Green Primer

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Project Overview

Introduction

Green Primer designs efficient houses. Users use Green Primer through an online interface which allows them to draw out a floor plan for their house. During this process, Green Primer issues warnings and suggestions to help users design a greener house.

Green Primer also provides simulation tools to help evaluate the air flow and ventilation within the building, as well as material analysis tools to help people pick the best building materials, within budget, dependent upon climate zone and other factors.

Audience

Green Primer targets the average American layman considering building a house. Because Green Primer's simulations are not 100% accurate, and because Green Primer works in a two dimensional environment, Green Primer's design does not suit professional architects. Rather, Green Primer serves as a wonderful drafting and initial analysis tool, helping prod consumers in the right direction before they send their plans to architects.

Green Primer is a web tool, which allows users to access Green Primer from any computer with internet access. This ensures compatibility between computers and provides an easy way for users to share their files with architects. At the moment, Green Primer documents are not exportable, but this functionality may be added in the future.

Rationale

The environment finds itself in the forefront of the public eye as humans have realized that saving their planet is essential for the survival of the species. When most people think about the environmental crisis that we face, they think about environmental disasters or coal plants or the transportation problem. What most people don't know is that buildings make up 70% of all electricity use, 55% of all natural gas use, and 39% of all carbon emissions in the United States. With these figures in mind it becomes obvious that energy efficient building

designs are essential for the survival of the species.

Furthermore, recent laws in the United States require that buildings be built to more and more stringent energy standards. Green Primer knows these energy standards, and will ensure that your building meets them, no matter where in the country you build it.

Building efficient houses is a critical mission for humanity, and Green Primer helps people do that. If you tell Green Primer the budget for and location of a building, Green Primer will calculate the most efficient bundle of construction materials that you can use within budget. Green Primer will also calculate the least-cost bundles of materials that are required to meet differing energy standards, and tell you how much more it would cost (or how much money you would save) by switching to an energy standard from the maximum-efficiency case.

Furthermore, building an efficient house is no easy task. Efficient houses have tightly controlled ventilation systems, and green builders need to keep air flow in mind to make sure that certain corners of the house do not get too moldy, too drafty; too warm or too cold. In order to assist in this fashion, Green Primer provides a fluid flow simulator that allows buildings to place vents and then see how the air flows throughout their house.

The Future

Green Primer is fully functional, but there are many more features it will implement after initial release, including local storage abilities, file sharing and exporting features, the inclusion of more cost and material data, the inclusion of more energy standards, and much more functionality within houses. At the moment, Green Primer allows builders to control the placement of walls, windows, doors, and vents. In the future, stairs, furniture, and other objects may also be included and will affect the air flow simulations used by Green Primer to help build more efficient houses.

Technical Design

Green Primer is, like all strong software projects, built upon the foundations laid by many other powerful tools. Green Primer uses these tools to build a rich user interface that provides constant feedback and simulations in order to nudge users towards greener houses.

Technologies Used

Green Primer was developed (and resides) on github, using the git version control system for development.

Green Primer initially sat upon Node.js, a ECMAScript-only event driven server. As Green Primer grew in size and began to serve hundreds of different files to individual pages, a more sophisticated packaging and versioning system was needed on the server side. At this point, Green Primer switched to Django with the generate_media plugin. Django is also used for its object relational mapper which manipulates the costing data used in the material calculations.

Client-side ECMAScript code makes heavy use of the jQuery library for manipulation of the document object manager (DOM) on client-side pages. jQuery UI was used to assist many user interface animations.

The building layout is drawn using the scalable vector graphics (SVG) standard, a newly-supported standard amongst many web browsers. The ECMAScript library Raphaël is used for creation and manipulation of SVG objects.

The fluid dynamic simulations are done using HTML5 Canvas, an even younger web technology. The physics simulations required for the fluid dynamics are done using the ECMAScript Box2Djs library.

Various other minor tools and utilities are used with Green Primer. Most notable among them is HISP, a special syntax that compiles to HTML developed for the express purpose of Green Primer after problems posed by the HAML templating language.

User Interface

The user interface is one of the largest components designed specifically for Green Primer. While no particular part of the user interface required particularly difficult implementation, the entirety of the user interface as a whole required addressing innumerable tiny issues. The result is a solid and versatile system for drawing line-based objects on a canvas. While Green Primer uses this system to draw building layouts, attaching things like windows, doors, and vents, others could easily use this same system for drawing any other line-based diagrams.

The Green Primer user interface was designed using a very modular system. It is simple to add new physical objects, and simpler still to add modes which control how the objects interact with each other. Green Primer keeps the internal logic separate from both objects and modes, to ensure that all objects and modes can interact with each other. Furthermore, Green Primer offers a universal "action stack", which makes adding actions to the undo/redo stack almost trivial.

Because of the modularity and flexibility of this user interface, it would be simple to take the Green Primer user interface and change it to make a system for, say, designing circuits or tracing routes or create any other line-base drawing tool. In fact, with only minor modifications, it would be possible to use the Green Primer user interface as the foundation for almost any SVG drawing tool.

Furthermore, Green Primer works hard to integrate the underlying HTML5 canvas with the SVG layer, allowing canvas objects (such as the fluid dynamic simulations) to appear to interact with the SVG objects (such as the walls and doors). Using this machinery, it is easy to create new objects that are static objects in the SVG but that interact with cool effects drawn on the canvas.

Fluid Dynamics

The fluid dynamic simulator provided by Green Primer required quite a bit of design and development. Initially, a pressure-preserving Navier-Stokes equation solver was envisioned. However, after much work it turned out that such a pressure-preserving solver would require

far too much computational complexity on an open system with arbitrarily-oriented objects, and was infeasible in the Green Primer system in real time.

A Lattice-Boltzmann equation solver was then considered, as were numerous other (potentially cell-based) methods. The arbitrary orientation of objects made the equations quite difficult to solve, and the openness of the environment made the problem even harder. As users are allowed to use the simulator before the design is complete, there is no way for Green Primer to guarantee that the system is closed before the simulation begins running, and no way for Green Primer to determine the difference between the outside and the inside.

The fluid simulation eventually degraded into a perfectly elastic ball bouncing simulation. Green Primer began developing an in-house physics engine for such simulations, but eventually decided not to re-invent the wheel and used the Box2Djs physics engine to do the fluid flow simulations that are part of the system today.

Graphical Analysis

Green Primer does some fairly intense graphical analysis in order to make suggestions and preform calculations. These calculations are all fairly well known problems with studied solutions, but many are difficult to implement and have never been publicly implemented in ECMAScript. Furthermore, while many are apparently easily solved, many of these graphical analysis problems have corner cases and edge cases that require quite a bit of extra thought.

For example, Green Primer has to calculate the amount of floor area taken by a building design. This may seem easy, except that the building design can be an arbitrary-length polygon. Finding the area requires finding the outside walls and then breaking the polygon into pieces that are easier to sum. This isn't difficult in it's own right, until you consider the possibility that users attempt to do a calculation before the outside walls are finished. If the outside walls aren't closed, or if they cross other outside walls, or if they are disjoint, there are many potential issues with analyzing the graphs generated by the walls.

Green Primer also runs disjoint graph tests to detect disjoint walls, which is actually a fairly simple graph operation and is not made unduly complex due to edge cases.

Data Analysis

Green Primer makes use of data offered by the National Institute of Standards and Technology in order to make a material analysis of buildings designed by the user. Green Primer uses American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) data concerning climate zones and building requirements across different energy standards, as well as data owned by the Reeds Construction company concerning pricing of different types of materials. The Reeds Construction data is privately owned and can not be used in a public setting nor be revealed to the public, so the process of getting the data for use by Green Primer was arduous.

Aside from the legal and logistical hurdles that Green Primer faced, Green Primer also needed to ensure both security and obscurity of the data once it was received. Furthermore, only a small subset of the data can actually be used, and a lot of the data that is used by Green Primer is calculated from extended calculations done in private. The numbers that Green Primer uses are useful and correct, but they are derived from RSMeans number and the original numbers can not be derived from the ones that Green Primer uses. Identifying what data was necessary and how to calculate it from the original data was another task that required both logistical and legal solutions.

Even once Green Primer had control of the data, the calculations to be done were not necessarily easy. Green Primer must find the optimal combination of materials within a budget, and finding such a solution is an NP complete problem. Fortunately, Green Primer could start with some good guesses from the ASHRAE energy standards and work from there. Also, thanks to the limited data, Green Primer did not have too many possibilities to search. However, as Green Primer adds more data types to the calculations, and as the budget exceeds what is necessary to meet the highest energy standard, more and more calculations are required to find the best combination of materials for a building.

Dynamic Feedback

Green Primer provides dynamic feedback as users build their house. This requires Green Primer to have a good working knowledge of what it takes to make a house more

energy efficient. In order to do this, Green Primer focuses on the "building envelope", ensuring that the exterior walls of the house can contain only insulation, wall joists, windows, and doors.

When making a house more energy efficient, the first thing that one must do is create a solid "building envelope", or seal. By sealing all tiny holes in the house and ensuring strong insulation, air flow in and out of the house is heavily regulated. This reduces heat loss and means that the internal environment can be heavily controlled.

Sealing a house alone can reduce energy emissions up to 20%. Controlling the interval environment allows the downsizing of Heating, Air Conditioning, and Ventilation (HVAC) systems. As HVAC systems are a huge portion of energy use in a house, the combined effects of sealing a house and reducing the HVAC systems can lead to a 50-80% decrease in the energy use of a house.

Green Primer's real-time warnings and suggestions are geared towards ensuring that the house can be adequately sealed. This means that Green Primer issues warnings and suggestions any time that it feels the user might be tempted to run ventilation systems, plumbing, or electrical systems through the outer walls of the house. Running anything through the outer walls of the house can break the building envelope, and severely reduces building energy efficiency.

Project History

The development of Green Primer began, conceptually, in August of 2010. Green Primer was first released in April of 2011.

Timeline

Green Primer spent a lot of time in the planning stage, between August and September of 2010. Initial development began in early October.

The first stage of Green Primer's development was the acquisition and testing of various technologies. Raphaël, Node.js, jQuery, and many other technologies were tested and integrated before the development of Green Primer was begun.

When development of Green Primer proper began, the first few months were spent designing the user interface. A demo version was completed in early December, 2010. This version successfully integrated SVG and Canvas, but was messy and not as powerful as desired. Using the knowledge gained by creating the first interface, the interface was scrapped and reimplemented. By early January 2011, the interface was essentially completed and close to it's final form. During the same time period, the Navier-Stokes simulator was worked on and eventually abandoned.

As the user interface grew in size, ad-hoc bundling and caching techniques were used with more and more frequency. Corresponding with the re-implementation of the interface, Green Primer began the switch to Django and the generate_media plugin to address this problem.

Throughout this entire process, negotiations were being made with NIST to acquire RSMeans costing data.

Once the interface was complete, the next essential component was the fluid dynamic simulator. This took quite a bit of work before an established ECMAScript physics simulator was settled upon, in late February 2011.

At that point in time, work began on the graphical analyzer, as well as on adding more

and more minor features to the user interface.

By early March 2011, Green Primer had acquired all the data that it would get from the Reeds Construction company, and began developing the data analysis tools. These were completed by late March, 2011.

After that, all that remained was testing and polish.

Challenges

The creation of Green Primer provided many challenges in many different domains. Addressing each of the challenges required very different approaches, but each had their own lessons to teach.

From a legal standpoint, acquiring the Reeds Construction costing data was one of the most difficult challenges of the project.

From a legal standpoint, the largest challenge was the fluid dynamic simulator: however, while the path was difficult, a simple solution was settled upon in the end.

From a programming standpoint, the largest challenge was the creation of the user interface. Though no particular problem was difficult, the user interface comprised scores if not hundreds of tiny problems that needed to be addressed almost constantly.

From an algorithmic standpoint, finding the area of a potentially unfinished arbitrary polygon was the most difficult challenge.

Each of these challenges was unique and difficult to tackle.

Lessons

Green Primer taught me is how important it is to know your domain. I could not have developed Green Primer if I did not have intimate knowledge of how to make a house more energy efficient.

Green Primer taught me the nightmares of acquiring and using proprietary data. This was a harsh lesson, but a necessary lesson for any who want to serve people tools that

manipulate extensive and accurate data sets.

Green Primer taught me that the simple solution is often the best. After months of struggling with fluid dynamic simulators, a simple simulation on a physics engine turned out to be good enough.

Finally, Green Primer taught me how important a user interface is, and how hard it is to get one right. The nature of a user interface is that when it works you don't notice, but when it doesn't work it gets in the user's way. Having to iron out all of the minor bugs and details within a user interface while providing simple and clean functionality really taught me to respect a clean and well-designed user interface and the effect that it has on the users.

Speculation

All in all, Green Primer is a success. If I had the chance to do Green Primer all over again, much of it would remain the same. Obviously, many things would be done slightly differently from the start. I would use a simple physics simulation early on, and I would use Django from the get-go. However, there are no large features that I would have included at the expense of features that are already in the 1.0 release.

Green Primer turned out to be a useful tool, both powerful and simple. Of that I am very proud.

That said, there are many things that Green Primer should add in the future. It should take more advantage of it's internet roots, providing the ability to share houses, duplicate houses, or provide baseline templates. It should export files to common architecture formats. It should support more energy standards, and it should differentiate not just by ASHRAE climate zones but by individual counties. Above all, Green Primer should use more material and costing data, if any can ever be acquired.

However, at the moment, Green Primer is fully operational and quite a powerful tool. As we know from the statistics above, buildings are an essential component of reducing national energy consumption. Green Primer assists that endeavor, and thus the betterment of humankind – and as such, I am very proud to have created this tool.