Workflow for Mapping Fuzzy Clusters of Genes to Biological Pathways

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ABSTRACT

A new fuzzy clustering algorithm was developed to identify relationships between fuzzy cluster of genes and biological pathways, and the result is promising. With new relationships identified using this algorithm, there emerges a need for a workflow to relate the fuzzy gene clusters to pathways. We designed software that implements the required workflow. We validated the software with the information obtained from the KEGG database. The software is able to identify and reveal relationships between un-annotated genes and pathways.

Keywords

Clustering algorithm, Fuzzy logic, Bioinformatics, Gene Ontology

1. INTRODUCTION

Scientists today have sequenced the entire human genome, however roles played by the various genes are not well understood yet. The study of the human genome involves a tremendous amount of data and computers are used to perform the required data mining and extensive computational analysis. Biological pathways are a sequence of enzymatic reactions by which one biological material is converted to another. They capture the role genes play in biochemical reactions that help sustain life. For example, over 10 enzymes mapped to specific genes play a role in the Glycolysis Pathway to help convert glucose into pyruvate [1]. The goal of biological research in pathways is to develop a library of pathways for all biological processes that manifests in all living organisms. There is a direct and an important relationship between genes and pathways.

There are bioinformatics databases used by biologists to store and share biological information. These databases contain raw information collected from past experimental results and analysis. They provide descriptive genomics, gene annotations, modeling and simulation of biological data in addition to millions of scientific publications [2]. Most of these databases have web interfaces to search for data. Examples of these databases are the NIH's National Center for Biotechnology Information (NCBI), the European Molecular Biology Laboratory (EMBL) and EXPASY Swiss Institute of Bioinformatics. Scientists rely on these databases to obtain certain information needed to perform scientific experiments.

Identifying genes in biological pathways is an important instrument for early disease detection and diagnosis [3]. They provide clues about what went wrong when disease strikes. Determining the relationship between gene expression data and biological pathway maps is a challenging task. Often, clustering algorithms are used as the first step. With a clustering algorithm, genes are grouped together based on certain common characteristics that they share in common, revealed from the use of explorative computational analysis. Wide ranges of clustering algorithms have been proposed to analyze gene expression data. Various methods have been applied such as hierarchical clustering, self organizing maps, K-Means algorithms, and more recently, graph analysis by biclustering [4]. However, gene clustering results are pure analytical, they are seldom related to existing biological knowledge such as biological pathways.

Research has shown that most crisp clustering algorithms were unable to identify genes whose expression is similar to multiple, distinct gene groups. However, fuzzy clustering method is able to identify clusters of genes that were not identified by other hierarchical or standard k-means clustering [4]. As a result, a new demand has emerged to map the fuzzy cluster genes to biological pathways. Currently, different pathway mapping tools are available for annotation and visualization of collections of genes. What lacked is a tool that allows the mapping of genes with fuzzy membership to biological pathways. In order to mitigate the problem, we propose a new workflow as well as its software implementation to integrate the fuzzy genes with existing gene oncology, map the relationships to pathway maps, and annotate previously non-annotated genes.

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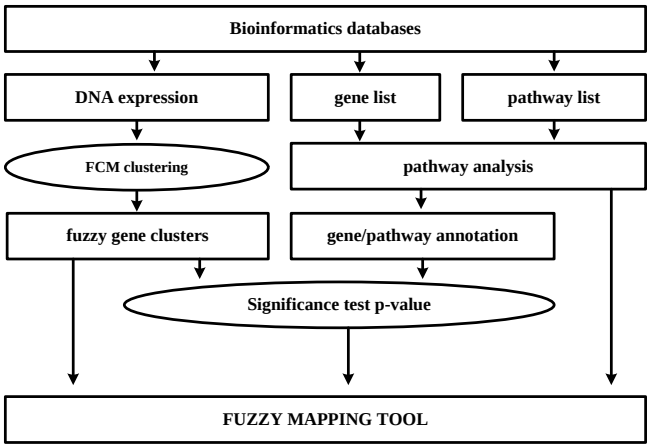

Figure 1. Data flow

As Figure 1 illustrates, three datasets are used in the workflow of mapping/annotating the fuzzy clusters of genes to biological pathways. Using gene expression microarray data, a fuzzy c-means clustering algorithm is applied to produce fuzzy clusters of genes [5]. To each gene in the fuzzy cluster, a membership value is apportioned on the basis of similarity between the gene's expression pattern and that of each cluster centroid [5]. A gene has a total membership value of 1.0 across the cluster centroids and each gene's membership value indicates it's proximity to the centroid. As Figure 2 indicates, gene's fuzzy cluster values are used together with gene's pathway annotation to determine a pathway's proximity to clusters. A hypergeometric

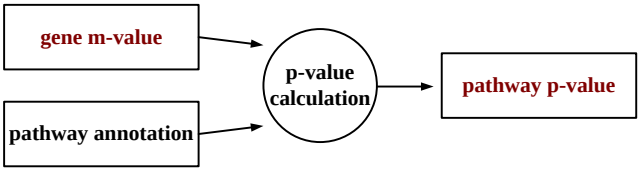

Figure 2. P-value calculation

probability is calculated to determine the significance of a relation between a fuzzy cluster and a pathway [6]. The lower the p-value, the higher a pathway's believability to the cluster is. Often, a value of 0.05 is chosen.

To implement the workflow, we have designed an application that maps a fuzzy cluster of genes to pathway based on a gene's fuzzy membership and the pathway's p-value. The application allows user to identify cluster and set value thresholds to cluster genes and cluster pathways. Having such tool provides an advantage in gene identification to biological pathways.

2. A MAPPING TOOL

Architecture of the application consists of three components: Cluster Data Uploader (CDU), Cluster Data Processor (CDP) and Cluster Data Analyzer (CDA). The application interfaces with users via web browsers. Java Servlets and jsp pages are utilized. Apache Derby is used to build, store and query biological data from local server. System can remotely utilize the KEGG database to obtain bioinformatics data.

To identify non-annotated gene, the application requires the three datasets to initialize. These are a) gene clusters with fuzzy memberships, b) pathways with p-value and c) pathway annotation data that indicates annotated relationship between genes and pathways.

2.1 Cluster Data Uploader

The task of the CDU is to allow users to upload data into the system. Using a loader object, CDP assists user to control and manage the two objects. The Loader object prompts user to upload three files in sequential orders. User will browse and selects the files to upload for local file holders. The loader will establish an input stream to the files and transfer the data into a local buffer. After successfully uploading the three files, the loader object will verify and validate the data uploaded. Each file will be assigned a batch id to associate the three files and allow additional clusters to be uploaded.

A user may analyze multiple gene clusters derived using multiple algorithms.

2.2 Cluster Data Processor

The CDP is used to process, update and maintain biological data stored in local tables. It manages and controls an XML Parser and a Remote Reader Object. The XML parser reads a System Biology Markup Languages (SBML) from bioinformatics databases. SBML is machine readable language based on an XML format representing models of biological processes [7]. Bioinformatics data are also available in other machine reading formats such as text files. The CDP's Remote Reader makes an ftp connection with remote bioinformatics servers to read and store bioinformatics data. Biologists update these databases by regularly modifying and adding new information. The mapping application will routinely seek updated information from the servers. One commonly used bioinformatics database is KEGG [1]. The KEGG Pathway database provides collection of metabolic pathway annotation classified in GO terms [8], with information describing the biological interactions and the interacting compounds in the activity. Pathway data obtained from KEGG database is used in this experiment.

The CDP's table builder reads and validates uploaded cluster files as well as raw biological data obtained from remote databases. It does this by parsing the files from local server and creating relational tables. Figure 3 illustrates the relationship between the data sets. If unable to build the required relational table, the builder will not validate the upload. Each table is unique to a user session and the files are assigned with batch identifiers. Each batch will have three files. For each batch and gene to pathway relationship data, there is a file that describes a gene's relationship to the cluster (fuzzy membership value) and another file that describes pathways relationship to the cluster (p-value). The table builder will enforce these constraints. If all files are uploaded successfully, the application will issue a confirmation batch id. This batch id can be used to reference uploaded clusters for future use.

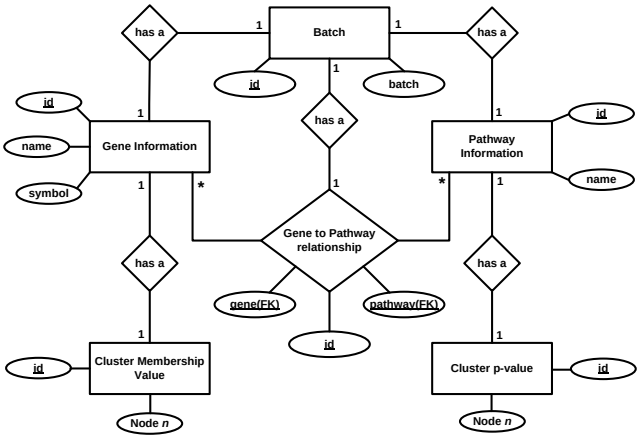

Figure 3. ER diagram depicting relationship among the datasets

2.3 Cluster Data Analyzer

The CDA component of the application will provide resources for user to execute the required workflow and perform analysis on the fuzzy clusters. It provides tools for user to select a set of clusters from uploaded cluster datasets. The application also provides a tool to enter threshold values to extract genes from the fuzzy cluster set. Genes with membership value greater than a membership threshold and pathways with p-values less than a user entered value are selected and displayed. The CDA also builds an appropriate data structure to manage the selected data, and guide user through the steps needed to reveal fuzzy relationship between pathway and genes.

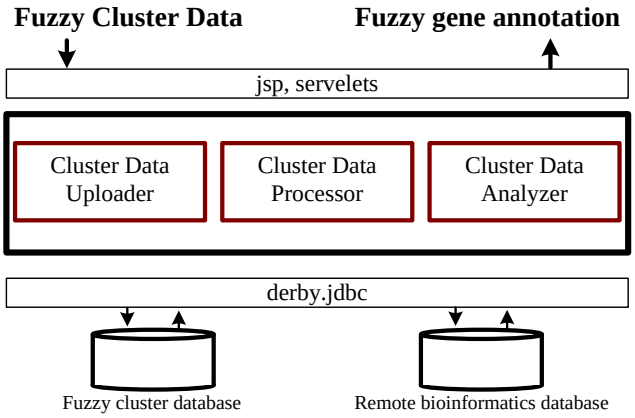

Figure 4. Basic application components

The CDA implements two classes, Table and Drawer. Table class provides primitives for the CDA to manipulate attributes of a cluster. Table may contain more than one Cluster class based on biologist's analysis needs. For this experiment one Cluster class is used. The Table class will interface with the database to request and process biological data for the cluster. The table class populates Cluster object with collection of genes and pathways that fall within user selected threshold value in the cluster. Each gene in gene collection has an array of pathway objects that it is related to according to KEGG's annotation. The cluster object also has a collection of pathways. Each pathway has a p-value that associates it to a fuzzy cluster. A pathway has a collection of genes that are active in its biological reactions. There is a many to many relationship between the cluster object's gene collection and pathway collection. Each gene object in the cluster has unique membership value.

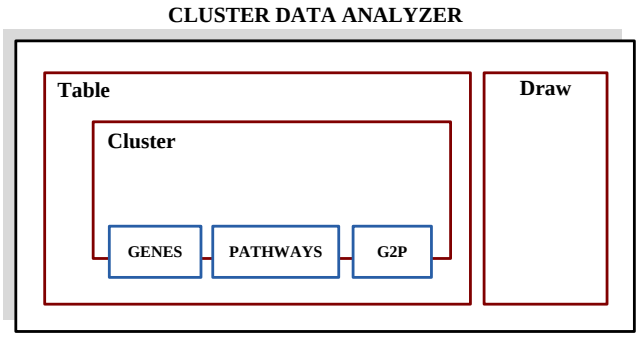

Figure 5. CDA components

In addition to gene and pathway collection, table's cluster object maintains a data structure that maintains the relationship between the gene and pathway objects. Figure 5 shows objects of the cluster. A gene may be identified to multiple pathways and a single pathway often consists of multiple genes. Using these three data structures, the cluster object facilitates the required workflow analytical functions.

The Draw object utilizes java applet to draw and annotate fuzzy genes to a pathway map. Information needed to draw the map is obtained from KEGG pathway database provided in KEGG Markup Language format (KGML). KGML format is an exchange format used for KEGG's pathway graph objects. KGML enables automatic drawing of KEGG pathways and provides facilities for computational analysis and modeling of protein networks and chemical networks [1]. CDP's XML parser described earlier will be used to parse KGML data.

3. VALIDATION

We validated the application using the datasets obtained from KEGG database. We collected a total of 605 genes and 126 pathway annotations. Based on the annotation, we found 1923 relationships between the genes and the pathway. A fuzzy c-means algorithm developed in-house was used to cluster 375 genes into 32 groups. P-values were computed for the 126 pathways based on hypergeometric distribution.

Table 1(c) Gene to pathway mappings

Gene symbol	Cluster 1	Cluster 2
PAPSS2	0.000898	0.000028
SULT1A2	0.004431	0.00038
GPD1	0.000699	0.000134

Table 1(a) Gene's fuzzy membership values.

Pathway	Cluster 1	Cluster 2
Anthocyanin_biosynthesis	0.000898	0.000028
Betalain_biosynthesis	0.004431	0.00038
Geraniol_degradation	0.000699	0.000134

Table 1(b) Pathway p-values

Gene	Pathway
ADH1A	1-_and_2-Methylnaphthalene_degradation
ADH1A	Drug_metabolism_-_cytochrome_P450
ADH1C	1-_and_2-Methylnaphthalene_degradation
CYP1A2	Androgen_and_estrogen_metabolism
YARS2	Aminoacyl-tRNA_biosynthesis

The application tool is initialized with fuzzy clusters of genes, pathway annotations and gene/pathway relationship datasets. The Uploader copied the files to a local folder, added a batch id to the file names and returned data validation with batch id. The application successfully created the tables for the uploaded data and displayed a cluster selection menu. The software application prompted user to select a cluster node from the uploaded files, enter a membership value and p-value thresholds for genes and pathways respectively (Figure 7).

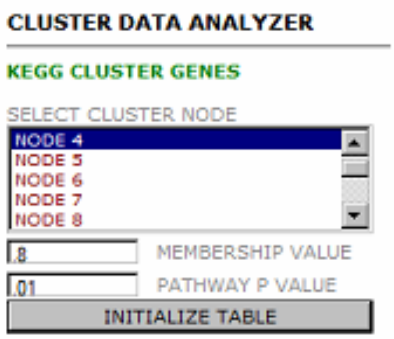

Figure 7. Cluster selection

We selected cluster 4 for our testing. First, we set the membership threshold value to 0.8 in order to extract genes that are close to the centroid with at least 80% similarity. Then, we entered 0.01 for p-value threshold to filter pathways that are significantly related to the fuzzy clusters. With these three inputs, the cluster data analyzer initialized the table and all the necessary application components. The System displayed the following list of genes and pathways that met our membership value and p-value criteria. See Table 2 below.

Table 2(a). List of genes that have fuzzy cluster membership value greater than 0.8

	Gene	membership value
1	GPD1	0.861694
2	PAPSS2	0.955509
3	SULT1A2	0.862279

Table 2(b). List of pathways that have fuzzy cluster probability value less than 0.01

	pathway	p-value
1	Sulfur Metabolism	0.0054757
2	Purine Metabolism	0.007608376

There is a relationship between the genes and pathways listed above. These genes have high similarity to the cluster centroid as indicated by their membership value. For example, gene PAPSS2 has 95% similarity to the centroid and is the closest from the other two genes listed. Table 2(b) lists pathways and their p-values to the cluster. Low p-value indicates high probability that the interacting genes and enzymes in the pathway have close affinity to cluster 4.

We chose gene PAPSS2 to view lists of pathways that it is annotated to (Figure 9). The two fuzzy cluster pathways listed in Table 2(b) are also listed as being annotated to gene PAPSS2.

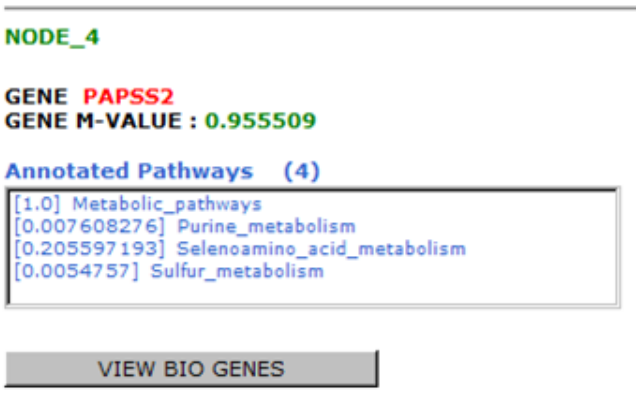

Figure 9. Annotated pathways for gene PAPSS2

This result confirms the effectiveness of the FCM Clustering algorithm; it successfully identified pathways that significantly related to a cluster as both pathways that the algorithm returned are already annotated to the gene. Since the two fuzzy pathways are already annotated to the gene, there is no new pathway in the fuzzy cluster pathway to which we may discover a new relationship.

Next, we selected gene GPD1 from our initial cluster result (Table 2(a)) to view its annotated pathways. The fuzzy mapping tool returned the following results as shown in Figure 10.

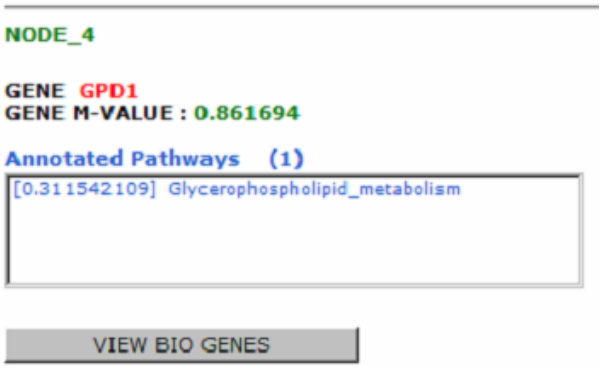

Figure 10. Pathway results for gene PAPSS2

As the figure shows, gene GPD1 is annotated to pathway Glycerophospholipid metabolism but Sulfur and Purine metabolism (table 2) pathways are not on the list. The fuzzy cluster algorithm has produced for us a gene with 0.8617 affinity to cluster 4 and two metabolic pathways with p-values less that 0.01. Given Dr. Zhang's hypothesis [4], there is a good chance that gene GPD1 is dangling somewhere inside the Sulfur or Purine pathway and is yet to be annotated. Thus, we selected the Sulfur metabolism pathway to display its map (Figure 11). Examining the map, a biologist sees relations between gene, proteins, and enzymes within Sulfur Metabolism pathway.

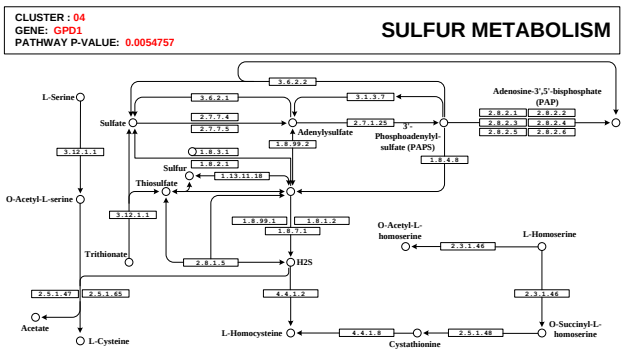

Figure 11. Sulfur Metabolism pathway map (KEGG).

5. CONCLUSION AND FUTURE WORK

We have successfully materialized a workflow for mapping fuzzy clusters of genes to the existing biological pathways. With the software application, we have isolated an un-annotated gene and mapped it to a metabolic pathway.

Bioinformatics databases contain large and complex informations. There is not a standard way of identifying biological pathways. The Gene Ontology project aims to create a uniform and standardized biological data naming process. Standardized naming protocol will help reduce the size of table currently needed to process bio-informations. Another functionality that needs study and implementation is to compare the fuzzy gene with other genes on the pathway map and estimate its location. This process can also be automated and integrated to function with mapping tools such as this.

ACKNOWLEDGMENTS

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Power or Portability? Creating a Connection Between Mobile Devices and Workstations to Enhance User Experience

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ABSTRACT

Many people own both a smartphone and a workstation computer. The reason for this is clear; there are advantages to both mobile devices and workstations that don't exist for both sides. While one can put a mobile device in one's pocket or wear it on one's arm, you can't say the same for a workstation. Meanwhile, a workstation has advantages of its own. One of the biggest reasons large applications can be used on workstations is because of their workstation setup. If we could take advantage of the workstation's setup and the portability of the mobile device together the advantage would be partially carried across both platforms. By creating a real-time connection between the two devices we could increase efficiency in many areas, most notably perhaps, data entry.

Categories and Subject Descriptors

B.4.4 [**Input/Output and Data Communications**]: Performance Analysis and Design Aids

General Terms

Measurement, Performance, Design, Experimentation, Human Factors, Theory.

Keywords

Data entry, iPhone, keyboard, efficiency, software testing, Mac OS X, smartphones, touch-screens.

1. INTRODUCTION

The computing industry is always changing, but that may not have ever been truer than it is now. The biggest influence of computing has shifted away from features and technical specifications and towards user-experience. Users want to be able to accomplish their tasks easily and with attractive user-interfaces. Another huge push in the computing industry has been the emergence of mobile computing, including smartphones. Smartphones have become more and more popular and significant to users, and as a result, over the past few years smartphones have seen large increases in sales as is shown in Figure 1 and Figure 2.

With a smartphone one can have this user-experience no matter where they go. Many users of smartphones choose to share emails, calendars and notes from their smartphone with their workstations. This creates a wonderful user-experience for the users of these devices, in fact, in a survey conducted by RBC Capital and ChangeWave Research, they found that 99% of iPhone 3GS users were satisfied with their iPhone 3GS. However, this user-experience could be taken even further. [1,5]

2. PROBLEM AND SOLUTION

Perhaps the largest difference could be made using a real-time connection between one's workstation and one's smartphone to keep notes updated and synchronized. In this case, these specifics will be regarding the iPhone and its operating system.

The iPhone, as well as many other smartphones, offers the ability to share notes with one's workstation; one method of doing this is to create a note in the mail application (Apple Mail, Microsoft Outlook, etc.) and synchronize the device through iTunes. The other approach to creating a note on your device is to simply type it into the Notes app directly on your device. If you choose to go this route the note will synchronize into your mail application once the device is synchronized as well. So where is the issue? One can create a note directly on the device, or one can create a note using their workstation's keyboard and synchronize it that way. If the user-experience approach is

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	2007 Units	2008 Units	2009 Units	2009 Market Share
Symbian	77,684.0	72,933.5	80,878.6	46.9%
Research in Motion	11,767.7	24,149.0	34,346.6	19.9%
OS X	3,302.6	11,417.5	24,889.8	14.4%
Windows Mobile	14,698.0	16,498.1	15,027.6	8.7%
Linux	11,756.7	11,262.9	8,126.5	4.7%
Android	-	-	6,798.4	3.9%
WebOS	-	-	1,193.2	0.7%
Palm OS	1,762.7	2,507.2	-	-
Other	1,344.0	1,519.7	1,112.4	0.6%
Totals	**122,315.6**	**139.287.9**	**172,373.1**	**100%**

Figure 1 – Gartner, Inc. Smartphone Sales Statistics as provided in Thousands of Unit

taken, we can enhance this ability even more. Imagine the case in which a family's shopping list is being created. Surely, one could create the note directly on the iPhone or create it inside of their mail application and synchronize their device, but this may take more time than it should. If there was a pairing between the two devices that could be used to automatically carry the notes over the air, then time could be saved and productivity could be increased. In fact, this connection could be shared across many devices and many workstations, meaning entire families could work on these notes together and they're all constantly in sync with each other. It's possible that an average shopping list could even be created in half of the time.

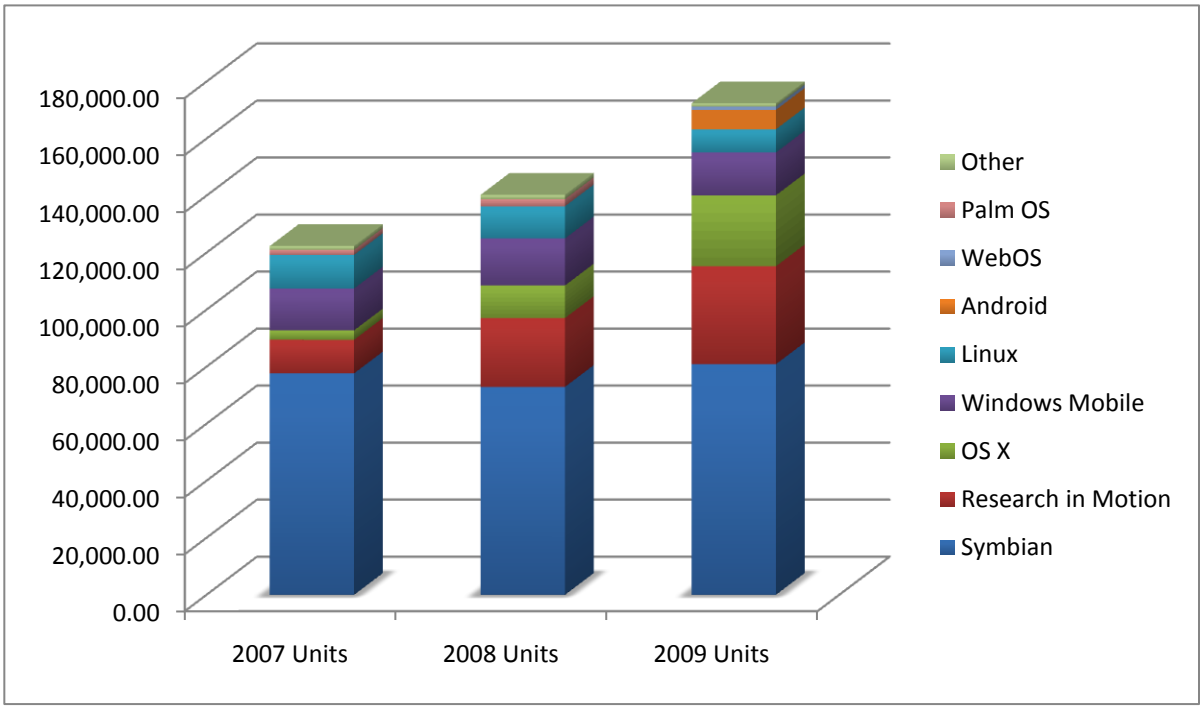

Figure 2 - Gartner, Inc. Smartphone Sales Statistics identical to those found in Figure 1 [3] [4]

3. METHODS

3.1. TECHNOLOGY

As is mentioned earlier, the iPhone is the primary mobile device for these tests, and in the tests the desktop class OS X will also be used. OS X apps, if they are for the iPhone or for the Mac, use referred to as Cocoa apps. The main idea of this is that they're written using Objective-C, which is a superset of C, and the full set of APIs that are very similar between the two platforms. The connection itself will use the local wireless network and a technology called Bonjour. [2] Bonjour allows the two devices to communicate over the network and share information in packets. Each time a key is pressed on the Mac keyboard or the iPhone keyboard a packet is sent to the other device with the updated information. Because this is a push method rather than a ping method it is extremely fast and saves on battery life.

3.2. TESTING

The testing will be based around the idea of a generic shopping list. The shopping list, as shown in Figure 3, will be used in three stages. Each stage will be timed as a total from the time in which typing starts until it is then on the device. Then this data can be compared to test the efficiency gained. In the first stage the users will enter the shopping list directly on the iPhone in the Notes application using the on-screen keyboard. During the second test, the user will enter the shopping list into a note in Apple Mail and will then sync the iPhone device using iTunes. In this case, the timer cannot stop until the sync is complete since before this happens, the shopping list isn't actually on the device yet. The third test will be when the user enters the information into the Mac application that was created for this purpose. This will then send the note to the device in real time and as such the timer will stop as soon as the note on the device is completely transferred.

Target Shopping List

-Hand soap refills

-Antiperspirant

-Sunblock

-Toothpaste

-Diapers

-Paper towels

-Gallon of milk

-1 loaf of bread

-Mountain Dew

-Cool Ranch Doritos

-Red 5 subject notebook

-24″ Windshield wiper blade for car

-Nike One Platinums

-Blokus board game

-Black dress socks

Figure 3 – The list of items testers entered

There are 20 test subjects, ranging in age from 20 to 23. The abilities of the subjects varied greatly. While some of the subjects were very proficient with both an iPhone and a full keyboard, some were familiar with neither.

4. RESULTS

The results, much like the testers, are varied. But if you look beyond the differences in the testing results, you can find commonalities that show the true findings. The data is shown in a raw form in figure 4, and the most obvious observation might be that the lowest time for every single tester was the written iPhone application.

Tests	Notes App	Mail + Sync	Written App
Tester 1	04:30.00	04:16.00	01:56.00
Tester 2	01:40.00	02:12.00	00:43.00
Tester 3	05:20.00	03:53.00	02:41.00
Tester 4	03:26.00	03:13.00	02:57.00
Tester 5	01:59.00	02:39.00	01:22.00
Tester 6	03:48.00	03:39.00	02:07.00
Tester 7	02:29.00	02:33.00	01:28.00
Tester 8	03:52.00	03:12.00	01:49.00
Tester 9	03:11.00	03:01.00	01:56.00
Tester 10	02:48.00	03:13.00	01:58.00
Tester 11	04:56.00	04:10.00	02:59.00
Tester 12	04:16.00	03:41.00	02:39.00
Tester 13	04:36.00	03:52.00	02:51.00
Tester 14	01:52.00	02:30.00	00:49.00
Tester 15	02:12.00	02:33.00	01:02.00
Tester 16	05:39.00	04:31.00	03:36.00
Tester 17	04:24.00	04:11.00	02:57.00
Tester 18	05:12.00	04:50.00	03:50.00
Tester 19	03:27.00	02:58.00	01:42.00
Tester 20	02:57.00	02:31.00	01:16.00
Averages	**03:37.70**	**03:22.90**	**02:07.90**

Figure 4 – Raw test results of all 20 testers as well as averages

This is a very easy observation to make, but is perhaps the most important. The reason it is seen is because of two reasons. The first reason is that everyone who has taken the test, and probably almost everyone else as well, is a faster typing on a full sized keyboard rather than an iPhone on-screen keyboard. The second reason is that this has completely eliminated the synchronization time. While it was expected that the average amount of time would be lower, it was largely unknown how much lower it would be. Figure 5 shows the amount of time saved as a unit of time for each tester, while figure 6 shows the average amount of time saved as a percentage of time for each tester.

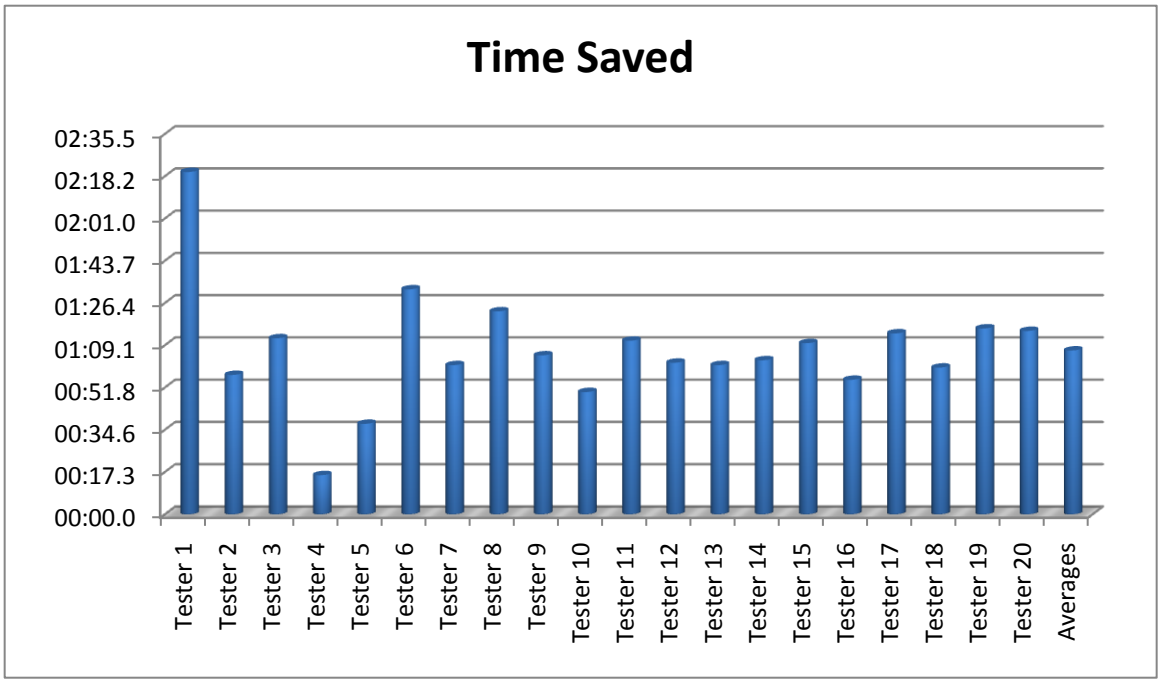

Figure 5 – Amount of time saved as a unit of time

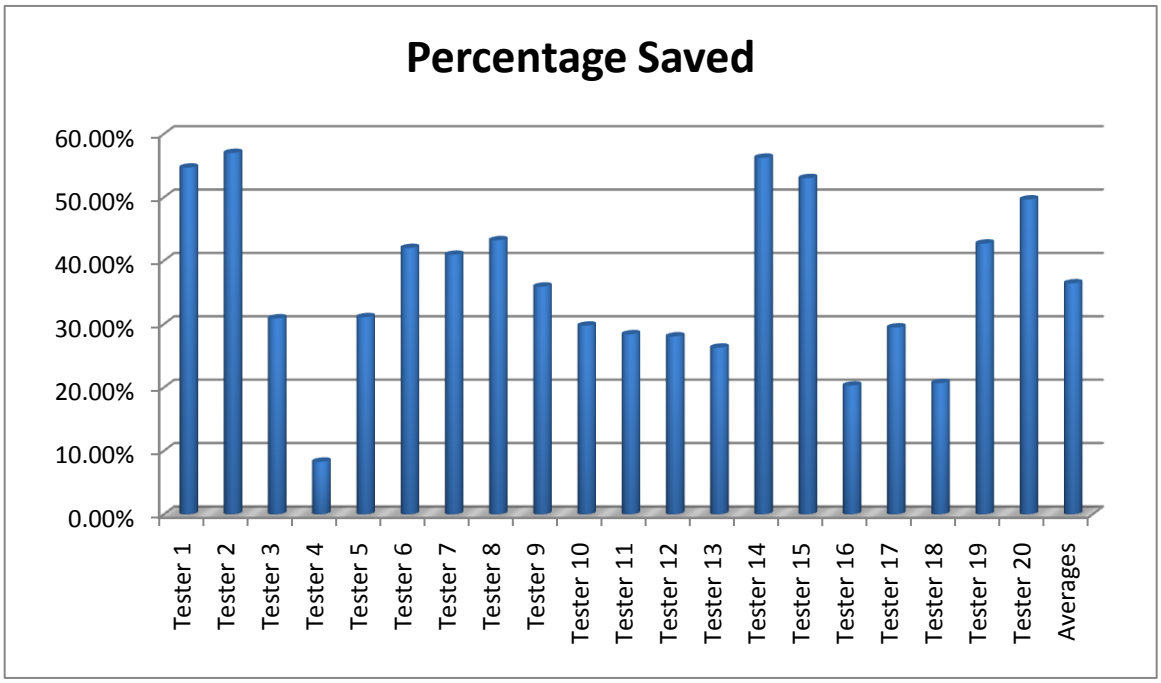

Figure 6 – Amount of time saved as a percentage of next best time

As is seen in the figures above, the most amount of time saved was with tester 1, who saved 2 minutes and 20 seconds. The most amount of time saved as a percentage of the previous time was tester 2, who saved 57% of their entry time. The average amount of time saved was 67 seconds and the average amount of time as a percentage was 36.43%.

Surprisingly, very few subjects were able to use a full keyboard very quickly, yet showed very slow speed

proportionally on the iPhone's on-screen keyboard, and this is supported by the fact that the percentage of time saved is fairly consistent.

5. CONCLUSION

It was estimated that one would be able to save approximately half of the data entry time. Through tests marking average user times in various data entry methods, I have shown that data entry on an iPhone can become more efficient. While the 50% target wasn't realized for the average user, it was seen in the results of testers numbered 1, 2, 14 and 15. Meanwhile, the average user saving 36.43% of their time is a pretty strong result. If an iPhone user were entering data quite often this would be a remarkable improvement for them.

Not only could this method be used to enhance data entry, it could also enhance many other areas. The same type of connection could share many other types of data as it is created or modified. When a user downloads a new song or changes the album artwork that change could be carried out to all that users devices wirelessly. Perhaps another very large improvement could be seen with pictures. Today pictures contain a great deal of metadata. They contain information such as where the picture was taken or who is in the picture. Not only could changes to this data be shared across the network like in the previous examples, but also pictures could be shared wirelessly using this platform across devices the moment they're taken. An iPhone could take the picture and it would instantly be on the shared computers. The user experience could be enhanced greatly using the foundation and methods presented here.

6. ACKNOWLEDGMENTS

I would like to extend special thanks to Jeff LaMarche who helped me gain a further understanding of Bonjour as well as other core principles of Mac OS X and iPhone OS development.

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Smart Cruise Control for Curvy Roads

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ABSTRACT

This research creates an alternative to cruise control that aims to improve gas mileage for a car. By taking into account the driving terrain we propose a heuristic that considers the forces on a car while it goes up and down steep hills. This research suggests a method to decrease fuel consumption by slowing down while going up hills and regaining that energy while going down a hill. The system uses pre-set parameters of a maximum and minimum speed, while the algorithm controls the accelerator, considering the effects of air resistance, gravity, rolling resistance and how they change based upon the road topology in order to minimize the amount of coasting and acceleration. This has the effect of reducing fluctuations in the engine and maintains the energy output closer to a happy medium instead of fluctuating while going up and down hills.

General Terms

Heuristic, Resistance (air, rolling, drag), grade.

Keywords

Energy preservation, Physics modeling,

1. INTRODUCTION

With the daily price of gasoline increasing, we are becoming increasingly conscious of fuel consumption; in order to meet EPA guidelines there are more and more electronic processors in cars today. This research aims to find fuel saving measures that produce significant gains in mileage over the common Cruise-Control by factoring in the topological information of a route.

Our objective is to retrieve terrain information from maps, GPS signals or any other source that lists elevation as a third dimension for a route; then use that information to make a decision about what speed will produce the best fuel economy.

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Using the topology of a route is also seen in commercial trucks[1]. There are commercial trucks available that use proprietary systems that we do not have access to. What is available is some research within this field that uses more advanced techniques to reduce fuel consumption, but these systems are more complex than what this paper proposes. This research expands on some of the research used in the truck industry by applying it to smaller vehicles and uses fuel saving techniques such as preventing idling while going downhill to achieve gains in gas mileage[4].

2. BACKGROUND RESEARCH

There are systems available that take into consideration the upcoming road terrain on the performance of a vehicle. We have come across research designed with considerations towards the commercial trucking industry with a complex least-cost algorithm that models the engine and physical forces to reduce fuel consumption. Our research uses some of the same physical models to make a generalized model [1]. We are using data that is readily available from any vehicle specifications such as weight, car dimensions and the coefficient of drag in order to calculate air resistance. With this information we will be able to apply an algorithm to reduce gas consumption.

3. HYPOTHESIS

There is a system that can consider the upcoming road topology that result in better gas mileage in comparison to standard Cruise-Control that produces a 7% gain in fuel economy over a road with 40-60% grade hills that are 25 feet or higher. We attempt to show there are gains that can be made in comparison to Cruise Control given the specified terrain.

4. METHODS

There are several steps for conducting this research. First, modeling the external forces that are applied to a car specifically air resistance, gravity and rolling friction while allowing for other factors to be considered that act upon the car causing changes to speed and fuel economy. Second creating a heuristic to take these factors into account and using that data to decide the vehicle's speed based upon the grade of the road for the route being tested. Next, the tests are conducted for three different routes that consider cases that were laid out in the model. The results of these tests are recorded using an Auto Tap streamer. This device connects to the OBDII port within the car. This has been an industry standard since 1996 and sends out

data about sensor readings in the car such as MPH, RPM, percent throttle or brake switch status. We use this to record speed, fuel consumption and distance for our tests. Our heuristic is implemented by taking the speed and distance of the car. Using this information we compute the recommended speed of our model and tell the driver the difference from the actual speed. Finally we tested our heuristic over a range of topologies (a low grade road that is relatively flat, a medium grade road with 40-60% grade hills that are 25 feet or higher, a high grade road with more than 60% grade hills that are 25 feet or higher) and compare this to using Cruise-Control. This allows us to show whether or not the heuristic allowed significant gains in fuel economy.

Our heuristic takes elevation data that was acquired from The National Map Seamless Server [6] for any given route. This site contains satellite scans of the USA that can range from 3 to 10 meters apart. Then with this data we can calculate the slope of the road and adjust the forces that are acting on the car at any given moment. The main objective is to minimize fluctuations in the engine's work so our model has the energy output for the engine set to a level that would maintain the average speed on level ground. We do this to prevent the radiator from removing too much heat from the engine. If the car is left to idle then when the pistons fire the engine is cooled down by the radiator significantly. Since "lower temperatures mean lower pressure, (Ideal Gas Law) [then] less pressure is left to push down on the piston" [5]. Thus by keeping the force constant the engine heat should be closer to constant. Once the engine is modeled as outputting a constant force the ideal speed is estimated by factoring in air resistance (EQ. 1), gravity (EQ. 2) and rolling friction (EQ. 3). These three forces are important because gravity and friction vary depending on the slope of the road and air resistance increases exponentially as the car gains speed. When we created this algorithm some considerations had to be made for the driver to ensure that the speed was not out of the range that they could drive safely. To take this into consideration we allow the user to specify a range within which they can safely drive their car. Once the range is known the sections that are outside of the desired speed are decreased or increased before the car gets outside of the range. We were unable to use data such as changes in speed limits to alter the car's speed. Although this feature could be added in future models.

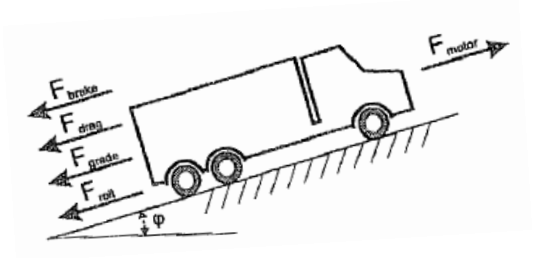

Figure 1. Model of the different forces on a vehicle. [1]

$$F_d = \frac{1}{2} D_{oa} V^2 A_{cs} C_d \qquad \text{(EQ. 1)}$$

D_{oa} Density of air.

V Velocity.

A_{cs} Area of a vertical cross section.

C_d Coefficient of drag.

$$F_g = G \sin \Theta \qquad \text{(EQ. 2)}$$

G Gravity.

Θ Slope/grade.

$$F_{rf} = C_{rf} N_f \qquad \text{(EQ. 3)}$$

F_{rf} force of rolling friction.

C_{rf} coefficient of rolling friction.

N_f normal force.

Figure 2. Equations describing the forces in Figure 1.[1]

We conducted three tests on Highway 61 in Minnesota from Wabasha to Lake City and from Red Wing to the intersection of Highway 61 and Highway 316. On Highway 61 in Red Wing to Highway 316 there is a section with large hills and a flat section so it was split into two different tests. Using an Auto Tap streamer on a 2002 Buick Century we collected data from the car's sensors for speed and fuel tank level. This data was used to determine the gas mileage, the distance the car has gone and what speed was desired based on our heuristic. In order to do each test, our routes had a fixed starting point so the heuristic had a reference point to know where the car was on the road, the air conditioning was turned off and the windows were rolled up. Once everything was setup our tests were conducted by driving three times using cruise control and another three times using our variable speed heuristic. Our heuristic was implemented using cruise control and manually changing the speed by one MPH when the model specified. There were two people in the car one to drive and one with a laptop connected to the auto tap streamer. The passenger recorded the data on the laptop and told the driver when they should increase or decrease the speed of the car.

5. RESULTS

The tests that were conducted on flat terrain had results that were expected; the speed stayed relatively close to the speeds that were produced with cruise control as shown in Figure 3. We can assume that with a flat surface it is optimal to set the speed as a constant since all forces on the car will stay the same.

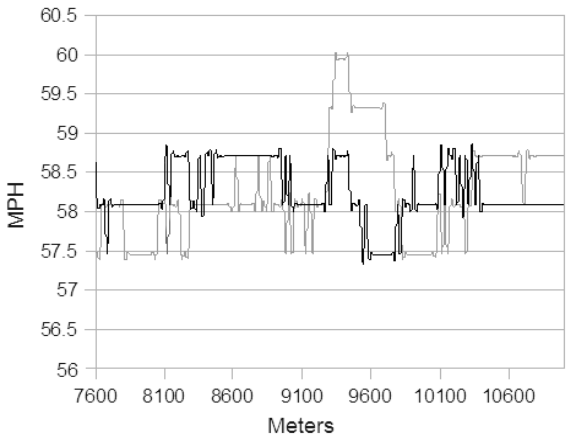

Figure 3. Speed data for a low grade road test.

The test conducted on a section of road with large hills can be seen in Figure 4. This test also shows what was expected from the heuristic because the road starts with a large hill going down and ends with a large hill going up. We can see that for the first two kilometers the car is moving close to or at the set maximum of 63 MPH. The car reaches a flat section for about one kilometer after the first hill and we can see that the car begins to reduce speed and soon after goes slower than the average speed of 60 MPH as the car begins to climb a hill. We can see that in between 3 and 4 kilometers the speed is close to 58.5 MPH when the minimum speed is set to 57 MPH. This is because the car is on a section of road with a lower grade than the section around 5 kilometers. At 5 kilometers when the car is at the steepest section of grade we hit the minimum speed because of steep grades along this path. This shows that our heuristic matches our intuition that the car will speed up while going down a hill and slowdown while going up a hill.

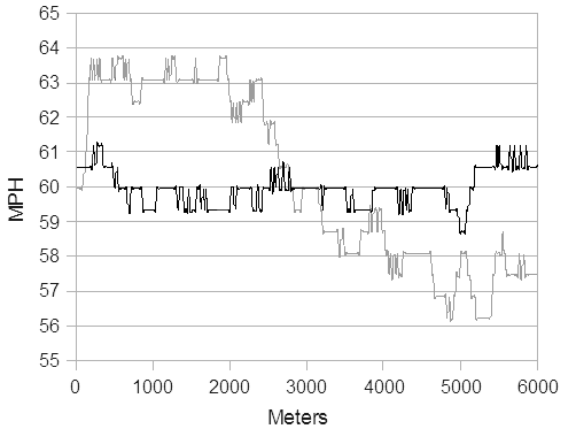

Figure 4. Speed data for a high grade road test.

The route used for Figure 5 had plenty of ups and downs and we can see that the speed adjusts accordingly. When comparing the speed held by cruise control and the speed recommended by our heuristic, we can see that both of these speeds fluctuate similarly. When cruise control fluctuates below the set speed our heuristic is moving at its minimum speed. This is expected variance for the speed of cruise control because the engine cannot keep the car at the exact value it was set to. The heuristics varies the speed of the car because it takes into consideration the terrain of the road.

Using Auto Tap it was hard to calculate meaningful data from the sensor that read the gas tank level. This was a challenge because the sensor is getting data directly from the tank's float readings and the tank sways when the car is moving thus it will return skewed data unless the car is resting on a flat surface. The first way we tried to compensate for this was to analyze the tank level using a regression line to find out the average fuel consumption per mile. Figure 6 shows how our data from the fuel tank sensor has been fitted to a regression line.

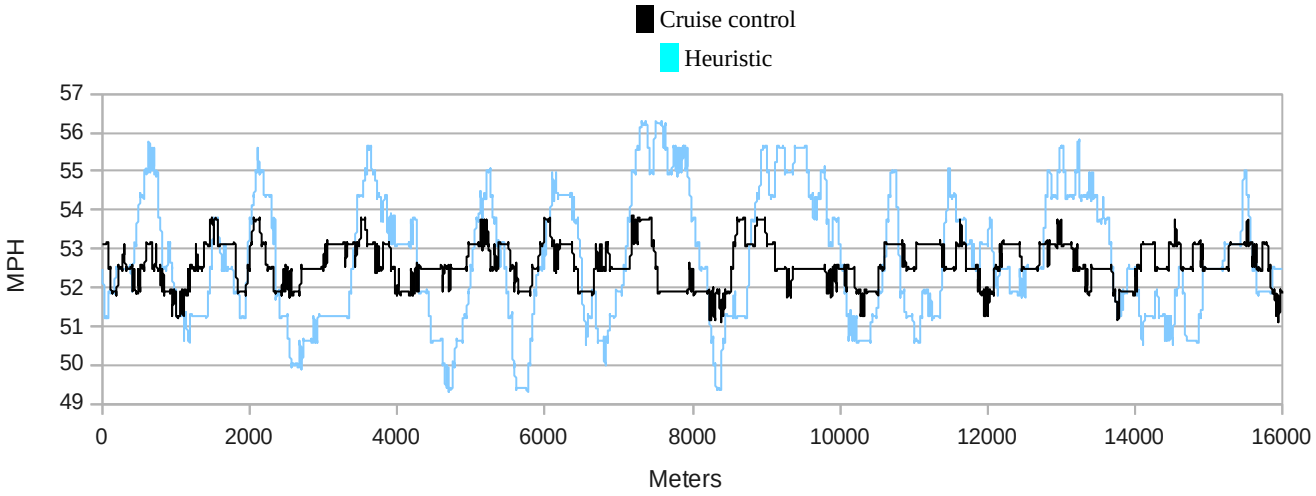

Figure 5. Speed data for a medium grade road test.

This only worked for the medium grade because the length of the trip allowed for more data to be collected and a more noticeable difference for the tank level at the start compared to the tank level at the end. The steepest grade and low grade gas mileage could not be computed using linear regression. The low grade test did not consume enough gas, so when using the regression test the line was calculated to have a slope near zero meaning that there was no actual gasoline consumption and that could not happen. The steepest grade test could not use the regression test because it would have shown that the tank was gaining gas. This happened because when the car is on a down-slope the gas moves away from the sensor artificially lowering the reading and when the car is on an up-slope the opposite happens, the gasoline flows to the sensor increasing its readings. This was showing data that would imply the car was gaining gas thus we could not use this type of test for discerning the gas mileage.

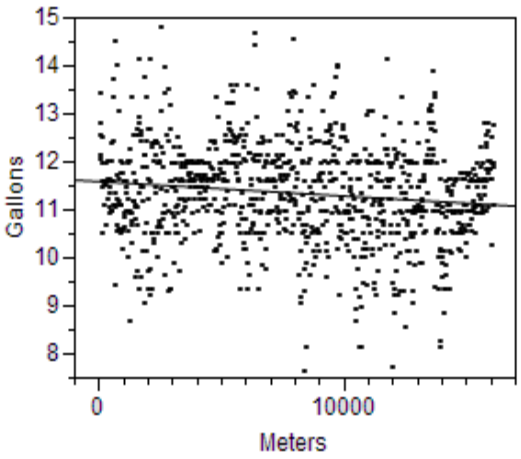

Figure 6. Linear regression line from the gas tank readings.

The data that was left that we could use to determine gas mileage was from the starting point (where the car was stationary and on flat ground) and by choosing a section of road close to the end that was flat enough to get a good estimate for the gas tank. Using this method has shown to be less consistent than linear regression; it also adds data from before the start of the tests. This is because we are getting the tank level from the starting point where the car is idle. From there we do not start the heuristic until we have accelerated to the speed limit.

Overall the results showed that the heuristic is working as desired and that manually inputting the speed is a valid way to test our heuristic. Our gas mileage results did fluctuate between tests showing there is a high margin of error. We attempted to correct this using linear regression but we could only do so with our medium grade road. The second trial of the high grade test received 35 MPG this is an outlier, the efficiency is much greater than the estimated MPG for the highway. From this we can assume that the actual MPG for the heuristic is less than the calculated average. The results for mileage were surprising; because from previous experience the car normally gets 25 MPG on the highway during the time of year these tests were conducted. This could be explained by the fact that the gas tank would not be uniform throughout. Our sensor was taking readings from the height of gasoline in the tank and that does not directly translate into gallons. Luckily the focus is on comparing two methods so the exact volume that was consumed was not a concern. In order to show one method outperformed the other we needed to know the values that we are comparing are scaled similarly. Otherwise the rest of the data results seem to be all within the same range and that is important for our comparison.

6. ANALYSIS

In order to make an analysis of our results the focus is on the ratio between the MPG ratings we found between cruise control and our heuristic as can be seen in Figure 7. For the low grade test the ratio between the two methods was very close; with the average MPG for our heuristic performing at 96 percent of the average MPG for cruise control. Both of these methods were expected to perform similarly because they were set to similar speeds and the road stayed consistent meaning there were not any hills. For the steepest grade road there is a large difference between cruise control and our heuristic with the MPG for cruise control sitting at 71% of the MPG rating for our heuristic. Considering the outlier within the dataset, the actual ratio may not be as high as the tests showed. Still with that consideration we suggest the actual may be closer to 85 percent instead of 71 percent and that would still be a significant savings in

		trial1	trial 2	trial 3	avg	ratio
low grade	cruise	21.05	13.23	10.8	15.03	1
	heuristic	10.1	23.36	9.61	14.35	0.96
medium grade	cruise	10.67	13.7	7.05	10.47	0.86
	heuristic	7.89	14.79	13.83	12.17	1
medium grade (linear regression test)	cruise	21.28	20.47	20.64	20.8	0.99
	heuristic	20.08	21.35	21.57	21	1
high grade	cruise	18.81	15.41	14.54	16.25	0.71
	heuristic	13.58	35.77	18.91	22.75	1

Figure 7. The MPG achieved with each test.
The linear regression test has more accurate results.

comparison to cruise control. Even though the high grade road showed results that would suggest our heuristic is getting better gas mileage than cruise control, we cannot support this due to our inability to have an accurate gas reading. For the medium grade road we used two methods. For all three scenarios we measured the gas tank by taking samples from the start and end of a test. For a medium grade road we used data that was analyzed using linear regression to achieve more accurate results. This was not feasible for the data collected on our low and high grade roads. When analyzing the data for a medium grade road using a regression test we found that the two methods produced almost identical results.

After conducting these tests we found some things in our methodology that could be improved upon. The main problem is the evaluation of the cars fuel consumption lost a significant amount of accuracy due to the gas tank reading fluctuating because the liquid was moving around in the tank. If the car had sensors that would give the instantaneous gas mileage by monitoring the gas line (as can be found in more modern vehicles) it would greatly simplify the process of analyzing the results. Another problem that was noticed after running the tests is that when we retrieved data for our route it was in latitude and longitude which did not have a direct mapping to miles so we considered the distance for one degree latitude and one degree longitude to be the same distance. This was incorrect because the length of the longitudinal degree becomes smaller when you move away from the equator. This did not have a noticeable effect on our experiments; because the change in the distance from the equator during our tests was negligible. In practice this could be corrected for simply by calculating the distance of a longitudinal degree.

7. CONCLUSION

Our goal was to show that we could make a heuristic that would consider the upcoming terrain in order to get better mileage. Considering our most accurate results for the medium grade road contradict our hypothesis we cannot support our claim. Our control tests were as we expected so we cannot point to any major errors within our test methods. We also cannot make a strong conclusion for a high grade road. Even though our results might suggest that our heuristic preformed favorably, considering the high margin of error within the data collected for the high grade road we cannot make a strong conclusion about how well our heuristic performs with large hills.

8. FUTURE WORK

There were some problems with reading the gas tank. This could be corrected by using a sensor that would read the amount of gas going through the gas line to produce an instantaneous MPG rating. There were also some factors that we were aware of but had left out of our considerations such as wind direction, the change of forces based on turns and rain causing the tires to lose traction. A good addition to this project would be to add considerations for when the transmission changes gears and try to optimize based upon what gear the car will be using. We also could have improved accuracy by having an odometer reading from our Auto Tap device that had an accuracy of 10-25 meters instead of calculating the distance based off of the speed of the car.

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The Point of Diminishing Returns in Autonomous Reconnaissance

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ABSTRACT

This research project will attempt to find the point of diminishing returns for the amount of time it takes to search a room/area while increasing the number of robots. The independent variables were the number of robots and the size of the areas/rooms and the dependent variable was the amount of area searched in a given amount of time. To help uncover a general formula for calculating the point of diminishing returns, this research project will use different size rooms/areas and multiple robots. We were thinking that while adding more robots, the amount of area covered should theoretically double for each robot added. This would also depend on what kind of algorithm would be used to search the room/area. A more thorough algorithm is going to search less area but be more accurate than a more exploratory algorithm. For the purposes of this research project, we implemented a random, wall-avoiding algorithm.

General Terms

Measurement, Performance, Experimentation, Theory.

Keywords

Robotics, Autonomous, Reconnaissance, Point of diminishing returns.

1. INTRODUCTION

This research project attempted to find the point of diminishing returns for the amount of time it takes to search a room/area while increasing the number of robots. The independent variables were the number of robots and the size of the areas/rooms. We had 15 robots to use and 3 different size areas/rooms. The areas/rooms were squares made out of section of wood, 7 by 7 feet, 10 by 10 feet, and 13 by 13 feet. The dependent variable was the amount of area searched in a given amount of time. For this project, we ran two sets of tests, one set at one minute for each test run and another set at two minutes for each test run. Collecting this data helped to uncover a general formula for calculating the point of diminishing returns.

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We were thinking that while adding more robots, the amount of area covered should theoretically double for each robot added. This would also depend on what kind of algorithm is used to search the room/area. A more thorough algorithm is going to search less area but be more accurate than a more exploratory algorithm. For the purposes of this research project, we implemented a more or less random, wall avoiding algorithm. This provided a good average of all the different types of algorithms.

The hypothesis for this research project was: as the number of autonomously controlled robots increases, the amount of area observed has an initial growth rate of 100% but decreases until a point of diminishing returns.

2. RELATED WORK

There are many aspects to robotics: movement, sensing, communication, teamwork, reconnaissance and the task of dealing with humans. One of the bigger topics is what type of algorithm to use to search or traverse an area. This is an important topic, because a good or bad algorithm can make or break any of the other aspects.

There are many different kinds of research projects being done on the topic algorithms. For example, what kind of search pattern searches the most efficiently [4], [5]. Another important topic is how robots could move around in the most efficient way given the environment it is in [1]. Once a robot is able to move around, the next task is location and mapping. Another aspect is position, as in the robot being able to know where it is and where the other robots are. Mapping is closely related with position; mapping is keeping track of where the robot has been and how to convey this location information to other robots [2], [3], [6]. Moving, sensing, and communication are all very important because the robot would not be able to do much without being able to perform some basic tasks.

3. PROJECT IMPORTANCE

Knowledge gained from a project like this is important because as robots become more prevalent in society, they will begin to work together to perform more complex tasks. Obviously, as more robots work together on a task, the task will be completed quicker and quicker; but just like any task when there are too many people working together, people start to get in each other's way. When dealing with robots searching a room or an area, there is a clear upper limit--the case when there are thousands or millions of robots. It just might be physically too many robots to fit in the area and still be able to move around, or

it might be so many robots that the communication channels between the robots are completely clogged with traffic.

There is a variety of situations and other projects or areas of study that could benefit from the knowledge gained this project. For example, humans could use the right amount of robots to rapidly search for victims in potentially dangerous areas like earthquake ruble while not redundantly or inefficiently using resources. Another example is using teams of robots to explore uncharted areas of foreign planets. The weight of a mission is very critical because it is expensive to launch rockets into space. The results from this research would be valuable to be able to calculate the optimal number of robots to use and still get the task done in a timely manner. The military also uses robots to investigate hostile areas; it would be beneficial to know how many robots it will take to search an area. The list goes on, but basically any task where the time and speed of a task could be reduced by adding more robots.

4. METHODS

To test this hypothesis, the research project was set up to use three different room sizes: a small area (7 feet by 7 feet), a medium area (10 feet by 10 feet), and large area (13 feet by 13 feet). This provides an incremental increase, which helped us to find a formula.

We had 15 robots available for this research project. This was enough to be able to analyze the amount of change of the observed area for each additional robot. The amount of robots was just enough to uncover where the point of diminishing returns is located.

The area searched was calculated by measuring the 12 inch tile grid on the floor. The robots were set to only 12 inches in front of them, so when the robot stopped to search for a wall, we estimated a foot of searched area around the robot.

4.1 HARDWARE

The robots that we used were RidgeSoft IntelliBrain-Bot educational robots. They use Java as the programming language. The IntelliBrain controller has support for a number of sensors, for this research project the robots used infrared sensors, and ultrasonic sensors.

The infrared sensors are used for watching the spokes of wheels and keeping track of the position of the robot. This is done by counting the spokes and then using the size of the wheel to know how fast the wheel is turning and how far the robot has traveled. The sensor works by returning the distance; when there is a wheel spoke the distance will be very close, and when there is not the distance will be far away.

The ultrasonic sensors are used for searching. Again, searching is just simply looking around for walls and then avoiding any walls. The sensor returns the distance by sending out a ping—a high pitch sound wave that is beyond the threshold of human hearing—and timing how long it takes to return to the robot. For this research project, we have set the limit of the sensor to 12 inches.

4.2 SOFTWARE

The algorithm used for this research project was a pseudo-random turning, wall avoiding algorithm. The robot randomly picks an angle in the range of negative 90 and positive 90, with zero being no change in heading. Then the robot drives 12 inches and searches the visible area—looking around for a wall. We set the sensors to be able to see only 12 inches. If a wall was found then the robot determines the angle of the wall and modifies the range for random angles. This ensured that the robot does not drive into the wall and only traveled parallel with or away from the wall.

We set up the algorithm to work off of a framework. Figure 0 shows the pseudo code for the algorithm used in this research project.

```
While remaining time is less than time limit:
      Search-for-wall();
      If wall exists then
            Modify-turn-range() to avoid wall;
      Else
            Set turn range to random(-90,+90;
      Endif
      Turn amount in turn range;
      Drive 12 inches.
```

Figure 0.

The details of the algorithm are contained in a few sub methods. The first one is the search-for-wall method, which involves moving the sonar sensor around and reading the values to determine if there is a wall. This sub method returns a Boolean as the result.

Another sub method was modify-turn-range to avoid hitting the wall. It took the angle of the sensor when the wall was closest and subtracted 90 from that angle to return a range of negative 90 to this newly calculated value; or if the angle of the sensor was less than zero, then the algorithm added 90 to return a range of this newly calculated value to positive 90.

The last two sub methods we used were a turning method and a driving method. The main algorithm would pass the angle to turn or the distance to drive, and these methods would manage the wheel servos to drive straight, or to turn clockwise or counter-clockwise.

Setting up this framework and having sub methods handle the details allows the program to be very human readable and flexible to how the details are preformed.

RidgeSoft has setup the robot to use Java and provides an extensive API to help programmers. For this research project, we wanted to use a robot that runs Java because that is the main programming language taught here at Winona State University Computer Science Department. Furthermore, RidgeSoft has a broad framework of pre-built methods that deal with hardware details. For example, instead of controlling the details of how to make the servo rotate, we only have to program how fast we wanted the servo to rotate.

5. RESULTS

We started with taking a base measurement of how much area was searched while using one robot within a particular area in both of the time frames: one minute and two minutes. More tests were run using the same area and increasing the number or robots. The results from this were graphed to show a curve and they illustrate where the point of diminishing returns is located.

The results appendix shows the data that we have collected for each of the areas: 7x7, 10x10, and 13x13. The data is also sorted by how long the test runs were: 1 minute and 2 minutes.

Figures 1 and 2 show the results from the one minute and two minute test runs.

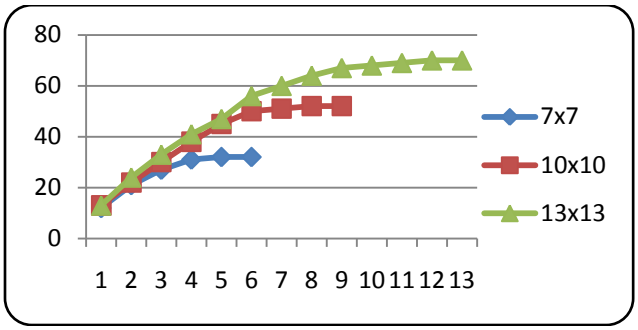

Figure 1.

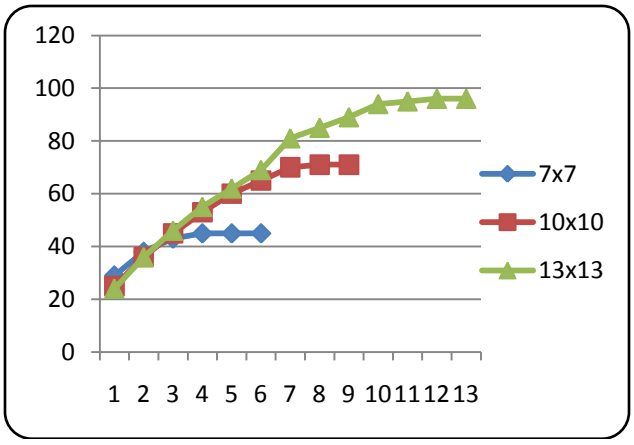

Figure 2.

The data confirms that the amount of area observed doubles per robot, but quickly diminishes and produces a logarithmic-looking curve. Using this data, we have created a formula that closely estimates the gathered data, shown in Equation E1. This formula was created by combining and substituting formulas of trend lines produced by excel. The goal was to make a formula that produced a trend line for all of the curves grafted.

S = B*R2 + M*R + E, where:
S = Amount of area searched
A = Area of the testing area
R = Number of robots
T = Time of the run
B = 0.0061A – 1.48
M = –0.0005A2 + 0.1019A + 8.1743
E = (0.25T – 14)

Equation E1.

This formula in Eqution E1 produces the following trend lines as shown in Figures 3, 4, and 5.

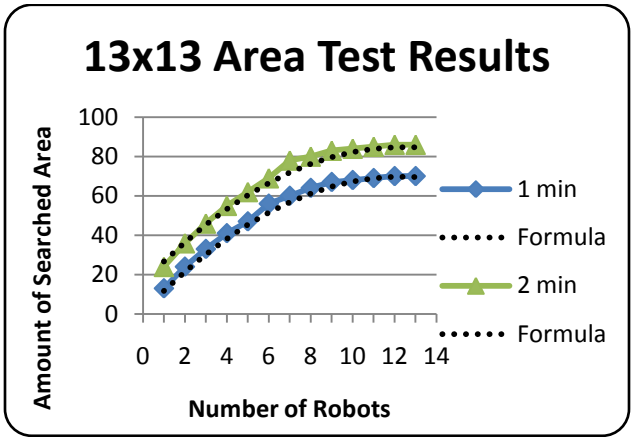

Figure 3

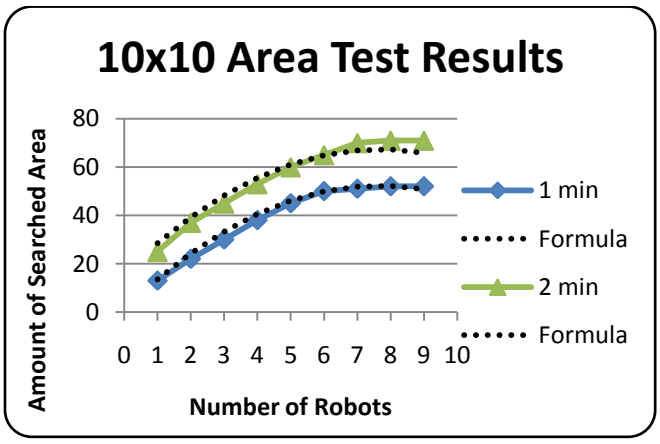

Figure 4.

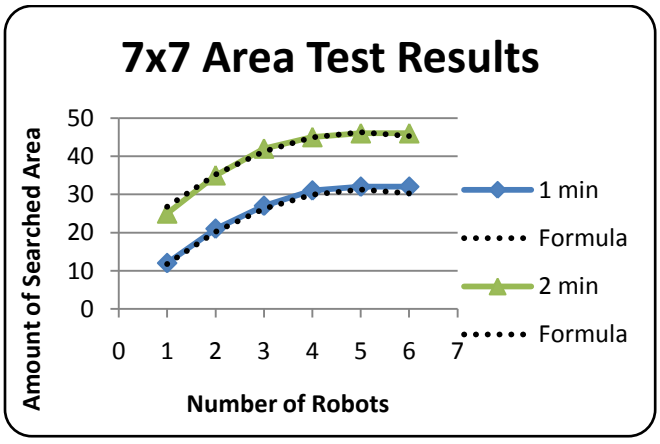

Figure 5.

From this data, we have also created a formula to estimate the point of diminishing returns, shown in Equation E2. We came up with this formula by just noticing a pattern between the area and the point of diminishing returns. For the one minute test runs, that point appeared to be at 2 minus the square root of the total area; and for the two minute test runs, the point of diminishing returns appeared to be at 3 minus the square root of the total area. We drew the conclusion that point of diminishing returns is the square root of the area minus the sum of time plus one.

R = Number of robots
A = Total testing area (feet)
T = Time of the run (seconds)

$$R \approx \sqrt{A} - \left(\frac{T}{60} + 1\right)$$

Equation E2.

Figures 6, 7, and 8, show where the cutoff is for the point of diminishing returns.

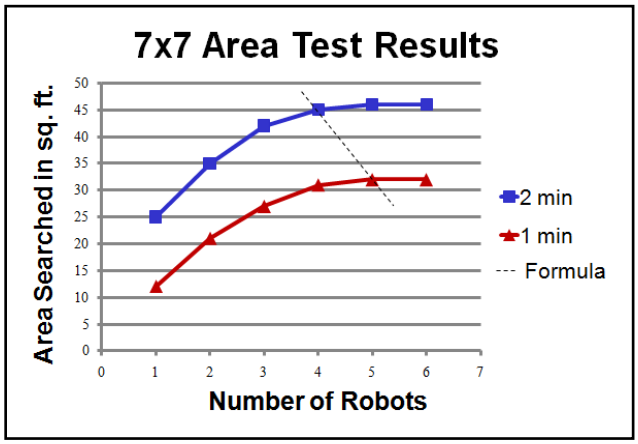

Figure 6.

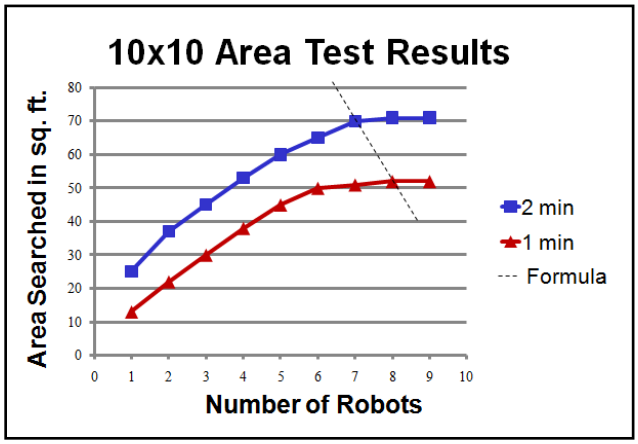

Figure 7.

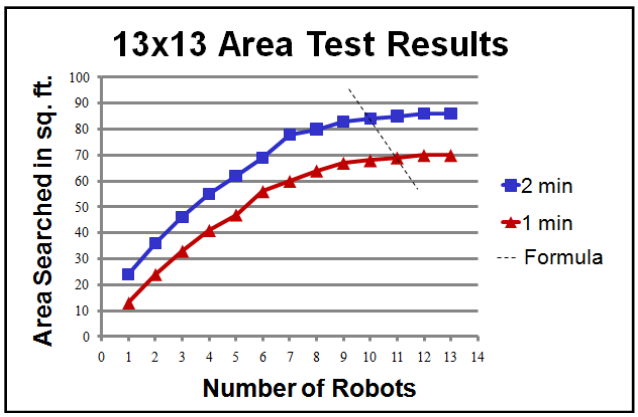

Figure 8.

The formula produces a number that is close to a number that a human would suggest as the point of diminishing returns. After this point, the amount of additional searched area produced by using one more robot is slim to none. This negligible gain in performance is the definition of the term, the point of diminishing returns.

6. CONCLUSION

Within the given parameters, the hypothesis has been confirmed. As the number of autonomously controlled robots increases, the amount of area observed has an initial growth rate of 100% but decreases until a point of diminishing returns. We have discussed and shown where the point of diminishing returns is; additionally we have provided two formulas. A formula that gives the position of the point of diminishing returns, and a formula that estimates the curve of searched square footage while increasing the number of robots.

7. FUTURE WORK

The formula is based solely on the data collected in the research project, so there will need to be a variety of future testing done on this formula; using different types of areas, a variety of range sensors, longer run times, and altogether different robots. Different types of areas include: rounded areas, areas with obstacles, areas shaped like a building floor plan, and many other types. Along with the different types of environments, there are many other types of sensors. Some can very quickly scan and return the distances in 360 degrees. Furthermore, with the advancement of robotics there are many different types of robots; some that walk on 2, 4, 6, or even 8 legs; some that balance on 2 wheels; and some that are much bigger and have more wheels. There are many more tests and studies to be done; which will provide many opportunities to add to and adjust the formula provided by this research project.

8. ACKNOWLEDGMENTS

Dr. Joan Francioni – Advisor for this research project, Winona State University Computer Science Professor.

Chris Bischke – Assisted with the inception, planning, and design, La Crescent High School Student, member of the La Crescent FIRST Robotics Team.

Dr. Gary Bunce – Loaned the robots to make this research project possible, Winona State University Computer Science Professor.

9. REFERENCES

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Appendix 1: Results of Test Runs

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	12	24%	
2	21	43%	18%
3	27	55%	12%
4	31	63%	8%
5	32	65%	2%
6	32	65%	0%

Figure A1. 1 Minute; 7 x 7' Area

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	13	13%	
2	22	22%	9%
3	30	30%	8%
4	38	38%	8%
5	45	45%	7%
6	50	50%	5%
7	51	51%	1%
8	52	52%	1%
9	52	52%	0%

Figure A2. 1 Minute; 10 x 10' Area

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	13	8%	
2	24	14%	7%
3	33	20%	5%
4	41	24%	5%
5	47	28%	4%
6	56	33%	5%
7	60	36%	2%
8	64	38%	2%
9	67	40%	2%
10	68	40%	1%
11	69	41%	1%
12	70	41%	1%
13	70	41%	0%

Figure A3. 1 Minute; 13 x 13' Area

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	29	59%	
2	38	78%	18%
3	43	88%	10%
4	45	92%	4%
5	45	92%	0%
6	45	92%	0%

Figure A4. 2 Minutes; 7 x 7' Area

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	25	25%	
2	36	36%	11%
3	45	45%	9%
4	53	53%	8%
5	60	60%	7%
6	65	65%	5%
7	70	70%	5%
8	71	71%	1%
9	71	71%	0%

Figure A5. 2 Minutes; 10 x 10' Area

Number of Robots	Area Searched	Percent of Area Searched	Percent of Additional Area Searched
1	24	14%	
2	36	21%	7%
3	46	27%	6%
4	55	33%	5%
5	62	37%	4%
6	69	41%	4%
7	81	48%	7%
8	85	50%	2%
9	89	53%	2%
10	94	56%	3%
11	95	56%	1%
12	96	57%	1%
13	96	57%	0%

Figure A6. 2 Minutes; 13 x 13' Area

Comparing the Efficiency of NIO Model to Thread-per-Connection Model in Java

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ABSTRACT

NIO, or "New Input/Output", is a Java API that uses non-blocking IO as opposed to the old Java IO API which uses thread-per-connection blocking IO. It is commonly believed that the thread-per-connection model is not as efficient as the NIO model and thus should not be used anymore. The aim of this research is to find if this is indeed true, and to determine if there are any situations in which using non-blocking NIO is as efficient as or even less efficient than the thread-per-connection IO model in Java.

Categories and Subject Descriptors

D.3.3 [**Networking**]: Input/Output Types – *Blocking IO, Non-Blocking IO.* Networking Transport – *TCP*.

General Terms

Performance, Design, Experimentation.

Keywords

Java, Networking, Input/Output.

1. INTRODUCTION

The Java New I/O (NIO) API offers several new features in comparison to the old IO API, but our focus is specifically on the non-blocking aspect of the NIO API. Because the NIO API in Java uses non-blocking IO unlike the thread-per-connection model, it is often assumed to be more efficient than the latter [1]. However, this may not be the case in all situations. The overall performance relies heavily on the underlying operating system that is managing the context switching between threads. There are many claims that newer versions of the Linux kernel handle threads quite efficiently; efficient thread-handling could make a difference in the efficiency between non-blocking IO and thread-per-connection IO.

The advantage of blocking IO is that it is significantly less difficult to implement and debug than NIO. This is because the programmer need only implement a thread class to handle a single connection, and spawn a new thread every time a connection is initiated. Switching between the connection requests is simple, because it can be left to simple context switching of the threads, which is carried out by the underlying operating system. With NIO, the programmer needs to be concerned with more problems, such as how many threads to use for the connections based on the nature of the application. Since NIO's implementations are usually more complicated, it is generally more default to debug than blocking IO. Due to its greater implementation complexity, NIO should only be preferred if the performance increase is significant.

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2. HYPOTHESIS

There is an operating system environment where the thread-per-connection model requires less CPU processing time and introduces less connection request latency than the NIO model.

3. METHODS

This research involved various experiments that compare the use of the Java NIO API (non-blocking IO) to the older IO API (blocking thread-per-connection IO), with everything else being equal.

The experiments were performed using two custom Java programs: a client and a server. During the experiments, there were five clients and one server, as shown in Figure 1. Each client had hundreds or thousands of TCP connections to the server. This was strictly a server-side analysis, so although the performance of the clients was monitored, we are only concerned with the results of the server's performance. The only piece of information that is gathered from the clients is the latency experienced with the server; this is determined by calculating the difference in time from when a client sends a request to the server to the time that it receives a response.

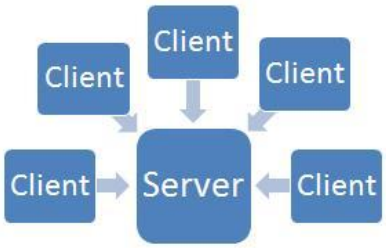

Figure 1. Server connected to five clients.

In each experiment, there was a distributed load on all the connections to the server. Each client sent a 1 KB request every three seconds on each connection to the server. When the server received a request, it then performed a minor simulated process,

as well as a small disk access. It then simply echoed the request data back to the client. This process was intended to make the test environment slightly more realistic and to put a greater load on the CPU.

The operating systems that were tested in the research are the following:
· Windows Server 2003
· Windows Server 2008
· Ubuntu Server
· Solaris

The MINA (Multipurpose Infrastructure for Network Applications) NIO Framework is used for the NIO server implementation. This is a Java framework that is commonly used for NIO implementations [2]. The thread-per-connection model is simple to implement in Java, so the Java API could be used directly when implementing it.

The analysis of these experiments was based on three criteria: CPU utilization, memory usage, and latency. CPU and memory usage were primarily evaluated from the output of the Java Monitoring and Management Console, which is a cross-platform tool included in the Java Development Kit (JDK). CPU utilization was also monitored with the resource monitoring tools provided in each operating system to get more detailed information of how each core of the CPU was being utilized. Since the thread-per-connection model will almost always have a significantly greater number of threads than the NIO model, it is almost a guarantee that thread-per-connection experiments will have greater memory utilization; thus, although memory utilization is used in comparing the different experiments, we are primarily concerned with comparing CPU utilization and latency between the two models.

The Java Virtual Machine (JVM) used for all of these experiments was the Java Hotspot Server Virtual Machine, which is included with the JDK. There were a number of settings that needed to be changed to the JVM and the operating system environments to make these experiments work. The heap space for the JVM had to be increased to 512 MB to allow for the greater memory that the blocking IO model requires. Additionally, since thread-per-connection by definition will result in thousands of threads during the experiments, the JVM thread execution stack size had to be decreased down to 128 KB to prevent too much memory from being used. In Ubuntu Server, the maximum number of file descriptors (sockets) had to be increased from the default value of 1,024.

The number of connections initiated in all the experiments was 6,000. Since it is not feasible to initiate this many connections instantaneously, each client initiated a connection every 500 milliseconds. The number of six thousand connections was decided for circumstantial reasons. Initially it was decided to use three different test scenarios of the number of connections, ranging up to 25,000. However, it was very difficult to obtain this number for a variety of reasons. Despite making several changes in the JVM and the underlying operating systems, only about 6,000 – 7,000 connections could be established in each experiment in the thread-per-connection model, despite having plenty of memory resources left in the system. This could be due to a limitation in the JVM on the number of threads, or even a limit in the underlying OS on the number of threads per process. Despite this, six thousand connections is still a large enough number to make comparisons between the two models. Indeed, many real environments do not need more connections than this.

4. RESULTS AND ANALYSIS

Most of the graphs that are shown in this paper are taken from the Java Management Console, which was used to dynamically capture information about resource utilization as the server was handling requests on the connections. It is important to note that the Java Management Console automatically adjusts the scale of these graphs dynamically, so one should pay close attention to the scale of each graph in this paper to properly make comparisons.

As expected, the server consumed much more memory when using the thread-per-connection model than when using the NIO model. This difference can be seen when comparing Figures 2 and 3. The thread-per-connection model used over 300 MB of heap space, while the NIO model used less than 40. The linear growth in memory usage is simply due to the steady increase of connections to the server; the line flattens out due to the server completing the initiation of all connections.

One interesting difference here is that the NIO heap usage does not seem to increase as steadily as the heap usage of the thread-per-connction model. Note that as the number of connections is increasing, the clients are already sending requests on the existing connections, so this affects the heap usage on the server as well. The most likely cause for the difference in "noisiness" is that the MINA Framework's implementation for some reason causes the Java garbage collection to be run more often. Again, the scales are different in the two graphs, so this difference is not as great as it seems.

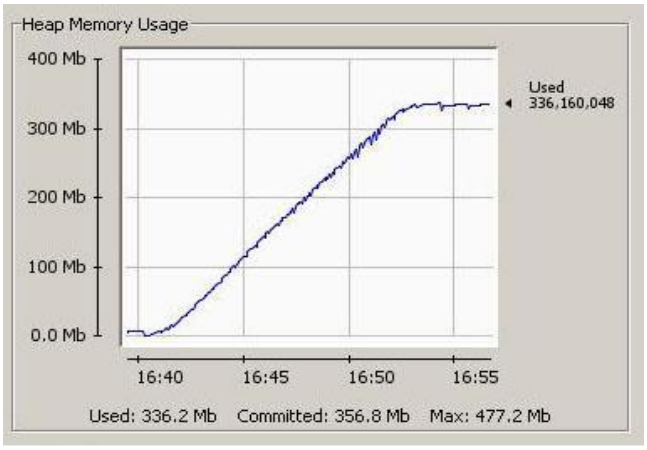

Figure 2. Thread-per-connection heap usage.

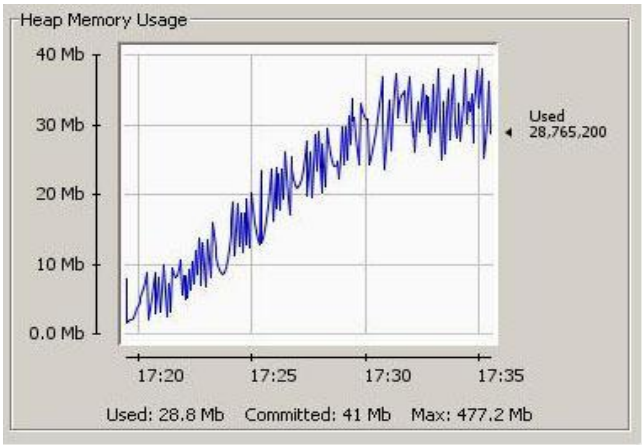

Figure 3. NIO heap usage.

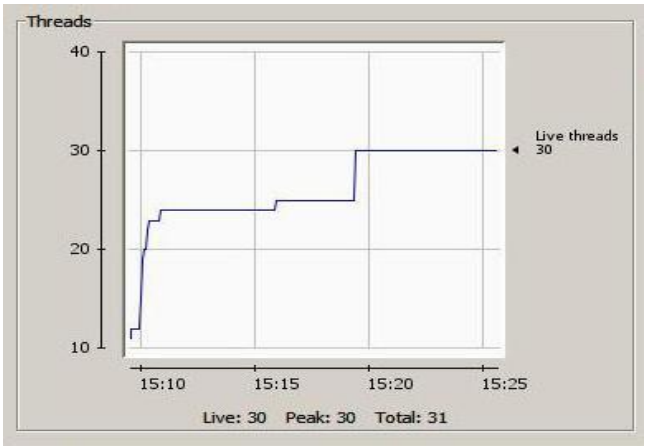

Figure 5. NIO Thread count.

Figures 4 and 5 show the difference between the two models in terms of the number of threads used and how that number increases as more connections are initiated. As mentioned earlier, the number of connections was purposely increased in a linear fashion by initiating a new connection from each client every 500 milliseconds. As expected, the graph of the thread count for the thread-per-connection model reflects this linear increase. The graph shows that the thread count stops at 6,011; six thousand of the threads are connection threads, and the other eleven threads are handling other tasks.

Figure 5 shows how the NIO thread count increases in a step fashion rather than a linear one. As the number of connections increases, the MINA Framework allocates more threads as necessary to handle them. Here, the thread count stops at 30, which is a significant difference from 6,011.

Figure 4. Thread-per-connection thread count.

The results of the CPU utilization from the experiments are interesting. In each case, the thread-per-connection implementation actually used significantly less percentage of the CPU than the NIO model. Figures 4 and 5 demonstrate how both models utilized the four cores of the CPU and to what extent. Here it can be seen that in both cases, all four cores are utilized nearly equally. However, the NIO model consumed more CPU resources.

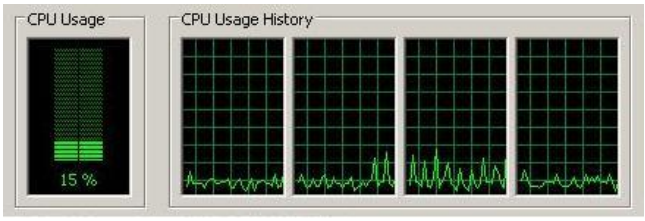

Figure 6. Thread-per-connection CPU utilization on Windows Server 2003.

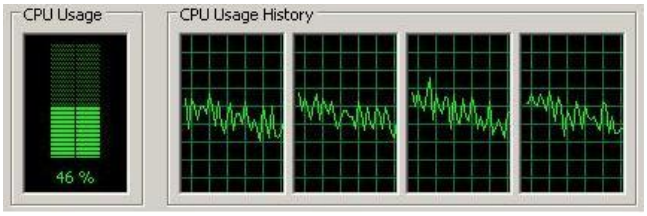

Figure 7. NIO CPU utilization on Windows Server 2003.

The following graphs compare the CPU utilization of the server for the two models across the four operating systems that were tested. Again, these graphs are taken from the Java Management Console.

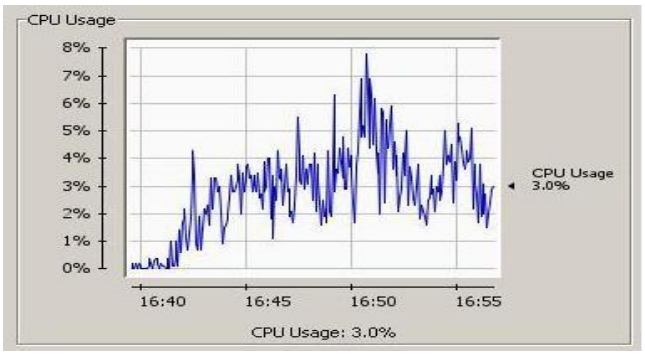

Figure 8. Thread-per-connection on Windows Server 2003.

Figure 9. NIO on Windows Server 2003.

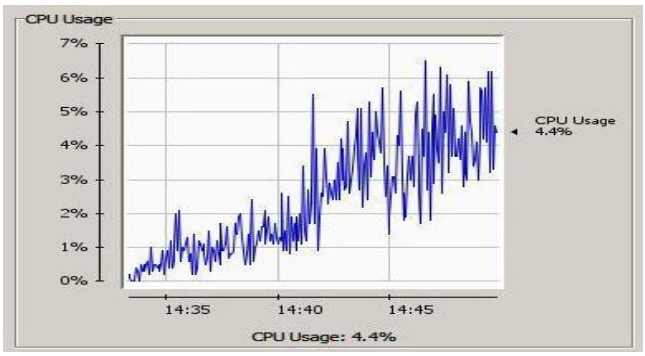

Figure 10. Thread-per-connection on Windows Server 2008.

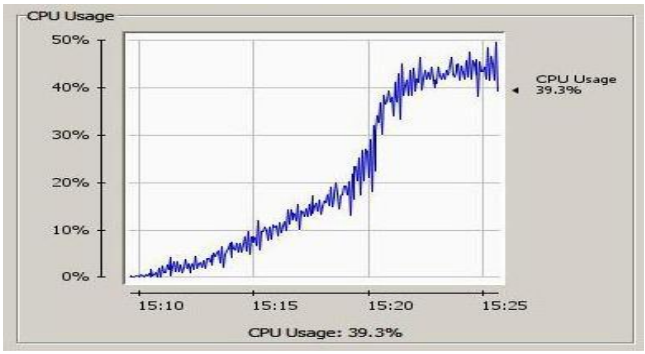

Figure 11. NIO on Windows Server 2008.

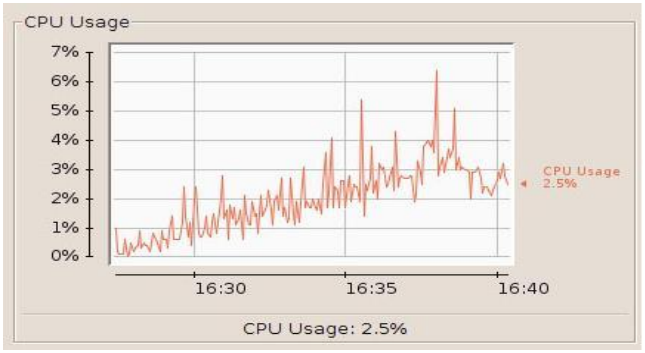

Figure 12. Thread-per-connection on Ubuntu Server 9.

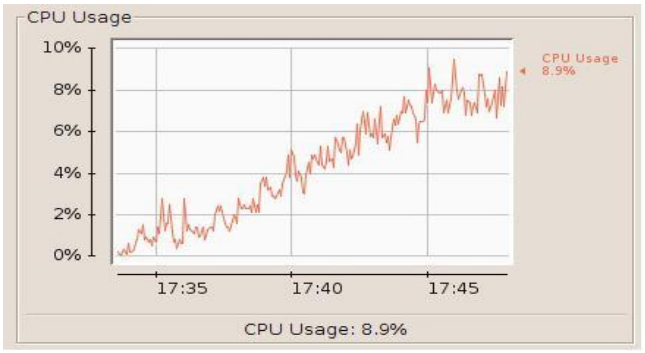

Figure 13. NIO on Ubuntu Server 9.

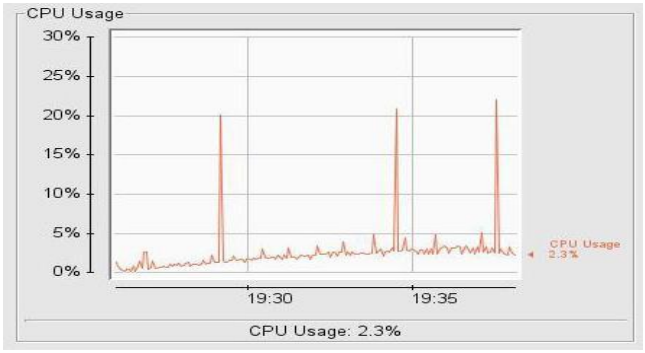

Figure 14. Thread-per-connection on Solaris 10.

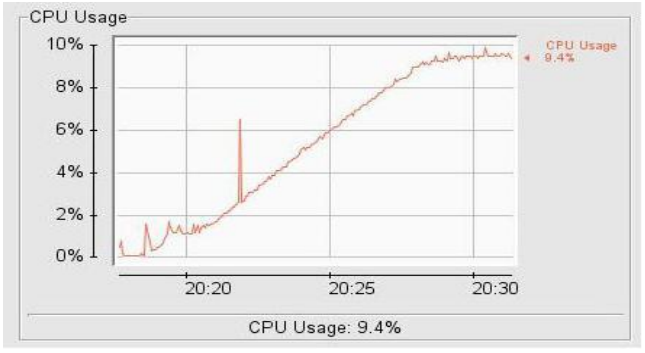

Figure 15. NIO on Solaris 10.

Windows Server 2003 and 2008 showed very similar results. In both, the CPU usage of the thread-per-connection ranged from approximately 4% to 7%, while the NIO CPU usage tended to range from 40% to 50%. This is roughly a tenfold increase.

Ubuntu Server 9 and Solaris 10 also had very similar results to each other. In both cases, the thread-per-connection model usually did not exceed 5% CPU utilization. Interestingly, in Solaris 10 there are a few brief dramatic spikes in CPU usage; the exact reason for this is unknown, but it is perhaps that garbage collection is running briefly and is for some reason taking up more CPU than in the other cases.

With the NIO model in Ubuntu Server 9 and Solaris 10, the CPU utilization did not exceed 10%. Again, this is a significant increase in CPU usage, but only twofold, unlike the Windows systems.

Again, the thread-per-connection model surprisingly outperformed the NIO model in all cases in terms of CPU utilization. This could be for a variety of reasons. One logical reason is that is partially due to the extra overhead the MINA Framework (or any NIO implementation) has of context switching between connections. In the thread-per-connection model, the context switching is handled by the operating system, and it could be that this overhead is not as great. However, Figures 8-15 do not fully capture the CPU utilization for things like thread context switching, because the graphs specific to the Java application. Figures 6 and 7 do show the full comparison of CPU utilization, but it is still clear that thread-per-connection outperformed NIO in these experiments. It is important to consider that, although there may be thousands of threads in the thread-per-connection model, in many circumstances most of the threads are sleeping due to waiting for a request to be received; thus those threads are not taking up any CPU time. They are, however, taking up a considerable amount of memory.

It is also possible that the implementation of NIO using the MINA Framework used in these experiments could be further improved to be more efficient. One improvement may involve finding ways to reduce the frequency that garbage collection is run. However, even if it were possible to drastically improve the efficiency of the NIO implementation, it is important to note that the measurements of CPU utilization of the thread-per-connection model in our environment were quite minor; thus, this model is certainly reasonable in a similar environment if memory usage is not a major concern.

It is interesting to see how Ubuntu Server and Solaris do seem to handle threads more efficiently than the Windows environments. The NIO model in Windows uses approximately five times more CPU than the other two operating systems, however there is not a significant difference of CPU efficiency across operating systems for the thread-per-connection model,

No accurate analysis could be performed on latency since the average latency in every test case was less than 10ms. This is mostly due to the fact that the clients and the server were on the same Local Area Network (LAN). Despite efforts to put a greater load on the server to induce higher latency, an average latency greater than 10ms could not be produced. This is not a great enough distribution to derive conclusions about latency.

5. CONCLUSION

In environments with a similar workload to these experiments, the IO model used is a tradeoff between CPU processing time and memory utilization. This paper demonstrates how the NIO model can be less efficient than the thread-per-connection model in some environments, depending on its implementation. Even if the efficiency of the NIO implementation in this research could be improved, it is clear that it is more difficult to gain this efficiency, and this is something programmers should be aware of. Since the thread-per-connection model uses a minimal amount of CPU resources in these experiments, it is sufficient for this kind of workload.

6. FUTURE WORK

More research needs to be done to see how blocking and non-blocking IO perform when there are more connections and when there is more bandwidth used than in these experiments. There are many other test cases that could be performed which may produce useful results. One such experiment would involve many connections being connected and disconnected throughout the experiment; this would be a more realistic test case for many environments.

6. ACKNOWLEDGEMENTS

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Scanning Email Content for Malicious Links

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ABSTRACT

Email is a common attack vector for phishing, spam and other malicious attacks. Undesired email messages are received by users on a daily hourly or even minutely basis. Currently, there are tools that will scan email attachments for viruses or won't display content until the user allows it; however, there seems to be a lack of tools to analyze other parts of an email. One of these areas is the links contained within an e-mail. In November 2009 ICANN officially started supporting the use of non-Latin characters in URLs. This opens up a whole new attack vector for malicious users to create links that look like credible URLs even when the actual URL is examined. The use of multiple character sets in a URL and links that don't resolve to a credible DNS lookup are things that should make a user more cautious of an email.

General Terms

Algorithms, Experimentation, Security.

Keywords

Email, Security

1. INTRODUCTION

It is common for hackers to send malicious links in an email in attempt to trick users to clicking on them either to send them to a phishing website to collect personal information or to collect information about valid email addresses to compile quality mailing lists to sell.

Distributed Checksum Clearinghouses or DCC has over 250 servers that use a checksum based method for detecting spam emails. Their servers tracked over 300 million email transactions on an average day in 2009. Figure 1 shows a graph from DCC that shows the total number of email transactions along with the possible and probable portions of that email that was spam [2]. The bottom area of the graph in pink shows the number of those emails that are spam, the middle red section is possible spam, with the remainder in blue showing the remainder of the total email going through DCC servers. According to their estimates 53% of the email transactions are likely to be spam with as much as 67% possibly being spam mail. Not only is there a huge volume of email being sent on a daily basis but also over 50% of that traffic is malicious or undesired. This is made possible due to the relative ease and low cost in creating email accounts and sending messages.

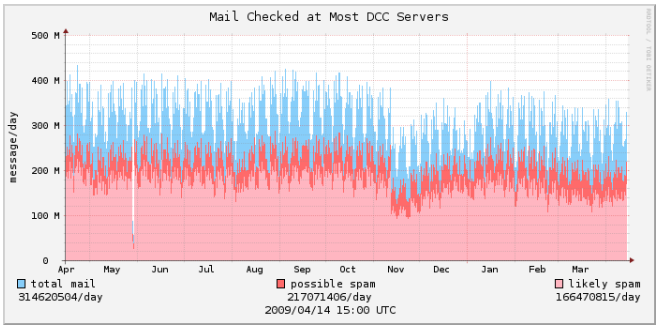

Figure 1. Graph of email and spam mail [2]

On November 16, 2009 ICANN, the Internet Corporation for Assigned Names and Numbers, launched its Fast Track Process which allows countries to include non-Latin characters in Domain Names [4]. While this is a big step forward toward a more internationalized Internet it also provides new issues in the realm of security. Already, the use of characters that look very similar to each other is causing concern and problems in computer security. At the 2008 RSA Conference, Chris Novak talked about how letter substitution is being used as an anti-forensics measure and to perform phishing scams through email. You can see in Figure 2 that the "a" characters look the same in both instances of the word "hack". The top instance uses a Cyrillic character that looks like "a" mixed into the Latin characters where the bottom uses all Latin characters [1].

Cyrillic	h	a	c	k
	\x0068	**\x0430**	\x0063	\x006B
	\x0068	**\x0061**	\x0063	\x006B
Latin	h	a	c	k

Figure 2. Different characters that look the same [1]

For a human it would be nearly impossible to tell the difference but as the figure shows, if the numeric or byte value of the

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characters are examined the difference becomes apparent. Most commonly letter substitution is used to hide files on a machine so a directory looks correct when inspected visually. Letter substitution could also be used to trick users by making new malicious URLs that look like common trusted links.

Which of the following links would bring you to a popular social networking site?

http://facebook.com

or:

http://facebook.com

Would you believe that one of those links contains non-Latin Characters? No matter how closely they are examined it is visually impossible to tell the difference, but the byte value of the "a" in the second link would show that it is Cyrillic not Latin.

In the past attackers have made links such as "http://fake.ru/usersBankSite/login" to try to trick careless users into thinking that the link is going to their bank's website. Now, that visual clue at the beginning "fake.ru" is not required for the attackers. When users see a link such as "usersBankSite.com" they must take a step back and ask if that is the link for their bank, or is that "a" actually from a different character set being used to trick the user into going to a malicious website.

Even for a careful user who is aware of this kind of trick it could be very hard, (if not impossible) to spot a good letter substitution. Microsoft Power Point uses the same visual character for Cyrillic and the Latin "a" which would make it impossible to tell the difference without looking at the byte value. The problem with this is that for a human, inspecting the numeric value of these links would be extremely tedious. Because of this, software is needed to aid users in identifying possible security threats of this kind.

Blacklists are lists of IP addresses that are thought to be associated with spam. Many different approaches are used to create these lists but the purpose is all the same. They provide a means to look up an IP address and see if it is known to be spam. Most email clients compare the IP addresses of incoming email traffic against some form of blacklist. This technology could also be used to do lookups on the IP addresses obtained from a DNS lookup on a link contained within in an email.

Currently many spam attacks have to be sent using many hundreds, thousands or millions of computers to avoid having the spam marked as junk mail by the blacklist filters. If the IP addresses associated with the links within these emails were also blacklisted attackers would have to not only send their spam emails from many locations but also host their malicious content at different IP addresses to try to avoid blacklisting.

We created a tool which when provided a pool of emails would parse through the text to find links. Then once the link is identified could look for multiple language sets in the links and if this test is passed it would do a DNS lookup on the link and compare the resulting IP addresses with a blacklist site. This tool is to be a proof of concept for using this kind of threat analysis and hopefully similar functionality will be added to email clients in the future.

2. METHODS

2.1 System Overview

Our system was developed in Java using the JavaMail API. The basic flow of the system is to open a specified folder in an inbox reading in each email one at a time. As the emails are read into the system it parses out the links from the body of the email and passes the links as strings to a checking method. In this method the links are parsed through byte by byte and the character set for each byte is stored. Once all bytes of the link have been processed heuristics are used to determine whether or not the character sets in the link should be cause for alarm.

If this test is passed the IP addresses associated with the link are then compared to several blacklisting servers to add another layer of checking for malicious links.

2.2 Link Parsing

Each email client has its own method for identifying the links in an email to make them be clickable. If the email is html based this is easy; however, finding a link in plain text email can be tricky. Gmail for instance appears to split the text by spaces and certain special characters and then does DNS lookups on the resulting strings. Outlook Express on the other hand looks for "www" and "http" as a signal that the text is a link and doesn't check what follows. Because of the inconsistencies in how a link is identified by email clients we decided to use a fairly simple method knowing that any email client that implemented this tool would use their own link parsing method. With this in mind the tool simply splits the text by spaces and "<" or ">". The angle brackets are used to separate out the links from html. After splitting the text into smaller strings the system checks for strings that begin with "www.", and "http" (which includes https).

2.3 Character Set Checking

Once a link has been identified it is passed as a String to a method that looks through the link one byte at a time, categorizing the bytes by Unicode character set. Before this byte by byte checking is performed all ".", "/" are removed, as well as any "www", "http://" and "https://" that start the string. This is done because those characters would still be used by URLs that are created with a different alphabet. Once those characters are removed the string is examined one byte at a time to determine which Unicode block each character fits into.

A Unicode byte that starts with a 0 tells us that it represents a full character by itself. When a byte is in the form 110xxxxx we know that the next byte is also part of the same character and is of the form 10xxxxxx [3]. When the value of the byte is less than 128 we know that the byte represents a basic Latin character. If the byte is 128 or greater we need to look at the next byte or two depending on the value of the first byte.

Once we have all the bytes for the character it is converted to binary and the leading bits that are used for the Unicode encoding are removed. For a two byte character this gives us a total of 11 bits. These strings of bits are then put together in order. This leaves us with the binary bits that make the actual decimal value of the character. Once converted to a decimal value it can easily be compared to the decimal ranges for the Unicode character

blocks. The character block that the character came from is then identified and a counter for that block is incremented.

2.4 Blacklist Lookup

Once the entire link has been examined the counters are analyzed. Percentages are created for what percent of the URL is in each character set. For this experiment, it is assumed that if 100% of the characters are not from the same character set, the link is most likely malicious and the tool will return a failure.

If a link passes the character set test it then goes through a blacklist check. The system does a DNS lookup on the link to retrieve all IP addresses associated with that URL. Then a lookup is done for each of those IP addresses against two blacklist sites. More sites could easily be added and there are many more to choose from. For our proof of concept it was decided that two blacklists would be sufficient. If the lookup succeeds, the link is considered to be malicious because it is listed on one of the blacklist sites.

2.5 Output

For our prototype system the results of the character set checking and the blacklist lookup are summarized and displayed in the consol for easy analysis. If this were to be implemented into an email client the return values from those methods could be used to filter the emails into a junk mail box or to alert users of a potential problem.

2.6 Testing the System

The original plan was to test our application against a large pool of real spam mail that was known to have examples of the target problems; however, the use of non-Latin character sets is so new we could not find any examples of this in real world emails or "in the wild". To combat this we had several of my colleagues send hand crafted emails to an email address that was specifically setup for testing this tool. They sent emails with many to no links, some with multiple character sets, some with just one, and some with URLs acquired from the blacklist sites the tool is using for blacklist lookups. This way all of the aspects of the tool received testing to show that the concept is a possible solution.

The test emails contained 23 valid Latin based links, eight links that were supposed to represent what a possible valid non-Latin link would look like, 27 were Latin URLs with non-Latin characters mixed in, and 15 came from blacklists. Within the eight non-Latin URLs two of them were predominately from a non-Latin Character set with the corresponding country code or top-level domain in Latin characters. The 27 Latin URLs with non-Latin Characters contained a valid URL with mostly Latin characters but also contained Japanese characters which led to a Japanese wiki article. In addition to these artificial emails, the tool was run against a personal junk mail folder containing over 600 emails with and without links.

3. RESULTS

3.1 Artificial E-Mails

After running the artificial test emails the results showed almost exactly what was expected. One problem that showed up was some of the links with non-Latin characters seemed to become split at the non-Latin character. This is due to some email clients creating an html version of the email automatically. When this happens href tags which are used to identify a link in html are put around the front part of the link and the part after the non-Latin character was left as plain text. However in these cases the links also appeared in a plain text section of the emails and so each link did properly go through the tool's analysis.

Table 1. Test Results

Type of Link	Total	Expected results	Failures
Latin Valid URL	23	23	0
non-Latin URL	8	6	2
Latin URL with non-Latin Characters	27	26	1
Known Blacklisted URL	15	15	0

Every fully Latin URL such as www.google.com, passed the test without being flagged. In every case where a link used a non-Latin character the use of these characters was correctly identified. When a link does contain more than one character set, like this one http://tēst.com**,** it is assumed to be malicious. However, one of the instances in our test cases was a non-malicious link that used Japanese characters mixed in with Latin characters. The URL "http://ja.wikipedia.org/wiki/日本語", points to a valid Wikipedia page, but the Japanese characters on the end cause it to be marked as malicious by our tool. This shows that our original assumption, that any URL with more than one character set used can be assumed to be malicious, is incorrect.

In the cases where links were simulating a link that is mostly non-Latin all but two passed. One that failed was using Chinese characters with ".cn" for the top level domain. The other was "http://क्स्व्ज्क्नन्द्फ्न्ज्स्द्फज्क.np" which is Nepali characters with the ".np" country code for Nepal. Depending on how the non-Latin character sets become used in real links something may need to be done to account for Latin top level domains with non-Latin characters for the rest of the URL, such as checking the country code and the character sets.

One thing that was not considered before this was links leading to file downloads. One of the artificial links that was provided led to a .doc file. The method for link parsing proposed here was able to handle this correctly. The special characters were removed and the remaining characters were categorized. But this would not work for a file name that is in a different character set that is hosted on a Latin URL. File names may need to be excluded from this type of character analysis.

Each of the 15 instances of blacklisted links that were included in the artificial test emails were identified without any issue. One problem that was discovered with the blacklisting feature is it can add a significant amount of time to processing an email. Links that are not found on a blacklist must timeout. This means an email with a significant amount of valid links could take a frustratingly long time to load for today's impatient users. Because of this the blacklists used must be carefully chosen and using more than one or two would probably not be practical in a real world application.

3.2 Real Spam

Surprisingly out of the 600 emails we ran through our tool not a single blacklisted IP address was found. There were also no non-Latin characters identified. Because the ability to use these characters is so new, this is not a surprise.

4 ANALYSIS

4.1 Artificial Emails

The results of these tests shows that by going through a link byte by byte an email client could identify when more than one character set is being used to create a link. The test case of a valid URL with Japanese and Latin characters tells us that more sophisticated parsing will be needed. The only real clue that the Japanese characters should be allowed is the "ja." at the beginning of the URL. One possible idea is to look for the top level domain or country code of the URL. Then, if the non-Latin character set is from a character set associated with that code a less severe warning could be provided or mixing between those characters and Latin characters could be viewed as safe.

The results seen in the blacklisted links shows us that we can expand the use of a well known technology to provide greater protection for email users.

4.2 Real Emails

Being that the application found no malicious content in the links of the real emails tells us two things. First, using multiple character sets to trick users into following a malicious link has not become main stream. While this was not found in the wild in this project, it is a problem that will be used to attack users in the future. The sooner counter measures are implemented to prevent this from happening; the harder attackers will have to work to utilize this attack vector. Secondly, blacklist sites currently are unable to provide the information needed to assist in identifying malicious links. That being said they could be. If blacklisting services began collecting data based on the IP addresses in the links that are contained within emails that are known to be spam, better blacklists for this information could be created, making them a very useful tool for stronger spam filtering.

5. CONCLUSION

Well over 95% of the malicious links in our test email were identified by this tool. This tells us that the methods we used for analyzing links to identify multiple character sets and performing blacklist lookups are possible to use. If this tool were to be implemented into an email client that client would provide another layer of protection to the user from malicious content. While there were no instances of the use of multiple character sets found in the wild this is a very real attack vector that is more than likely going to become a problem in the future. By implementing protections against the attack before it becomes common could potentially stop many early attacks from being successful. The problem; however, is that a very large percentage of non-malicious links were flagged as malicious. Most of these problems arose from the initial assumption that any link containing a mixture of character sets must be malicious. When the use of non-Latin character sets for URLs becomes more common work will need to be done to modify this tool to account for how these character sets will be used for non-malicious links. It may require ignoring the top level domains, allowing for a small percentage of Latin characters in a non-Latin link, ignoring certain characters that are used universally, or something currently unforeseen. By its nature heuristics are not perfect, but if the methodology can be refined to not provide many false positives, having protection that works some of the time is usually much better than having no protection at all.

The most surprising result was that not a single link, in over 600 spam emails, lead to a blacklisted IP address. More research needs to be done on this to determine if it is because the IP addresses that these links point to, are so spread out that blacklisting will not work, or if the issue is simply that the IP addresses associated with these links are not being blacklisted. If it is the later, we can start blacklisting the IP addresses found from links in known spam emails and build new blacklists to be used to block messages coming from new senders but trying to attack users with links that lead to known malicious hosts.

6. Future work

The main improvements the tool needs are better heuristics for identifying when mixed character sets should be flagged as a possible threat. Experiments with the country codes and character sets especially need to be done. The two areas where the tool did not perform as needed were cases when the alternate character set matched the country code. A new heuristic that allows for mixing Latin characters with those from the character set associated with the country code would be one possibility. Another possibility would be to assign different levels to the threat and mark those links as less severe of a threat than ones with a country code that does not match the character sets.

Work should also be done to determine the validity of using character set analysis for links to documents. A study could be done to determine the likely hood of someone receiving a non-malicious file that has non-Latin characters in the name. If it is highly unlikely then the same or a similar approach could be taken as with links to web pages. Otherwise, something else could be done to make the tool customizable so certain character sets are allowed by the user. This way a Chinese user could allow Latin and Chinese file names, while disallowing Korean characters to be mixed in.

Chris Novak pointed out in his presentation that certain Latin characters (a, c, e, l, i, o, p, s, x, y), were more commonly used in letter substitution than others [1]. Research needs to be done to determine if there is a significantly smaller subset of characters to actually be concerned about. If there is, character analysis tools could be refined to specifically look for those problem characters and hopefully provide greater accuracy and usability.

More testing with blacklisting sites still needs to be done. Only two blacklist services were used in our tool and while they could find links that we knew lead to IP addresses on the blacklist, none of the 600 real emails that we tested had a link that was on either of those blacklists. With so many blacklist providers out there it is possible that one would be better for checking links than others, and comparative testing could be done to look for that. Blacklists are an imperfect solution. It would be impossible to blacklist all malicious URLs due to new URLs or improper identification. There is a new tool proposed that does analysis on a URL and classifies the URL without knowing the contents of the page that it takes a user to. This classification is then used to determine whether or not the site it leads to is malicious in some way [5]. If proven to be effective, this technology could be combined with traditional blacklisting and character analysis to prove a more robust defense for user's email contents.

7. ACKNOWLEDGMENTS

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Sensor Equipped Parking Solution

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ABSTRACT

Everyone who drives a car has at one point or the other come across situations where he or she deals with parking issues. This is seen happening in parking lots of shopping malls to daily work places. As a result of this, people trade off between fuel energy, time and finding parking spaces. In order to reduce this problem, an intelligent parking solution can save much of people's important time and resources. Thus, in this paper, we suggest the use of distance sensors in a parking lot within a zigbee network, to develop a mobile device application to help people find available parking spaces without too much loss of their valuable resources. One main concern with the distance sensors that need to be tested is their usability and accuracy in different weather conditions. Once this is tested, a parking lot will be set up with the distance sensors and implemented within a zigbee network, which will provide the necessary data to feed the mobile phone application; and hence the application users will be notified of their closest parking space.

General Terms

Design, Testing Environment, Parking Space

Keywords

Parking, Distance Sensor, Infrared Proximity Sensor, Zigbee, Mobile Phone Application, Wireless Network

1. INTRODUCTION

Parking lot problems have been of great issue for many years. Many research projects have been carried out to come up with reasonable solutions to create a problem-free parking lot. There have also been researches trying to find out the solution with respect to parking lot designs to make people fight less for parking spaces [1].

Efforts have also been made by comparing different types of sensors, for example acoustic, visible – light, ultrasound, temperature sensors etc. to find out which one would be the best to use in a parking lot [2].

The aim in conducting this particular research is to use distance sensors in creating an intelligent zigbee – enabled parking lot to assist in easy parking solutions.

This research will also help in finding out if the sensors give accurate results in different environmental settings such as temperature that's too low or too high, in a normal day and under rain etc. For example, the distance sensors that may work just fine at 60°F may not produce the same, rather reliable results at -15°F; similarly, the sensors that are dependable in normal dry days may not give consistent outcomes when it rains heavily.

After testing the distance sensor in a variety of weather conditions, a mobile device (iPhone) application can be developed that will assist the vehicle owners to find an unoccupied parking spaces in the parking lot.

The importance of this research study is that the answers obtained through this research can provide a new dimension to the study of the Parking Lot Problem and can prove to be beneficial to the vehicle owners, as they will not have to spend the extra time and fuel looking for vacant parking spaces.

2. HYPOTHESIS

By integrating zigbee nodes in a distance sensors equipped parking lot system, is it possible for the system to function in 80% of the various weather conditions including weather at temperature ranges between below freezing (-20F) and very high temperature (115 F), rainfall, cloudy condition, in a dusty environment and also very humid environment.

3. METHODOLOGY

3.1 Testing Environments

In order to perform this study, the distance sensor was used in the different natural or simulated environments. For instance, to test the sensor at a very low temperature, it was planted underneath a snow pile as well as inside the freezer where the temperature is relatively low (below freezing). To test the sensor under rainy condition, the environment was simulated using water spray. Similarly, the sensor can also be tested for windy and hot weather conditions by using a powerful hair dryer and also by performing the experiments in natural settings.

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Testing environments for the distance sensor:

- Low temperature, without snow
- Low temperature, with snow
- High temperature
- All the temperature range between the lowest to the highest
- Rainy weather
- Dusty environment
- Windy weather

3.1 Working of the Distance Sensor

The infrared proximity sensor was connected with the zigbee such that any distance sensed by the sensor would go as a data to the zigbee.

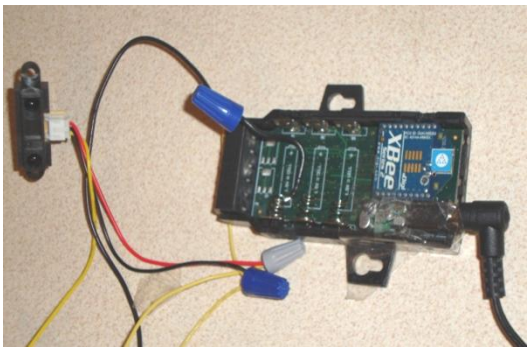

Figure 1. Set up of distance sensor with zigbee

3. 2 Design of the Parking Lot

The parking lot was set up with an infrared proximity sensor. To differentiate between an actually parked car and other objects lying around in the parking lot, for example, twigs and branches, rocks, soda cans etc. two distance sensors were used at the two ends of a parking spot. Thus the proximity sensor was implanted in the parking spot, in the ground so that a parked car would come between these two sensors.

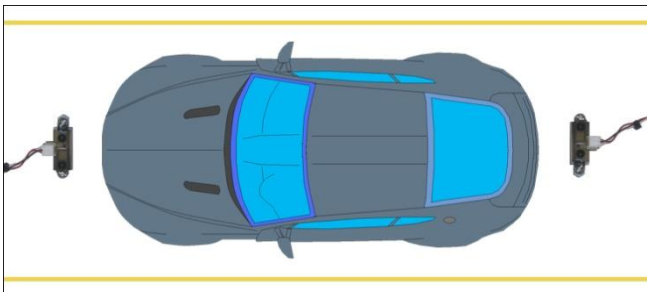

Figure 2. Top view of parked car between sensors

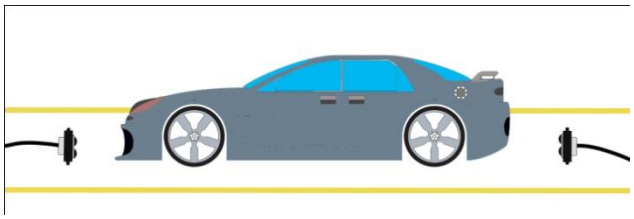

Figure 3. Side view of parked car between sensors

With this setup, a minimum and a maximum distance were set for each sensor. If there is a car parked in a particular spot, the data yield from both the sensors will be much different than that obtained in a vacant parking space. If the data received from the sensor was more than the maximum value set, then the result obtained from the sensor was false for a parked car. The data obtained from the sensors can be translated as follows:

- The data obtained such that both the sensors showed the presence of some object within a certain range at the same time, would translate the data for a parked car.
    - Car_parked = true
- If the data yielded from only one sensor showed the presence of some object within a range and the distance obtained from the second sensor was comparatively out of the range, the data translated into the presence of other small bodies and not a parked car.
    - Car_parked = false

For the prototype and research purposes, only one of this parking lot was established.

3.3 Data Collection

Since zigbee technology is evolving as a form of efficient wireless network technology, we decided to use this very equipment in establishing our required wireless network. Multiple zigbee nodes were used including the gateway to establish the wireless network between the sensors and the idigi platform and the server.

Once the parking lot was set up with the necessary equipments, the infrared proximity sensor and the zigbee network, some raw data were collected to ensure the proper working of the zigbee network. The data was then collected from the sensor which sent the data to the idigi website through a gateway. Our application then received the required data of a particular time from the idigi platform.

Figure 4. Flow of data from sensor to gateway to iDigi to iPhone

This system was tested in weather conditions whose temperature range from below freezing (1.39 F) to high heat (115.75 F). Also in rainfall and dry days with varying humidity. When the information was gathered under which the system's performance was satisfactory, the following step was to gather the acquired data in a simple mobile device application to let the app users know about the parking availability.

After completing the necessary tests for the distance sensor, an iPhone application can be developed that will communicate with the sensors via the zigbee network and provide a real-time parking solution to the drivers using the application by directing him/her to the closest available parking spot.

Although, for the research's scope and testing purposes, the prototype system could be tested with only two zigbee networks, one in the proximity sensor and the other in the gateway, our system was tested with four zigbee nodes: two in each of the proximity sensors, one in the router, and one in the gateway. The results obtained can be extrapolated towards the communication in the system across any number of zigbee nodes and will help in the expansion of the system easily.

3.4 Mobile Device (iPhone) Application

A simple iPhone application will be developed using an iPhone simulator in an Apple Macbook. XCode is the IDE that will be used to code in Objective C and run and test the application.

It will also be interesting to analyze if all or many of the parking lots can be equipped with this kind of wireless system. Thus making a standardized parking lot with this wireless system and the possibility of making the mobile device application available to all will can be studied and analyzed.

4. RESULTS

4.1 Results from the Experiments of Distance Sensor

The results obtained from the experiments performed showed that the infrared proximity sensor provided satisfactory results in most of the weather conditions. The two summary table given below show the range of temperature in which the experiments were performed, what weather conditions were the sensor tested under and what kind of results were obtained from each of the experiments.

Table 1. Results from tests in varying temperatures

Temperature (°C)	Temperature (F)	Sensor Works
Below -17	Below 1.39	No
-17 to 46.53	1.39 to 115.75	Yes
Above 46.53	Above 115.75	No test performed

As shown in the table the proximity sensor worked very well for the temperature ranging between 1.39 F to 115.75 F but did not work for temperature below 1.39 F. It also yielded very accurate results for very high temperature (115 F). Considering the fact that the temperature of 115 F is very high and the record high temperatures in the last 15 years has not exceeded 106 F, experiments were not performed for temperatures higher than 115 F.

Similarly, experiments were also performed to test the results of the sensors in varying levels of precipitation, windy and dusty environments. The sensors worked normally under most kinds of precipitation environment including drizzle, rain, and light snowfall.

Table 2. Result from tests in different precipitation

Condition	Sensor Works	Correct Results
Clear Day	Yes	100%
Drizzle	Yes (but not accurate)	67%
Light Rain	Yes (but not accurate)	50%
Heavy Rain	Yes (but not accurate)	50%
Light Snow Fall	Yes (but not accurate)	50%
Snow Fall	Yes (but not accurate)	33%
Windy Environment	Yes	100%
Dusty Environment	Yes	86%

However, if there is a considerable amount of snow piled in front of the proximity sensor, the sensor will return a value for the presence of some object in the parking spot. Since the infrared proximity sensor used in this research emits the infrared, which propagates through the air and is reflected back on the sensor once it hits any object, it does pretty much the same thing for the snow during snowfall. The proximity sensor does not tell us what object is right in front of it but only tell us that there is some object present before it.

The following graph summarizes the accuracy of data obtained from the distance sensor with the increased level of precipitation.

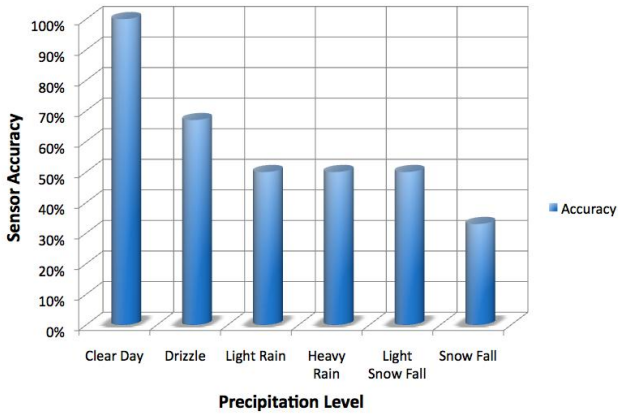

Figure 4. Accuracy of data obtained at different precipitation levels

4.2 iPhone Application

After all the tests were performed and the data were received, the next step was to be able to export the data on to the iPhone in real time. A sample application was created using the java.net.URL library in Java to request the data from the device, which gave an expected output of the data from the experiments.

Similar approach can be considered while developing the iPhone application to help the app users to find an available parking in a parking lot that uses this system. Following are the screen shots of the input and output screen of the iPhone application.

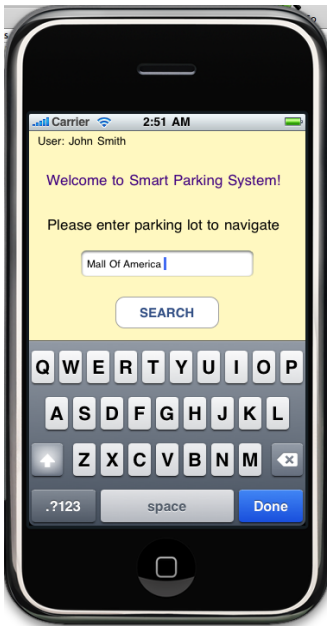

Figure 4. Screenshot of iPhone app input screen

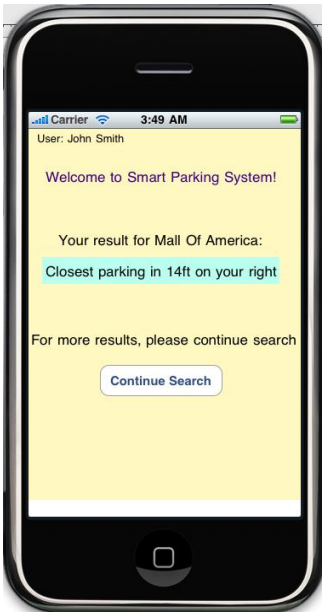

Figure 5. Screenshot of iPhone app output screen

5. ANALYSIS

Use of zigbee nodes to establish a wireless network proved to be an efficient, energy saving tool in the overall design of the parking lot. It is indeed possible to get real time data from the parking lot where the infrared proximity sensor used to let the users know of what parking spaces are available.

One helpful observation made from the experiment was the fact that using two distance sensors in the parking lot was more beneficial than using just one. This helped us differentiate a parked car from the other objects such as a soda can, twig, human being or any other object present in the parking spot. The use of one distance sensor did give the desired result when an object came before the sensor; but since any other object would give the same result as a parked car, using two of the distance sensors helped in figuring out the difference between them. This was possible by giving each of the sensors a maximum value to check.

From the experiments, we can see that it is possible for the users of the application to be notified of the available parking space closer to them. Since this parking system will help the drivers find a parking space much faster, it will contribute towards saving his time, fuel, money and his anxiety.

One thing to keep in mind however is the fact that from the experiments conducted, we can see that the infrared proximity sensor did not give us any result below 1.39 F. However, it worked perfectly for a very high temperature of up to 115 F (and could yield results for even higher temperature). Similarly, the experiments in a clear weather condition, without any rain or snow proved the sensor to work fine. But the sensor only gave a 50% accurate result for weather conditions with rainfall and only 33% accuracy during snowfall. Also, the sensor worked very satisfactorily under windy and dusty environments.

These results help us understand that using infrared proximity sensors in an area which may get heavy snow or whose

temperature can go below 1F during cold seasons is not a good idea. The system that uses the infrared proximity sensor can be very helpful in areas such as southern United States which does not receive snowfall for a long period of time or whose temperature is stable between 35 F and 98 F around the year. But areas in the colder part of the United States such as Minnesota, Wisconsin etc. that receive a record low of -20 F and snowfall for a considerably larger time period, such smart parking lot systems may have to be designed using appropriate proximity sensors.

The other point to be noted in this system is positioning of the sensors in the parking lot. Many different parking lots are designed in different ways. In some parking lots, placing the sensors in the ceiling can be more effective than planting them on the ground. For parking areas nearby the curb, planting the sensors right on the curb can be one way to set up, but in parking areas with open spaces and without a ceiling, a different approach may have to be applied.

Wherever the sensors are placed, we need to ensure that it has been placed in the parking spot such that it does not get destroyed by a vehicle.

With the parking lot set up with all the necessary sensors and the system ready to work, one problem to address would be to handle a situation when the system returns the same parking space at one time for two or more vehicles trying to find a parking lot.

If these issues are worked on according to how a particular parking lot is designed, setting up the system can be a task that can begin without much problem.

6. CONCLUSION

The main objective of this research project was aimed to understand whether or not the using the distance sensor in establishing a smart parking lot was possible under various weather conditions. Thus by integrating zigbee nodes in a distance sensors equipped parking lot system, we found out that is it possible for the system to function in 67% of the various weather conditions including weather at temperature ranges between below freezing (1 F) and very high temperature (115 F), rainfall, cloudy condition, in a dusty environment and also very humid environment. And if it worked in the different weather conditions, a mobile device application such as an iPhone app can be developed by acquiring the data from the sensor. This will help the vehicle owners using the app, find a parking spot very easily in a busy parking lot. In addition to this, this system will contribute towards saving fuel, time and energy of the app user.

7. FUTURE WORK

The addition to this project will be developing a complete mobile device application that is integrated with the parking lots to use the data in helping the users find a free parking space. This can done by creating a protocol that can talk to the GPS system to start downloading the details of the parking lot as an app user approaches near it, so that the application can display where all the available spots are.

Another good implementation that can be done using this system is the improvised parking reservation mechanism. With the help of this parking system, the vehicle owners will be able to reserve a parking space in a lot so that the reserved spot does not show up for any other driver in the parking lot. This way, the one who has not reserved the parking spot will not be directed to that spot but someone who reserved that spot will have a secured parking spot.

The system can also be useful in integrating with the parking lot billing system. This can help to figure out how long the car was parked, and how much the person should be charged if he needs to be charged in an hourly basis.

Since the mobile device application is not device specific, the application for the system can also be developed in devices with different platform. In this paper, we have discussed about developing the application in the iPhone. But the same implementation can be done in other platforms and devices such as Android, Windows mobile devices, Blackberry, or the parking lots' own digital display device such as a wide screen monitor to locate a driver's current location and the closest parking spot.

8. ACKNOWLEDGEMENT

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Political Campaigns for the 21st Century: Are Electronic Records more Efficient?

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ABSTRACT

The intent of this research paper was to examine whether migrating data for political campaigns to twenty-first century technologies will increase the efficiency of collecting data. A usability study was conducted that consisted of a sample population of ten students from Winona State University. The results of the usability study indicate that using an iPhone, as a vehicle for collecting voter preferences is more efficient than the traditional paper walk-lists that are currently being used during political campaigns.

General Terms

Measurement, Reliability, Design, Human Factors, Experimentation

1. INTRODUCTION

The election of Barack Obama in 2008 brought computer science to the forefront of political campaigns. The rise of social networking sites such as Facebook and Twitter increased participation among young people in an unprecedented way. SMS text messaging, YouTube, and dynamic web applications provided a vehicle for supporters to tune into every moment of the campaign, and this is just the beginning. Political campaigns are transforming into technological machines. The Obama campaign developed a program called "Houdini," which allowed the campaign to verify every identified supporter of Barack Obama and whether they voted on Election Day [1].

Every year in this country there is an election, whether it is Congress, the Presidency, or a local school board race. There is a need to collect data from voters, perform analysis on that data, and target voters who are likely to agree with a particular candidate or campaign on the issues. Currently, major political parties have a central database of voter information. They have identified by a number of factors which indicate who is likely to be a Democrat, Republican, or an independent. Volunteers call potential voters or go door-to-door asking voters their preferences. Volunteers write down responses given to them by voters they have contacted. Once the volunteers finish the walk or call list, the data collected is entered into a database. Mistakes are frequently made during this transaction of data. Incomplete or poor handwriting leads to inaccurate information.

Digital medical records have increased accuracy, legibility, and reduced costs in our health care system [2], and the same rationale should be applied to transitioning the archaic system of identifying voters to increase efficiency in the data collection process. The Mayo Clinic in Rochester, Minnesota, implemented digital medical records to improve patient care [3]. The same approach can be applied to elections and the ways in which campaigns and parties contact voters. Many other questions can be raised when discussing digital campaign walk lists. Do digital campaign walk lists increase voter contact? Can fewer volunteers contact more voters? Although these are important questions, they are outside of the scope of this project. The focus of this project is to determine if contacting voters can become more efficient. Electronic Health Records (EHRs) have made patient care more efficient [4]. We believe that electronic voter records and the electronic acquisition of voter data will provide the same benefit to the political world.

2. BACKGROUND

The motivation behind the creation of electronic medical records was to improve the quality of patient care [2]. The same motivation can explain the recent increase in electronic voter records that major political campaigns/parties have been using throughout the past decade. Political parties using electronic records will allow political campaigns to easily access their supporters. In other words, political parties would contain a "master list" of voter information gathered from the several states, and various political campaigns can utilize this information to benefit their campaigns.

Electronic voter records have helped change the landscape of elections for the distant future. In local and statewide races, electronic voter records have served as a pseudo-means for campaign finance reform. Local races are usually not allowed to spend as much money as federal elections [2]. However, having a nationally compiled list of voters, local and statewide candidates

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can focus more on talking with voters, and determining what needs to be improved within the area, rather than focusing on fundraising.

The purpose of using electronic voter records has two distinct advantages. Foremost, the ability to utilize mobile devices to connect with a centralized voter database, and secondly, to improve the efficiency of entering data from newly contacted voters. Using mobile devices to collect voter information, specifically party, candidate, and issue preferences, will greatly increase the efficiency of collecting voter data.

3. HYPOTHESIS

Migrating campaign walk lists to a mobile device will increase efficiency by at least twenty-five percent.

4. METHODS

Software development was utilized in order to shed light on the hypothesis. This project has two major software components: a desktop application and an iPhone application. The software engineering practice that was used for this project was agile development. Agile development worked well for this project because it was broken up into one-week sprints, which composed of a realistic task list. The project was completed early in the semester to perform a usability study on the software.

Both the iPhone and desktop applications were developed following object oriented design principles. The strategy that will be followed to complete this project is as follows:

- Prototype of desktop application
- Prototype of iPhone application
- Write pseudocode of algorithms
- Create skeleton of desktop application
- Create skeleton of iPhone application
- Implement algorithms from pseudocode
- Document code

These steps were refined and broken into sprints with specific tasks for each sprint, and these were completed each week.

In order to verify that the proposed hypothesis is correct we conducted usability studies on a sample population of students. The hypothesis proposes that the efficiency of digital records will increase the process of collecting voter preference data by at least twenty-five percent. The sample population was ten students from Winona State University, and they filled out ten different campaign walk lists. They then wrote down notes for each person that they interview to collect voter preference data. Once the voter preference data was collected, the student then entered their findings into the Java desktop application. The time was recorded to determine how long it took the students to enter data into the application. Once the data was entered into the voter preference application, the first part of the study was complete.

The second part of the study will be conducted with the same students from the first part of the study. The only difference is they will be using the iPhone voter preference application. Ten students will once again ask their partners to simulate an exchange between a potential voter and a volunteer. The students will enter in the information provided by their partners. The data collected from part two will be compared with part one. Calculations will then be conducted to see if the mobile application is more efficient. It could be argued that collecting voter preference data with the iPhone second supports a bias. This argument is not valid due to the directions given to the student participants. The students asking the questions were given a script from which they read, which explained why they were speaking with them today, who they supported in the upcoming election, and what they thought was the most important issue of this election. The students responded to questions from a uniform script, but the responses to each question verified. Occasionally, the participants agreed to follow along with the questioner, and at other times acted like they were not home, or choose not to respond at all. This experiment truly was a theatrical display of actual conversations that occur when door knocking.

The results from the second part of the study were compared with the first part of the study. In order for the hypothesis to be correct, the second part of the study should take significantly less time to complete reporting.

A few things need to happen before the previous statement can be addressed. First, an application must be created on both a mobile device and a desktop computer. For this particular problem, iPhone OS will be the platform of choice. IPhone applications are written in Objective C, Xcode, and Interface

Gerald Strauss	**Candidate**: 1 2 3 4 5
426 West 8th Street	**Issue**: 1 2 3 4 5 6 7 8
Winona. MN 55987	**Availabilitv**: H. NH. MV. RF

5. EXPERIMENT

The experiment was designed to determine whether it was more efficient to use an iPhone application over traditional campaign walks lists. Campaign walk lists are a targeted list of voters that a campaign needs to communicate with. Each voter name on the walk list is associated with preference data. The preference data can range from whom they feel will best represent the country as president through which issue they feel is most important this election season. The following diagram will provide an illustration of a segment of a campaign walk list.

As you can see there are three different things that are of interest when talking with a voter: candidate preferences, issue preference, and whether or not they were available to speak. Candidate preferences are labeled one through five, one being strong Democrat and five being Strong Republican. Issue preferences are labeled one through eight and have the following meaning:

1. Education
2. Labor
3. Health Care
4. Jobs

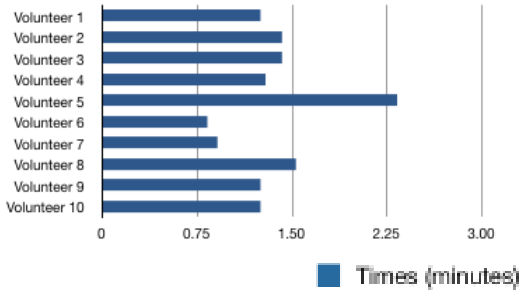
5. Economy
6. Energy Reform
7. Urban Planning
8. Social Security

Availability is concerned with whether the volunteer was able to speak with the voter, and the abbreviations are defined as (H) Home, (NH) Not Home, (MV) Moved, (RF) and Refused. It was explained to all of the students what these abbreviations meant before the experiment took place.

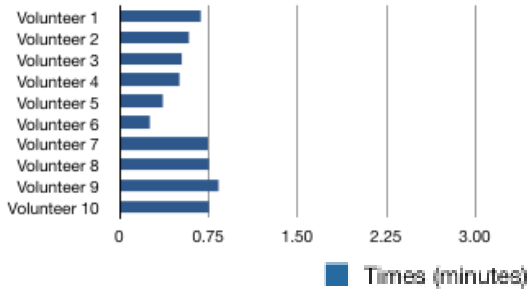
The experiment consisted of students role-playing a volunteer speaking with a voter. The students proceeded to ask each other questions that would yield a result from each possibility. By doing so resulted in a real-world set of results. The students queried each other using paper walk-lists, and then entered their findings into a Java desktop application. Once the students completed entering their results into the Java desktop application the experiment was repeated using the iPhone application. Again, students queried each other maintaining integrity in the results by going through all possible responses.

6. RESULTS

The results from the experiment confirmed the hypothesis. It is more efficient to enter voter preference data on an electronic device than it is handwriting voter preference data, and then entering that data into a computer application. There are two graphs displayed in this section; Graph 1 and Graph 2, which display the times of entry for the iPhone and desktop applications. For the most part, people who work on campaigns tend to be more tech savvy, and it is reflected in the campaign portion of the experiment. The argument could be made that if experiment was conducted with an older generation that the iPhone application would have had slower times.



Graph 1. Paper walk-list plus data entry time



Graph 2. IPhone data entry time

7. SOFTWARE USED

Two pieces of software were required for this experiment; a desktop application and an iPhone application. The requirements for the desktop application are as follows.

- Retrieve voter information
- Enter new voters
- Enter updated voter information
- Search for voters

The requirements for the iPhone application are similar in nature.

- Display a list of voters to contact
- Selection box for candidate preference
- Selection box for issue preference
- Selection box for voter availability

The desktop application was written in Java and has a graphical user interface (GUI) that users interact with. The GUI was designed using NetBeans GUI developer for Windows. The iPhone application was written in Objective C with the assistance of Interface Builder and XCode for Mac OS X. Tables 1, 2 and 3 display how the iPhone and Java desktop applications look, and how the users would interact with them.

Table 1. IPhone List View

Table 2. IPhone Voter Preference View

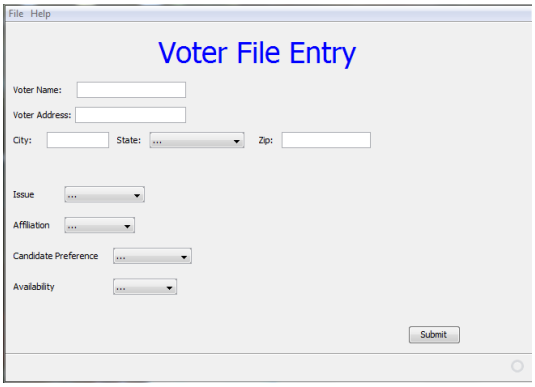


Table 3. Java Application View

8. ANALYSIS

There was a 54% improvement over the traditional paper-walk lists, and the iPhone application. This is not surprising considering there are two steps involved with the traditional paper-walk lists compared with one for the iPhone. The spread of improvement was 19% through 85%. Some students took longer to gather information because of the confusing process involved with paper walk-lists. Often times when students entered data into the desktop application it took longer than expected due to the quick writing involved and the resulting difficulties in reading the handwriting. This is a potential issue for errors with the paper walk-lists.

9. FUTURE WORK

Looking forward there are several enhancements that could be made to this software to make it an actual campaigning tool: adding functionality such as database connectivity, Google maps, and adding additional views to the application, specifically detailed voter data. Having the iPhone application connect to a remote database will allow each user to contact voters within a specific precinct [5] mimicking existing practices within political campaigns. Once the list of voters is loaded into the application, all of the houses to be contacted will appear on a Google map that is customized for that particular precinct. As volunteers are guided through their assigned precincts by the GPS connectivity that is built into the application, contacting voters may no longer be a choir. Something else that is lacking from the existing iPhone application is specific information about the voter. When contacting voters door-to-door it is useful to ask them if they would like to volunteer, host a yard sign, and give monetary contributions. If the iPhone application had these functionalities incorporated it would be an even more useful campaign tool.

10. CONCLUSION

The purpose of this project was to determine whether mobile devices in political campaigns made a difference. After examining the results from this experiment it is evident that mobile devices can speed up the voter contact process. The ten test subjects verified this by completing paper walk-lists and entering the results in a computer application, then repeating the experiment using an iPhone application to record voter preferences. The students were confused while using the paper walk-lists to record information. The walk-lists have a lot of information and it is difficult to fit everything in the small space provided, therefore it is necessary to have voter preference data assigned to a key value. The key value can be determined by looking at an additional piece of paper that identifies each piece of voter preference data, and displays the assigned value. The results reflect the difficulties the students had when completing the experiment. Students were much more receptive to the iPhone application as they only needed to enter voter preference data once. As most students have already had previous experience using iPhone and Android applications, the learning curve was minimal.

11. ACKNOWLEDGEMENTS

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