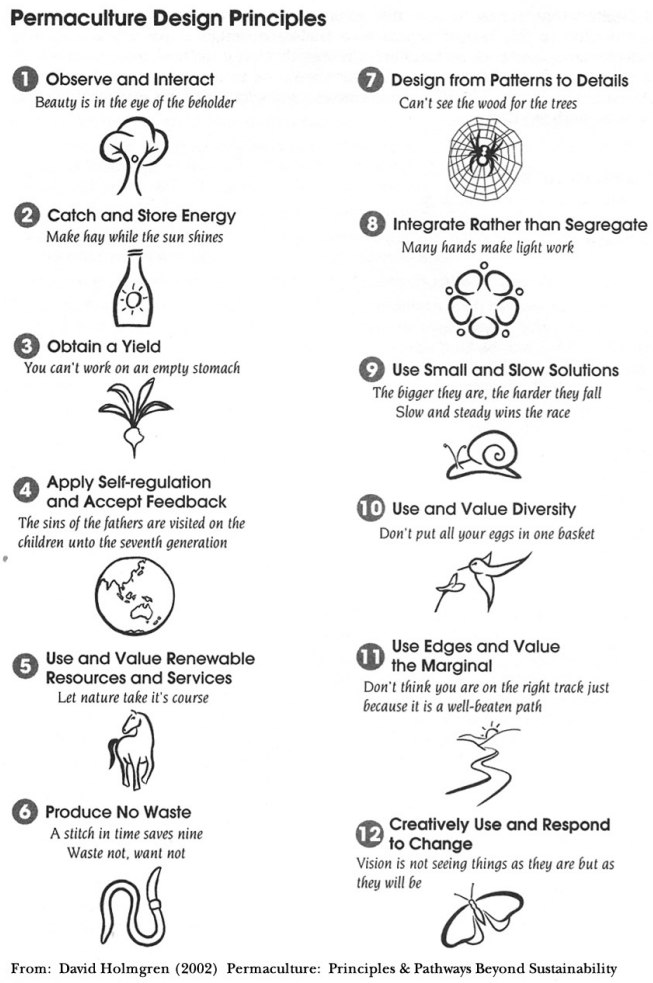

Fig. 2. Permaculture Design Principles after [5].

1) Use ecocentric and anthropocentric metrics to qualify the designed human system as sustainable: The qualifying metrics will ensure that humans' needs are supported in addition to the plants'. These metrics may include, but are not limited to: benefit and utility to the human, protection of the native ecosystems, and soil fertility restoration. The designs produced via the application must qualify as sustainable to alleviate the problems contributing to environmental detriment.

2) Identify environmental data required to design the most efficient sustainable system: These requirements include data only available to experts or acquired by professional technology. Given all the necessary environmental data, the application should enable the user to produce a sustainable human system design optimized for the intended environment.

3) Design to condense the time the user spends with the application relative to the entire process of creating the sustainable human system: The user's existing knowledge of the system and receptiveness of the lifestyle change are key factors in the time they're willing to spend in the design process. To determine an appropriate amount of time spent using the system an upper-bound may be found by observing potential users who are highly motivated to make the sustainable lifestyle transition, and a lower-bound may be found by observing those who are resistant.

4) Provide the user with the information they need to implement the design and utilize the system: The application should be incorporated into a complete system construction program, whether it is computerized or teacher-guided, so that the system is installed and utilized. Such a program should take into account the directly related socioeconomic concerns of the user in the application design, an implication for design established in [4].

5) Maximize both sustainability and convenience: Maximizing both sustainability of the designed human system and user convenience in designing and implementing the system is key for creating effective software in this domain. The convenience metric is dictated by the amount of work the user is willing to do, and will vary depending on user expertise. Systems that focus only on convenience are frequently unsustainable (e.g., plastic plates and utensils so the 1950's housewife doesn't have to wash dishes after a party). Conversely, systems that prioritize the sustainability of the designed human system may be too difficult for non-experts to use without an intensive time commitment to learning.

6) Require users to provide easily observable environmental data, but use experts and power users to fill in information gaps: Typical users should provide the system with easily observable information so that they become better acquainted with their environment. Experts and power users (i.e., non-expert self-motivated users) will likely put forth more effort than average users to provide the system with detailed information. This information should be catalogued and used to infer necessary environmental information not provided by average users (see [12] for an example) and to optimize future designs created by the sustainable human system design application.

These generalized design requirements, intended to enable simple transitions to a convenient, more sustainable lifestyle, are geared towards small-scale sustainable human systems (i.e., for families or communities versus regions or countries).

IV. Requirements Documentation

After the first set of interviews and the first data collection sessions of the ongoing field study, we used an artifact-based approach to consolidate the gathered information. The requirements artifact model is based upon earlier work by [6] and [10].

The figures provide an overview of the stakeholder model, the goal model, the context and system vision, and the constraints.

A. Stakeholder Model

The stakeholder model (Fig. 3) depicts the organizational and constraining units like the housing authority and the local government, the research environment with the university, the advisor and the developers, as well as the future users and customers for the system.

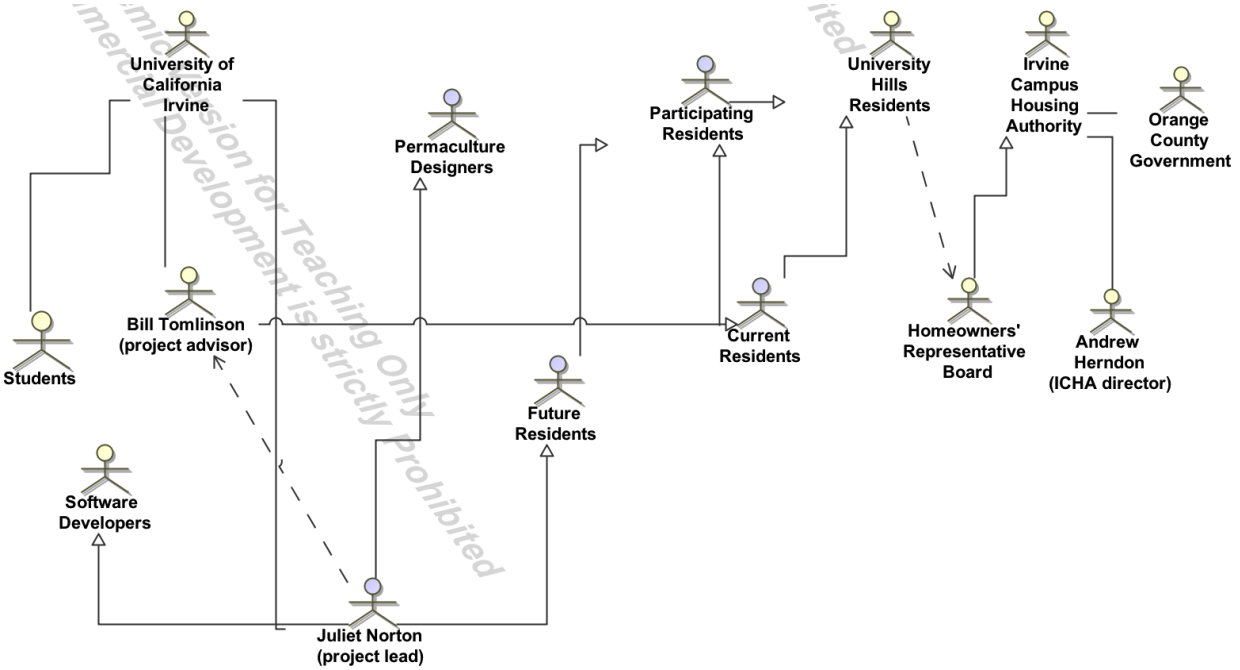

Fig. 3. Overview of the Stakeholder Model

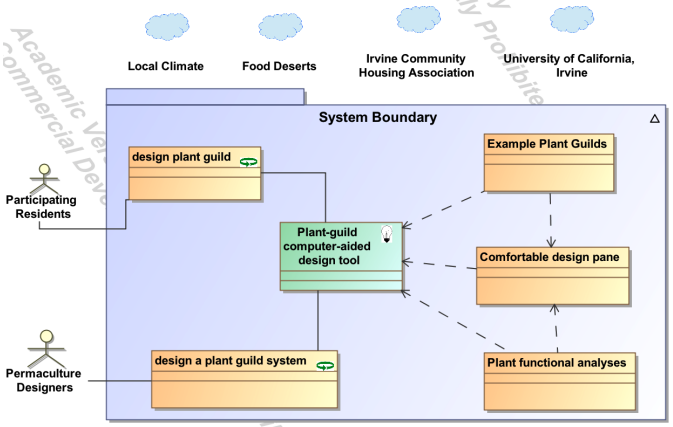

Fig. 5. Overview of the Context and System Vision

B. Goal Model

The goal model (Fig. 4) provides an overview of objectives and goals for the system. There are three types of goals: business goals depicted in purple, left side of Fig. 4, usage goals in green, top-right of Fig. 4, and system goals in red, on the lower right side of Fig. 4.

C. Context and System Vision

The context and system vision (Fig. 5) give an overview of the most important elements of the business and operational context of the system as well as the core features of the Plant Guild Composer.

D. Constraints

The constraints (Fig. 6) provide the most important restrictions by the rules of the local housing authority that have to be adhered to and influence the design of the plant guilds. These have to be taken into account for design constraints during the modeling of use cases and scenarios.

E. Further Development

These models and further artifacts will be extended over the duration of the ongoing field study and the design of the system.

V. Plant Guild Composer - A Vision

Long before you sat down on the bamboo bench in your backyard, you faced the challenge of creating the plant guild. When you decided to transition to a simple, sustainable lifestyle you weren't sure where to start. Then you were introduced to the Plant Guild Composer, the app that helps you grow a self-sustaining garden. The steep expense of purchasing fresh food, and the deaths of your late potted plants, motivated you to give plant guilds a try.

A. Location Requirements

The application first asked for your address. Once entered, a diagram of your lot containing your house's location was presented. It then asked you to confirm or edit the diagram. You went outside and walked around the house to make sure the PGC didn't miss anything, and spotted the utility connections under the Live Oak canopy in the front yard. At this time you also took note of high and low-lying areas, points of erosion, and soil properties. After you completed your property's diagram, the program asked for your priorities:

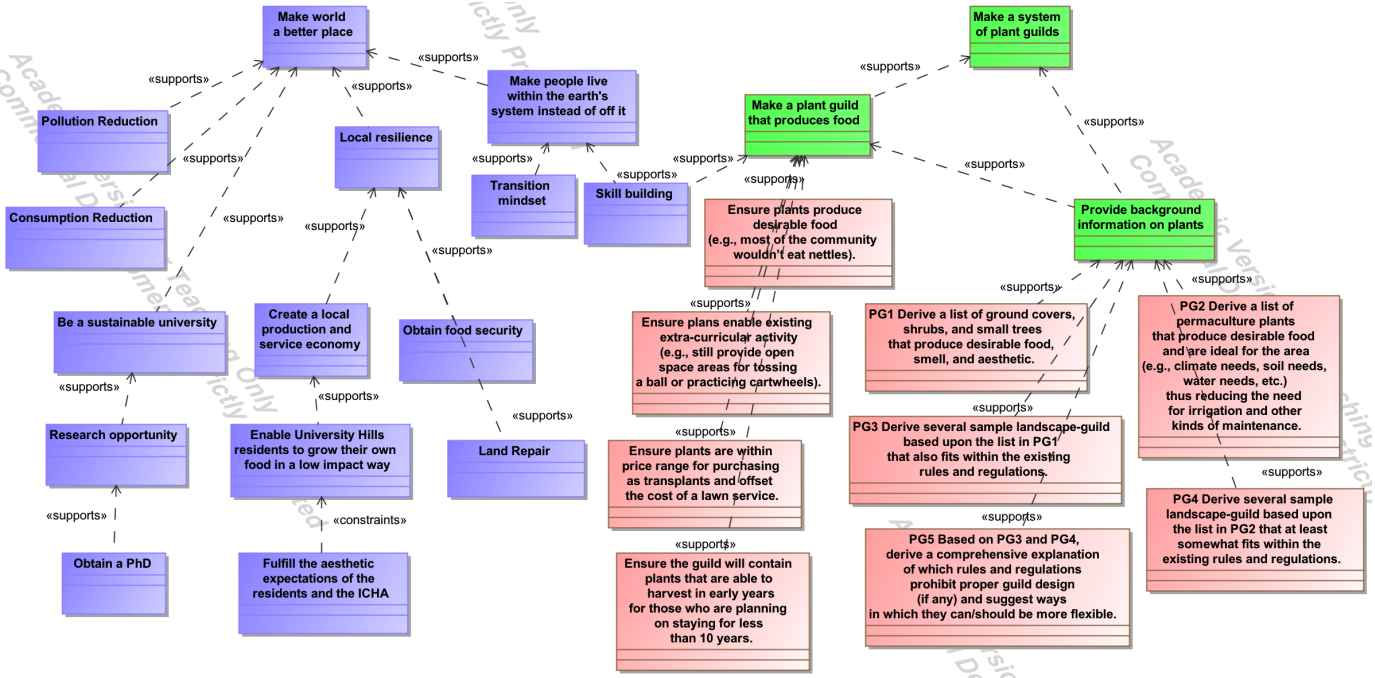

Fig. 4. Overview of the Goal Model

food, natural medicine, building materials, household items, wildlife sightings, environmental restoration. You chose food as the primary function and decided that growing building materials and household items would also be useful on site. Then you specified cost of implementation in terms of time, money, and resources.

B. Plant Guild Requirements

From there you specified your primary food requirements from a generated list of plants that grow in your climate and location. First, you investigated the fruits and noticed a native variety of persimmon, a fruit you used to buy. When you chose to include the persimmon tree, a simulation showed where it could be planted on your property. The PGC displayed suggestions for plants, relative to your goals, that could provide the persimmon tree with its needs. It took into account that your soil was alkaline (pH) and persimmon prefers a neutral range. The PGC suggested perennial peanut, a low-growing legume that makes nitrogen more available for the persimmon. While you continued choosing plants based upon the PGC's suggestions, the simulation continued updating in size, arrangement, and location. You realized you had wanted to include another plant. It was no longer eligible and the system told you why (too expensive, not compatible with guild optimal location), so you removed some plants that were less important to add it instead. You proceeded with this until the guild reached a closed system, (i.e., each guild member's needs is supported by the other members and the environment) and your desires were met.

C. Result: Design Layout

Once the design was finalized, the PGC produced the guild layout and location in your yard, the places to obtain the plants, tools, and compost within your budget, and instructions on how to implement the guild. Two weekends later a mound with thirty young plants setting root was in your backyard. It had only taken you one morning to get the free municipal compost, a day to acquire the plants and about 2 hours to put them in the ground with two friends. You watered the guild a couple times a week at first, then about once a week when they started really growing, until you found they no longer needed watering. In a few weeks fresh herbs spiced your dinner, in one season the fragrance of flowers was in the air, and shortly after your first crops were harvested. Now, less than a year later, you obtain most of your food, and even some building materials and cleaning supplies, from your backyard. You don't worry about going to the store in rush hour traffic or minimizing expenses so you can eat healthy. Life really did become simpler with the domestic plant guild.

VI. Discussion

Our PGC vision is an example of an application designed with a balance of user convenience, awareness of user role, and environmental sustainability.

A. Reduction of Complexity

We believe that the PGC has the potential to reduce the complexity of transitioning from our modern, complex, consumer lifestyle to one that is simple and sustainable. We described how the transition to a simple, sustainable lifestyle can be obstructed by up front complexity with the Domestic

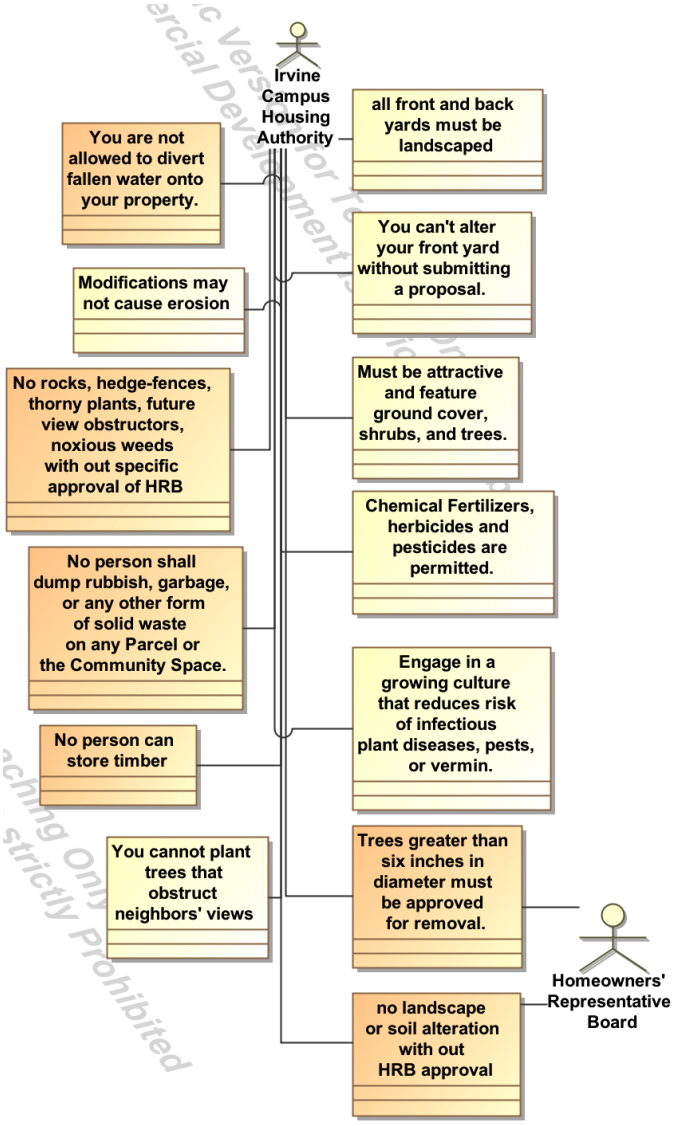

Fig. 6. Overview of the Constraints

Plant Guild example. We believe there are many human sustainable systems, especially in permaculture, that also have this complexity challenge.

Designing earthworks for water collection requires intimate knowledge of natural water flow through land. Building an off-the-grid house requires extensive knowledge of the many ways energy can be produced. We've suggested masking the complexity by finding the point of greatest convenience that still produces a sustainable system. We believe the RE community should be researching how to enable people to utilize sustainable human systems without being bogged down by the complexity of learning how to get started; it is a contribution RE can provide in the world's movement towards simple, sustainable living.

B. Conveying Sufficient Knowledge

Our vision and requirements feature the idea of reducing complexities to the threshold where users still have the opportunity to learn at a higher, more leisurely level. We also believe that by removing all the complexities, the user wouldn't have the opportunity to understand, utilize, and appreciate the support the system provides (i.e., awareness of user role). We feel that the awareness challenge complements the convenience challenge and that a single solution can be found for both, although it will vary for each sustainable human system.

C. Providing Access

Accessibility to information is key in achieving the balance of convenience, awareness, and sustainability. It is essential to explore ways to gather information that can't be acquired from public resources and are too complicated for average users to acquire. Methods that should be researched include: gathering and analyzing information produced by experts and power users into designs, using mobile technologies to aid the user in a more detailed analysis of the environment, and unconventionally utilizing common household items to indicate otherwise elusive properties of the environment.

VII. Conclusion

In this paper we described the need to develop technologies that enable people to transition into a simple, sustainable lifestyle. We introduced the concept of a domestic plant guild to show how sustainable human systems can effectively support such a lifestyle. We presented a series of requirements for building the Plant Guild Composer, a tool to develop plant guilds.

The requirements suggest the incorporation of requirements analysis techniques to reduce the complexities associated with its creation. Without these techniques, the Plant Guild Composer would only be usable by permaculture and horticulture experts. We feel that this research area needs further exploration and that our requirements could be applied to tools that support a user's journey towards a simple, sustainable lifestyle.

Future Work

Right now we are working on the first prototypes of the Plant Guild Composer. A screenshot is provided in Figure 7.

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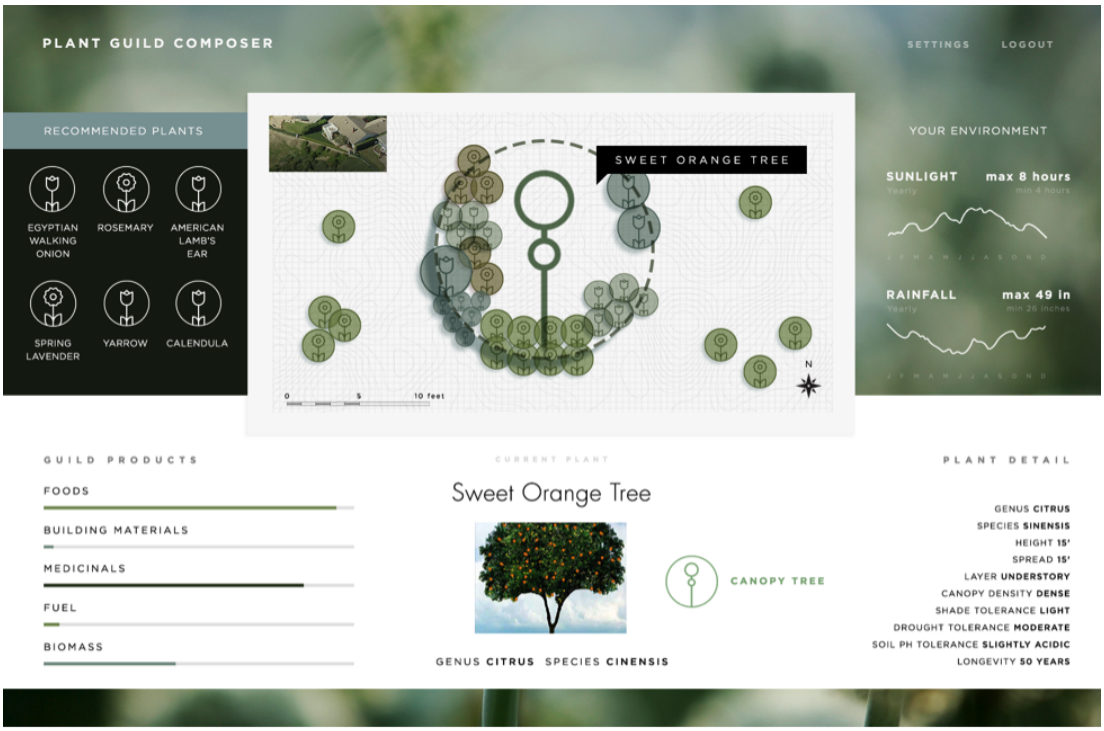

Fig. 7. Screenshot of a Prototype of the Plant Guild Composer

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