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1 Abstract

Statistics show that the diabetic population in the United States currently tops over 16 million (1). 4.9 million of those with diabetes are reliant upon daily insulin injections for survival. In order to maintain the acceptable health condition, insulin-dependent diabetics must strictly adhere to their prescribed regimen. However the prescribed daily insulin injections can become quite numerous, up to six times every single day. Over time, these injection points become tough and calloused forcing the diabetic to rotate injection areas. To receive their insulin dosage, diabetics must live under the continuous cycle of painful glucose testing, meticulous dosage measurement, and insulin injections. This regimen must be performed at various times throughout the 24-hour day. If the task of insulin dispensing seems overly complicated at 3 in the afternoon, imagine the difficulty the insulin-dependent diabetic must overcome at 3 in the *morning*. A single mistake or oversight on the part of the diabetic in just one of the phases of the regimen could prove to be life threatening.

According to Eli lily and DCCT, many diabetics do not follow their insulin regimen. Our solution plans to ease the responsibility of the insulin diabetic. Our device will offer a virtually non-invasive method of controlling diabetes that will require minimal input from the wearer. We believe that given this simplified insulin administration protocol, insulin-dependent diabetics will be more likely to maintain their regimen.

2 Description

According to a research conducted by DCCT (Diabetes Control and Complications Trial), there is no substitute for healthy dietary and exercise routines and blood sugar control to prevent serious complications and perhaps even early death. Furthermore, DCCT in a ten-year study has concluded that if the blood glucose levels were kept close to normal, the complications caused by diabetes are likely to be less severe (2). The present diabetic regiment is very painful which involves finger pricking, injecting insulin in to bloodstream and on top of it, it requires a lot of mental stamina and also it is demanding. *Diagram 2.1* illustrates the disjointed nature of the current insulin prescription regimen. The current regimen is non-automated and requires the user to implement all of the elements of the insulin regimen.

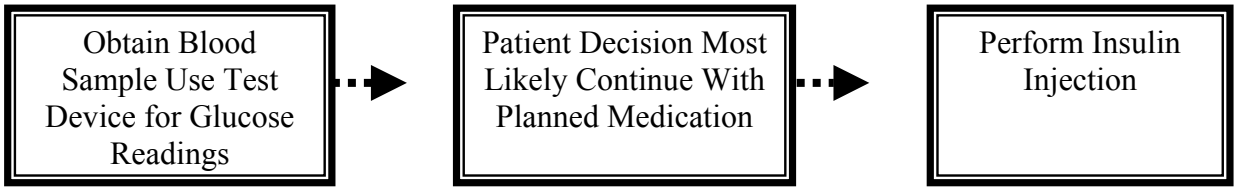


Diagram 2.1

Our goal is to develop a small "watch-like" prototype. That will successfully monitor the blood glucose levels every twenty minutes. This device helps diabetic patients to keep track of their blood sugar levels (5). The computational device will dispense insulin accordingly to the readings obtained from the watch-like device. This "automated" non-invasive blood glucose tester will help integrate the glucose level reader with insulin dispenser. Its associated software is the critical interface that will merge two technological advances into a practical diabetic medication device as depicted in *Diagram 2.2*.

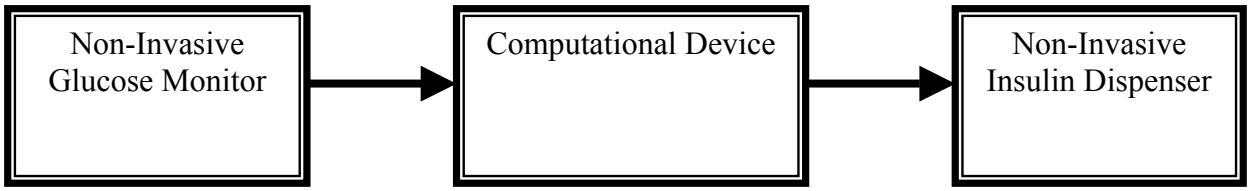


Diagram 2.2

The major components of the product include a monitoring device to monitor glucose levels every 20 minutes and a dispensing device, which can be controlled internally. These two products are available off the shelf. The Food and Drug Administration have recently approved Cygnus, Inc. product GlucoWatch Biographer for consumers designed to measure glucose levels frequently, automatically and non-invasively (3). The frequent and automatic measurements provided by the GlucoWatch Biographer can identify blood-glucose trends and track patterns in fluctuating glucose levels that would be difficult for people with diabetes and their health care teams to detect using current testing techniques alone. The GlucoWatch Biographer provides readings frequently up to three times in an hour. The device is intended for use by patients anywhere. The GlucoWatch Biographer is indicated for use in detection and assessment of episodes of hyperglycemia and hypoglycemia. The GlucoWatch Biographer differs from other glucose monitoring systems in several ways. It is non-invasive, collecting glucose through the skin and not from the blood. It automatically measures and displays glucose levels and detects trends and patterns in glucose levels as opposed to a single, discrete reading. It has alert systems to inform users when glucose levels are too high, too low or declining rapidly (14). The Biographer can store up to 4000 values in an electronic diary that can be reviewed at the touch of a button or uploaded into a software program to enable detailed analysis of glucose fluctuations. All this advantages makes the GlucoWatch biographer a number of components for our device. This would be a device that we would develop further to achieve our goal.

The third main component in our device is the insulin patch, which is used to deliver insulin continuously. We will make use of the newly approved Ustrip technology (10). These patches are placed on the skin to provide a continuous, low level of insulin, controlled by an ultra sound device, which will help in increasing or reducing the skin permeability. The ultra sound device, which is built in to the patch, is useful because of the highly impermeable stratum corneum (the skin) to most large molecule. The ultrasound is another area where researchers are using to increase skin permeability. These devices deliver low frequency sound waves to induce thermal, chemical and mechanical alteration in the skin tissues. Studies already done in rats and rabbits have shown to increase the permeability of skin by a thousand fold (12). Helix BioPharma, a company from Canada, is developing a transdermal patch containing insulin and shown significantly reduced glucose levels as a result. In Germany, IDEA is conducing phase one trials for transdermal insulin that uses its tranfersomes drug delivery system (15). This is being tested at the WHO diabetes reference center and is available for licensing. Once this component is available which won't take too long, components required to develop our product will have been acquired.

3 Diabetes Overview

Diabetes typically is a chronic, progressively debilitating disease whereby the body loses its ability to maintain normal glucose levels. Insulin is secreted by groups of cells within the pancreas called islet cells (4). The pancreas is an organ that is behind the stomach and has many functions in addition to insulin production. The pancreas also produces digestive enzymes and other hormones. Carbohydrates are absorbed from the intestines into the bloodstream after a meal. Insulin is then secreted by the pancreas in response to this detected increase in blood sugar. Most cells of the body have insulin receptors, which bind the insulin, which is in the circulation. When a cell has insulin attached to its surface, the cell activates other receptors designed to absorb glucose from the blood stream into the inside of the cell. Diabetes is the sixth leading cause of death by disease in the United States and has no cure. Diabetes can lead to severe long term health complications, including blindness, kidney disease, heart disease, stroke, nerve damage and peripheral vascular disease, potentially leading to amputation. The American Diabetes Association, or ADA, estimates that 15.7 million people or 5.9% of the population in the United States have diabetes (6). The ADA estimates that in 1997 total U.S. healthcare expenditures incurred by people with diabetes exceeded $75.0 billion and diabetes-related hospitalizations totaled 13.9 million days, with a mean length-of-stay of 5.4 days (6). Current methods for measuring glucose, whereby skin is lanced and a blood sample is obtained for measurement, are painful and inconvenient to the user. The vast majority of people with diabetes do not perform frequent glucose testing, despite substantial clinical evidence of the benefits of more intensive diabetes management. The ADA estimates that on average people with diagnosed diabetes test their blood glucose levels slightly more than once per day (1).

4 Managing Diabetes

Current methods for measuring glucose, whereby skin is lanced and a blood sample is obtained for measurement, are painful and inconvenient to the user. The vast majority of people with diabetes do not perform frequent glucose testing, despite substantial clinical evidence of the benefits of more intensive diabetes management.

The ADA estimates that on average people with diagnosed diabetes test their glucose levels slightly more than once per day.

4.1 Good Sugar Levels

It is very important that a diabetic follows the treatment that his/her doctor or diabetes nurse has advised. Diabetic person will feel much better if his/her blood glucose levels as near normal as possible. Blood glucose levels are measured in millimols per liter of blood. This is shortened to mmol/l. Diabetic patient should aim for a level of 4 - 7 mmol/l before meals, rising to no higher than 10 mmol/l two hours after meals, according to Dr. Michael in an interview. The doctor or diabetes nurse will advise diabetics on what is best for them (8). After a number of years, diabetes can lead to serious problems in your eyes, kidneys, nerves, gums and teeth, and blood vessels. The best way to take care of diabetic health is to work with the doctor to lower high blood sugar. People with diabetes should consult their health care providers for individual guidelines on target blood sugar ranges that are best for them. The lowest safe blood sugar level for an individual varies, depending on the person's age, medical condition, and ability to sense hypoglycemic symptoms.

4.2 Hypoglycemic

A target range that is safe for a young adult with no diabetes complications, for example, may be too low for a young child or an older person who may have other medical problems. Because they are attuned to the symptoms, people with diabetes can usually recognize when their blood sugar levels are dropping too low. They can treat the condition quickly by eating or drinking something with sugar in it such as candy, juice, or non-diet soda. Taking glucose tablets or gels (available in drug stores) is another convenient and quick way to treat hypoglycaemia. People with Type 1 diabetes are most vulnerable to severe insulin reactions, which can cause loss of consciousness. A few patients with long-standing insulin-dependent diabetes may develop a condition known as hypoglycaemia unawareness, in which they have difficulty recognizing the symptoms of low blood sugar. For emergency use in patients with Type 1 diabetes, physicians often prescribe an injectable form of the hormone glucagon. A glucagon injection (given by another person) quickly eases the symptoms of low blood sugar, releasing a burst of glucose into the blood. Emergency medical help may be needed if the person does not recover in a few minutes after treatment for hypoglycaemia. A person suffering a severe insulin reaction may be admitted to the hospital so that blood sugar can be stabilized. People with diabetes can reduce or prevent episodes of hypoglycaemia by monitoring their blood sugar levels frequently and learning to recognize the symptoms of low blood sugar and the situations that may trigger it. They should consult their health care providers for advice about the best way to treat low blood sugar. Friends and relatives should know about the symptoms of hypoglycaemia and how to treat it in case of emergency. Episodes of hypoglycaemia in people with Type 1 diabetes may become more common now that research has shown that carefully controlled blood sugar helps prevent the complications of diabetes. Keeping blood sugar in a close-to-normal range requires multiple injections of insulin each day or use of an insulin pump, frequent testing of blood glucose, a diet and exercise plan, and guidance from health care professionals (9).

4.3 Hyperglycemia

Hyperglycemia is when a diabetic blood sugar stays over 13.3 mmol/l (1). High blood sugar usually comes on slowly. It happens when a diabetic don't have enough insulin in his/her body. High blood sugar can happen if diabetic misses taking diabetes medicine, or eat too much, or don't get enough exercise. Sometimes, medicines diabetics take for other problems may cause high blood sugar. Having an infection or being sick or under stress can also make a diabetic's blood sugar too high. That is why it is very important to test ones blood and keep taking medicine (insulin or diabetes pills) continuously, especially when a diabetics have an infection or are sick. Diabetics' blood sugar may be too high if you are very thirsty and tired, have blurry vision, are losing weight fast, and have to go to the bathroom often. Very high blood sugar may make Diabetics feel sick to their stomach, faint, or throw up. It can cause diabetics to lose too much fluid from their body.

5 Insulin

5.1 Insulin Syringes

For now, insulin is injected subcutaneous (under the skin) to be effective. Injection with a needle and syringe—which, for years, was the only available option—remains the predominant choice for most insulin-treated patients in the United States today. Fortunately, the devices currently available—disposable, lightweight syringes, with shorter, ultra fine needles—have made daily injections more convenient and less painful than ever before. With proper training and practice, most people with diabetes become extremely proficient at self-injection. One advantage of syringes is the wide variety of sizes and styles. When deciding what is most appropriate for diabetics needs, consider the syringe capacity, ease of use, and readability. Syringes may also be best for those who must mix different types of insulin into one dose; pen injectors offer less flexibility. Syringes and insulin vials are bulkier than insulin pens, and may not be convenient for people with active lives. In addition, manipulating syringes and vials may be too difficult for people with limited manual dexterity—for example, those with arthritis or tremors.

5.2 Insulin Pens

Insulin pen injectors combine an insulin container and syringe into one compact device. Two types are available: reusable and prefilled. With reusable pens, patients load a cartridge of insulin into the pen, attach a needle, and "dial in" the dose before pressing a plunger to administer the injection. The prefilled pens are easier to use—they contain a built-in insulin cartridge, and are discarded after the insulin is gone—but they may be more costly than reusable pens. Insulin pens are more convenient and portable than syringes and bottles of insulin. In addition, patients are often more accurate at measuring doses with pens than with syringes. Some patients find using insulin pens more comfortable than using syringes; because the pen needle does not have to penetrate a rubber stopper first, it is sharper and the injection may be less painful. However, the pen needle must be left in the skin slightly longer than with a syringe injection. Pens may be easier to use than syringes for people with poor physical coordination. Some pens have large-print numbers and an audible click to measure the dose as it is dialed in, which may benefit those with impaired vision. Pens may not be the best choice for people who must take very large insulin doses. A major drawback to most pens is that they do not permit you to mix different types of insulin; thus, two injections are needed. One new model, however, allows patients to fill the pen from a standard insulin vial, and thus to personalize mixtures of insulin. Pens are somewhat more expensive than syringes.

5.3 Jet Injectors

Jet injectors use a high-pressure jet of air to send a fine stream of insulin through the skin. While the elimination of needle sticks may sound appealing, these devices have had only limited use so far. Jet injectors deliver accurate doses that are more rapidly absorbed than subcutaneous injections. They may be of particular benefit for patients who have an extreme fear of needles. These devices are bulkier than syringes, however, and also require the user to carry vials of insulin. They must be cleaned every two to three weeks (though newer models have disposable nozzles). Some people find jet injectors no less painful than needles. They may still cause pain and bruising at the injection site, and can damage the skin if not used properly. Jet injectors are expensive.

5.4 External Insulin Pumps

Recent technological advances have lead to smaller, easier to use, and more comfortable external insulin pumps—making them an ideal option for carefully selected patients. About the size of a pager, these computerized devices are usually worn discreetly on a belt or placed in a pocket. Insulin passes from a reservoir within the pump, through a thin, flexible tube, to a fine needle inserted beneath the skin and taped in place. Also known as continuous subcutaneous insulin infusion, this method delivers a constant, measured amount of insulin throughout the day; in addition, patients simply press a button on the pump to release a supplemental dose before each meal. Patients adjust the size and timing of these bolus doses. The basal rate of insulin can be adjusted. The pump also makes it easier to adjust mealtime bolus doses. Often, therefore, better blood glucose control may be achieved than with standard self-

injections. In addition, the pump offers greater convenience and a more flexible meal schedule, which may particularly benefit people who are very active or who travel frequently. Most people find the pump quite comfortable, even during vigorous activity. The pump unit is waterproof, or has a waterproof pouch, and so can be worn during bathing. It can also be removed for brief periods, like during exercise or for special occasions. However, pump therapy is only appropriate for people who are highly committed and responsible. Since the pump uses only rapid-acting insulin, any sort of malfunction such as a detached needle, blocked tubing, or battery failure—causes a rapid drop in blood insulin levels; dangerously high blood glucose levels can develop within hours. For this reason, patients must frequently monitor blood glucose levels throughout the day, and diligently keep their pump in working order. This includes making sure the basal rate is set correctly, checking the tubing for blocks or kinks, keeping the insulin reservoir full, and changing the infusion needle every two to three days to prevent infection. Moreover, Pump therapy is expensive.

5.5 Insulin Patch

Development of the patch, or U-Strip, began in February 2000, and the group will soon be sending its data to the Federal Drug Administration to gain permission to begin human clinical testing (10). The patch is about to begin its second round of animal testing, and hopes to be able to begin human clinical trials of the product by the end of the year. U-Strip works somewhat like the nicotine patch, and is one of the first non-invasive insulin treatment devices ever. The patch is placed on the arm and activated by an ultrasound device. "Ultrasound waves cushion the drug through your hair follicles," Redding said. "Usually the molecule size is too large to allow [insulin] to pass through, but with our technology it can." Unlike other non-invasive procedures currently under experimentation, the patch would not cause damage to the area of the body it is applied to. "We have already done tests for rashes," he said, "and there has been no discoloration, no burning, no itching, and no reaction. The ultrasound device used to transport the insulin from the patch into the pores is low in voltage -- only one-fifth the power of a sonic toothbrush. "This is generally not enough power to cause damage to skin tissue," he said. "We have done tests on animals and human skin samples, but some things you never can tell."

5.6 Glucose Monitor - GlucoWatch Biographer

The GlucoWatch could be the next step towards an artificial pancreas, releasing both type 1 and type 2 diabetes patients from a lifetime of monitoring blood sugar levels, adjusting insulin and other medications, and freeing up diabetes patients from worries about hypoglycemia (14). Cygnus' GlucoWatch enables people with diabetes and their physicians to identify trends and track patterns in fluctuating glucose levels that would be difficult to detect with current testing techniques alone (3). The GlucoWatch Biographer is comprised of two components: a durable component known as the Biographer, and a consumable component known as the Auto Sensor, which measures glucose for up to 12 hours. The GlucoWatch Biographer differs from other glucose measuring systems in several important ways.

Cygnus' GlucoWatch Biographer: is non-invasive, collecting glucose through the skin, not from blood, automatically measures and displays glucose levels, detects trends and tracks patterns in glucose levels as opposed to a single, discrete reading, alerts a patient when glucose levels are too high, too low, or declining too rapidly, stores up to 4,000 glucose values in an electronic diary that can be reviewed at the touch of a button (14). The GlucoWatch Biographer is designed to be worn during the day or night for glucose monitoring and is expected to mitigate the lack of frequent monitoring due to the pain and disruption of repetitive finger sticking. The Biographer uses proprietary algorithms and performs multiple data integrity checks in order to effectively track trends and patterns in glucose levels. The GlucoWatch Biographer has been designed to recognize fluctuating skin conditions, such as perspiration, and will automatically exclude a reading in order to preserve the integrity of the data (16).

6 Performance Site

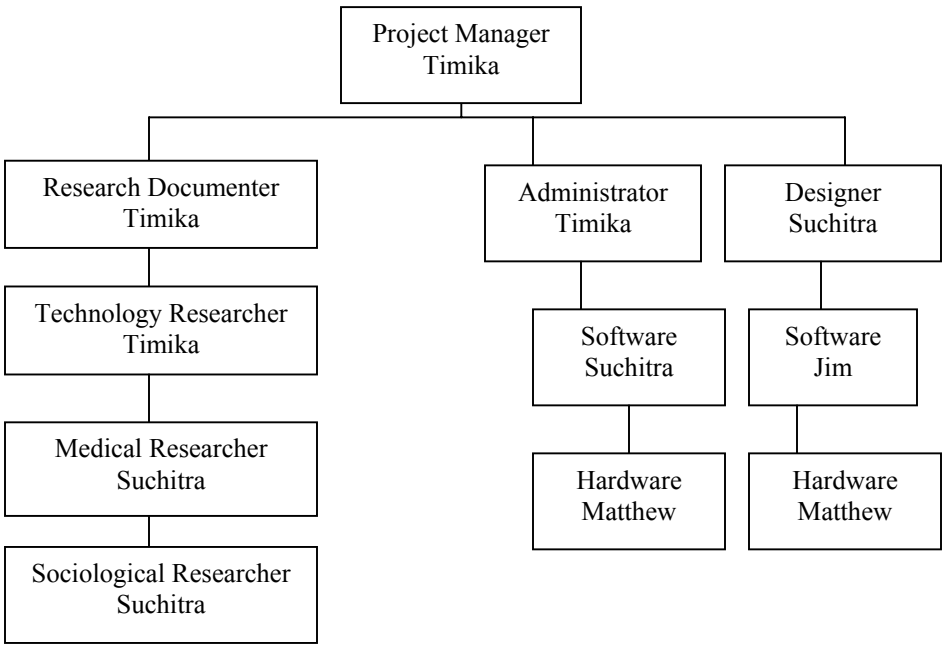
This device, which combines the three top technologies that are available in the market, will help diabetics to easily monitor their blood glucose levels and also maintain their daily insulin regimen non-invasively and non-intrusively. Our long-term objective is to maintain on the top of market regarding the device by making it smaller, cheaper and more available to the public. The performance site includes Education building in Old Dominion University to reduce the cost of the resources utilized in developing our product’s prototype.

7 Objectives

Our objectives to determine the success of the product includes successfully demonstrating a device, which will monitor glucose levels and dispense the insulin in to the blood stream non-invasively and non-intrusively for diabetics. Long-term objectives will be to modify the device further and further to customize it to consumer needs. Our sub objectives include in order to be successful with our main objectives would be to acquire materials needed to integrate our device, meet hardware requirements and software requirements, and also successful testing of software. Software would be our major controlling part of the whole entire device deciding how much insulin should be dispensed factoring in the input entered by the user.

8 Management Plan

Our management structure is presented by the following structure:



Jim Forgy as a software designer will be helpful to this project since his background in software designing company. He is a graduate of Old Dominion University with a degree in computer science and has undertaken courses in software designing. He has experience in military, which would bring us a new outlook to the project.

Mathew Parks as a hardware designer will provide us with the design for our components to fit together. Mathew Parks is a graduate of Old Dominion University with a degree in computer science and geological sciences. He is undertaken many courses in hardware designing. With his excellent experience in marketing and as a presenter in many occasions will look after the hardware designing issues and also acquiring materials from our retailers.

Suchitra Vijayakumar the head of designer team will be graduating from Old Dominion University majoring in computer science and a minor in management. Since her background is in management, she will be the assistant to project manager and an inline manager to the designing team. She would be the presentation coordinator since the communication skills are excellent. Besides she brings a new outlook to the project since she is from India, so a global prospective would be helpful when the company will go global.

Timika Gatdula as a project manager would take care of the project being in task and presenting the material to the board meetings. Timika Gatdula is going to graduate from Old Dominion University with a degree in both Computer science and Information Technology. With the respective background she will bring an excellent reputation to the AGRID Company.

AGRID will utilize the space provided by Old Dominion University to integrate the components and designing the software and creating a prototype. The software program will be coded on the grounds of Old Dominion University.

The progress in the team will be maintained by the following considerable activities:

- Determining the status of work on the project
- Analyzing the state of the project in terms of the schedule
- Assessing the quality of the work
- Motivating and encouraging the team
- Getting issues and opportunities resolved
- Reporting to management

The project manager will keep on top of the project at all times. Even areas and activities that are either minor or seemed to be making progress last month or last week need to be checked. Communication is especially important among the team members. The communication can be in person and telephone conversations. The electronic email is an obvious tool for obtaining status on projects. Some of the key features following the email form of communication are to follow a standard format for the message and should cover the status of the active tasks as well as done tasks.

To determine the project status we will be following these steps:

- Enter the updated information
- Review new mathematical and managerial critical path versus that of the previous schedule
- Review planned versus actual overall schedule
- Review non-critical active tasks

Project administration includes documenting the results of reviews and keeps track of information about the project generally. The project manager will be able to quickly get her hands on almost everything about the project. The project manager is the basic source of knowledge and experience on the project. After updating the schedule and issues, the management will publish the results on the website for the team members to access.

9 Budget Justification

Timika Gatdula will combine two different components to simplify the diabetic regimen in addition to utilizing the consulting team that has been created for this project. The aim of phase one: simplify the regimen to ease the diabetics' life. The medication will be delivered non-invasively and non-intrusively from the insulin patch, which is controlled by the integration device, which takes in the input from the user and as well as from the automatic reading from the watch.

- Acquiring GlucoWatch biographer to monitor blood glucose levels non-invasively and non-intrusively. The watches cost about 260 dollars per piece excluding the maintenance materials. Cygnus Inc. Corporation developed the GlucoWatch biographer.
- Acquiring Insulin patches, this will be soon be available in the market and has been approved by the Food and Drug Administration. The insulin patch is necessary to continuously dispense the insulin.
- Acquiring Ultrasound device to adjust the dispensing of insulin when the blood glucose readings are high or low. The ultrasound device is developed by Sontra Medicals.
- The essential component of the AGRID device is the computational/integration device. The computational device will require microprocessors.
- Focusing on developing the innovated software to ensure the correct results in regards to the inputs given by the user and the GlucoWatch

Jim Forgy as a software designer will be helpful to this project since his background in software designing company would be a necessary thing to design our crucial part of the project, which is the software. The software controls all of the decision making process.

Mathew Parks as a hardware designer will provide us with the design for our components to fit together. With the background Matthew parks have, the design would be superior.

Suchitra Vijayakumar the head of designer team and also the caretaker of software programming will overlook the design team and see to that all the members stay on their task as well as program the code for the computational device.

Timika Gatdula as a project manager would take care of the project being in task and presenting the material to the board meetings. As a person who has manager skills with a computer science degree and information technology minor, she is a better-qualified person to take care of the team.

10 Resources

10.1 Facilities

Old Dominion University will provide us with some computers to construct our computational devices. The facilities will include the use of computer labs.

10.2 Major Equipment

AGRID has to build a prototype that utilizes GlucoWatch Biographer, Insulin Patch, and Sontra Medicals Ultrasound device (12).

The AGRID device also utilizes a computational/integration device, which has to be developed as a part of prototype production. The testing will also take place with in the company.

11 Basic System Input Methods and Characteristics – The Inputs, Sensors, or Observation Devices

The AGRID device will be developed to be a simple, non-invasive, and accurate method to help insulin-dependent diabetics responsibly maintain their blood-glucose levels. The AGRID device is designed to require a minimal amount of user input to maintain the optimum level of blood-glucose in the wearer. The coupling of a continuous glucose-monitoring device with a continuous insulin-dispensing device will ensure that the diabetic will continuously maintain the optimum glucose levels; which will ensure optimum health.

The reason that the following devices have been chosen is that they are all virtually non-invasive methods of attaining the necessary input while still performing the same functionalities as their intrusive predecessors. All of the devices that we propose to use have received government approval by passing many stringent testing requirements. These input devices are available off-the-shelf in today's American market and will require minimal alterations in order to be effective in our project.

11.1 Input Device Descriptions

11.1.1 Non-Invasive Glucose Monitoring System

Among the various methods of glucose monitoring, we have chosen to use the GlucoWatch Biographer developed by Cygnus (13). This device has the ability to monitor the wearer's glucose levels in non-invasive manner using FDA approved software, which is called the GlucoWatch AutoSensor. The GlucoWatch Biographer is able to read the glucose levels through the use of an extremely low-level electrical current. This low-level current is able to extract a small sample of the wearer's glucose from the interstitial fluid that surrounds the skin cells. The information that is obtained from the sample is then passed from the GlucoWatch Biographer to the GlucoWatch AutoSensor software.

The GlucoWatch AutoSensor software then analyzes this sample of glucose. The AutoSensor software then calculates the wearer's glucose levels using Cygnus' proprietary biosensor technology. The AutoSensor is calibrated with a standard blood glucose measurement. In order to obtain the standard blood glucose level the AutoSensor must go through a warm up period that takes approximately 3 hours. Following the warm up period the AutoSensor will then measure the wearer's glucose level every 20 minutes for up to a 12-hour period. As they are measured each input reading will then be transmitted to the integration device while also being stored within the monitoring device.

11.1.2 Non-Invasive Insulin Patch

In the current configuration of the AGRID device, the one-use insulin patch must back device the monitoring element. It is because of this set up that the currently available insulin patch will need to be minimally reconfigured. The insulin patch that is currently available has no such device to regulate its dispensing properties. In order to attain the required level of functionality, a chip will have to be placed within the patch. The chip would serve simply as an extension of the glucose-monitoring device. This extension's input responsibilities would simply be the transfer of the glucose sample information from the user's skin to the back to the GlucoWatch AutoSensor software.

11.1.3 User

In order for the AGRID device to dispense the required amount of insulin the user must input only a single parameter into the device. The parameter that will need to be inputted is that of the carbohydrate level. In order for this to occur the user will simply select carbohydrates option listed on the LCD screen. Once that is selected, the grams of carbohydrates will then be selected by using the up and down buttons that are located on the monitor face. This information will then be passed to the integration device.

11.2 Integration Configuration Requirements

To create the prototype for the AGRID device, we will be required to create the integration device that will be responsible for reading in the required inputs. The first input that will need to be entered into the device is that of the current glucose reading as well as the past two consecutive readings. The user's blood-glucose history is to be stored in the glucose-monitoring component of the AGRID device similar to the way that the GlucoWatch Biographer is able to store historical data. The glucose reading element will then give these three inputs to the integration device. The other input that will need to be entered into the integration device, is that of the user's carbohydrate intake. The carbohydrate intake will be given to the integration device indirectly by the user through the user interface.

11.3 Testing Characteristics

AGIRD (Automated Glucose Reading Insulin Dispenser)

The automated glucose-reading element of the device will need to be tested to determine its overall accuracy. To test for the level of accuracy of the GlucoWatch Biographer, the results calculated by the monitor were compared to that of the standard finger-prick test. According to the Cynus' test reports, the glucose-monitoring element has a 71% acceptable accuracy rate when compared to that of the standard finger-prick. Based on these results, we estimate that our monitoring component will have a comparable level of accuracy.

Also approved by the FDA for medical use, the insulin patch has proven itself effectual in it duties of dispensing insulin through the skin. However due to our planned modifications, further testing will be required for our modified insulin patches.

12 Hard Core Computer System Characteristics

The Computational Element

The established input devices have proven themselves to be functional when used separately. The innovation of the AGRID device is that AGRID will utilize newly created integrated software that will allow all of the separate components to work together. This will help to eliminate the current need for constant user intervention to maintain healthy blood-glucose levels—which is one of our main goals. Our other primary goal is to provide insulin-dependent diabetes with a device that is as non-invasive as current technology will allow. In order to fulfill these requirements we will need to design new software as well as an integration device to run the software.

12.1 System Design/Development Configuration

The design of this software is fairly straightforward. The integration software will read in the previously defined inputs as explained in section 1. Using these inputs the device will then determine which of 5 actions need to be performed. The user's blood glucose levels can either be within range, high, too high, low, or too low. The functional *Diagram 12.1* clearly illustrates the functionality of the AGRID device.

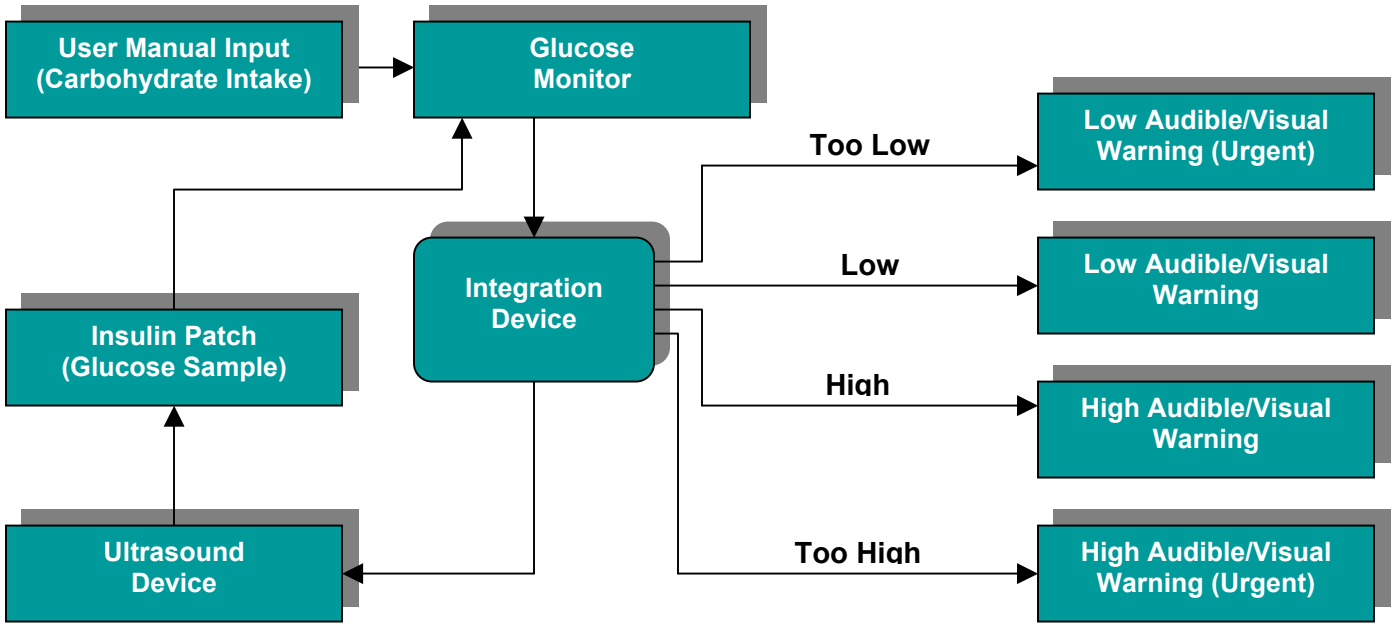


Diagram 12.1

12.2 System Integration Requirements

The integration device must fulfill our established criteria. In order to be considered successful the integration device must be able to read in the inputs as explained in section 1 of the text. The integration device must come to a decision about action based on the inputs received. Once the action has been determined, the integration device will put the required action into motion by sending information to the ultrasound device. The ultrasound device will take the signal that it receives from the integration device. The signal that the ultrasound component receives will determine the length of time that the ultrasound device emits the ultrasound rays. The duration of the ultrasound session directly determines the rate at which the insulin is absorbed into the skin.

12.3 System Test Configurations

To gain FDA-approval the AGRID device must undergo stringent testing. Before designing the prototype we will first test our integration device to ensure its proper functionality. We will have our software tested through an independent facility that will thoroughly test our integration software for any errors or defects in the program. If there are defects within our software, they will be resolved during this phase. We will try to have all components issues resolved before we reach the prototype development stage that corresponds with phase II of the SBIR.

13 Support Computer Based Application Programs – The Software Element

The completion of this project requires the creation of new software that will allow for the integration of the following components: glucose monitor, insulin patch, and ultrasound device. These three devices are all FDA-approved, currently available in the American market, and ready for use in our project. Since all except for one of the components that we plan to use are available off-the-shelf we feel that the integration of the components will be successful.

13.1 Available Off the Shelf Administrative Applications

AIDA Freeware

Available online at www.2aida.org there exists freeware that may have some use in the creation of our software. The AIDA freeware helps insulin-dependent diabetics adjust their insulin dosage to better maintain their glucose levels. We will be able to use this software to determine how much insulin should be dispensed in consideration of the current glucose levels and the carbohydrate intake. With this information we will create switch case statements that will determine the actions taken by the integration device.

13.2 Applications Written for Project

If the integration device determines that the blood glucose levels are within the acceptable range then there will be no audible/visual warning and the information will be simply be sent to the ultrasound device that will adjust the skins level of permeability in taking into consideration the level of insulin that is required to bring the wearer's glucose level to the optimum level of 100.

If the glucose level/carbohydrates are either low/low or high/high an alarm notify the wearer while information is sent to the ultrasound device. This warning alarm will steadily flash the wearer's glucose level as well as produce an audible beep once every 5 seconds to notify the wearer. The user can disengage this warning at any time with the push of a button located on the user interface. If the wearer's blood glucose levels reach the too high or the too low state, information will still be sent to the ultrasound device in an attempt to control the glucose levels. The audible/visual warning will then enter the urgent state. In the urgent state the flashing of the blood glucose levels and audible warning will still be performed; however, the frequentness in which they are done will be increased to once per second. If in this state it will be recommended to the wearer that an injection of insulin is dispensed manually to quickly get the blood glucose levels within the desired range. This user will also be able to disengage this warning if desired. If there is no user intervention then the warning alerts will shut off automatically once the blood glucose levels fall with the acceptable range. In all cases the integration device will notify the ultrasound component to make adjustments to skins permeability.

The established ranges of the AGRID devices are defined within table 13*.1*. These ranges have been chosen in accordance to what the American Diabetes Association has determined to be acceptable glucose levels. The average carbohydrate intake level that should be consumed by diabetics for each meal has determined the carbohydrate intake ranges that have been established in this table. The integration device will then perform the explicit that corresponds with the inputted information.

	Inputs		Outputs	
Case Number	**Glucose Level**	**Carbohydrates**	**Insulin Level**	**Warning State**
1	Too Low	--	Minimal	Low Warning (Urgent)
2	Low	Low	Minimal	Low Warning
3	Low	Normal	Minimal	Off
4	Low	High	Minimal	Off
5	Normal	Low	Minimal	Off
6	Normal	Normal	Continuous	Off
7	Normal	High	Continuous	Off
8	High	Low	Continuous	Off
9	High	Normal	Increase	Off
10	High	High	Increase	High Warning
11	Too High	--	Increase	High Warning (Urgent)

Table 13.1

Glucose Level	
Too Low	<= 50
Low	51-80
Normal	81-130
High	131-300
Too High	> 300

Carbohydrates	
Low	<= 5
Normal	6-15
High	> 15

Insulin Level	10/20/30 mg
Minimal	.2/.4/.6 mg/h
Continuous	.4/.8/1.2 mg/hr
Increase	Increased Linearly

Legend for Table 13.1

13.3 Unique Product's Domain Specific Applications

The AGRID device is designed for insulin-dependent diabetics. AGRID will not be helpful to those diabetics who are reckless in the management of their diabetes regimen. Our product will also not be beneficial to those who would not benefit from the dispensing of insulin. The benefits of using this device are that a normally invasive, painful process will be made simple and non-intrusive.

13.4 Software Testing Requirements

Before we commence with the creating of the prototype, we must thoroughly test the proper function of our software. AGRID plans to implement an independent testing agency. Testing agencies are often implemented in projects such as this to ensure the integrity of their design. The accuracy of our software is of the utmost importance. We will heavily emphasis the proper functionality in our testing specification. We will created many versions of test parameters and use these multiple cases to test our software. The cases will test all of the ranges that we have delineated in section 13.2 along with all of the boundary conditions possible.

14 Basic System Output Methods and Characteristics-- The Outputs, Methods, or Warning Devices

Once the input readings and the data from the user have been processed, the processor will branch in to one of three decisions, which will generate three different actions. The three possible situations are described below. First, when the glucose reading rises above the preset upper boundary the first signal would be sent to the observation device, which

we described in the “input methods” section, the observation device is a LCD. The display will then flash in the manner of once per second until the execution button is being pressed which will then send a stop signal. Along with the first signal, a signal would be sent to the audio warning device. The audio warning device functions like the alarm in a digital watch. It sends sound warnings or beeps in the manner of once per second until the execution button is being pressed which the user can then terminate. If the blood glucose does not fall back below the preset upper boundary for three reading cycles, which translates, to 40 minutes the ultrasound device is activated. When the ultrasound device is triggered, it emits a low frequency ultrasound to the skin under the AGRID device for certain amount of suitable time, which helps in enhancing the permeability of insulin from insulin patch. The treated skin would then be able to absorb the insulin from the patch at a much faster rate about 3 units in an hour. Presumable, the insulin applied on the insulin. When the third signal is sent, it also sends a first signal and an urgent second flash in the manner of once per second until the execution button is being pressed and sends a stop signal back. The urgent second signal would cause four times per second until the execution button is being pressed and sends a stop signal back. When the glucose reading falls back below the preset upper boundary, a first signal and a second signal is sent to the output devices can make them perform the same tasks as stated above until the execution button is being pressed and sends a stop signal back. These warnings provide the user with notice when blood sugar exceeds the bearing level.

The first signal would again be sent to the observation device. The observation device will then flash in the manner of once per second until the execution button is being pressed and sends a stop signal back. Along with the first signal, the second signal would be sent to the audio warning device. The audio warning device functions like the alarm in a digital watch. It sends sound warnings in the manner of once per second until the execution button is being pressed and sends a stop signal back. If the blood glucose does not rise back to the preset lower boundary for two reading cycles, which means 40 minutes, a first signal and an urgent second signal would be sent out. The first signal works as stated above, cause the observation device to flash in the manner of once per second until the execution button is being pressed and sends a stop signal back. The urgent second signal would cause the audio warning device to send sound warnings until the execution button is being pressed and sends a stop signal back. This helps the user to take the immediate actions for sugar intake. When the glucose reading rises back above the preset lower boundary, a signal and a second signal is sent to the output devices and make them perform the same task as stated above until the execution button is being pressed and sends a stop signal back. These warnings provide the user with notice when blood sugar falls below the bearing level.

15 Supporting Technology of Project Domain--The Fundamental Requirements of the Domain

While the project will not invent of create a new technology, it does incorporate several relatively recent technological advances. The two most significant advances in the management of diabetes that are critical to the success of the project are the non-intrusive blood sampling technique and the non-intrusive delivery of medication. By incorporating both of these diabetes support methods, we provide the diabetic with substantial reduction in the daily diabetic regimen.

Identification and Use of Existing Technology

In the creating of our AGRID device we plan to use three existing components. The first one is GlucoWatch Biographer developed by Cygnus Inc, which helps in monitoring the blood glucose levels non-invasively and non-intrusively. The second one is insulin patch, which is our dispensing product to dispense insulin in to the blood stream without vein puncturing, is still yet to be in the market. The U-strip patch is approved by the FDA. We are aiming to use in our prototype building. The third component is Ultrasound device developed by Sontara Medicals, which helps in enhancing the permeability of insulin, depending on the output from the integration device.

16 Description of Required Modifications of Existing Technology

We intend to replace the finger pricking or vein puncturing methods of obtaining a blood sample with a “through the skin” sampling technique. This technique has been recently introduced to the diabetic community in the form of new monitoring devices. As with any new method, we need to remain somewhat skeptical with conclusive evidence over a

prolonged use period confirms the methods as satisfactory. Currently there is little in the literature to suggest that this method of sampling has any significant limitations or drawbacks. Since the key factor of the project, is the modification of the diabetic regimen, this technology is critical for the project's success.

As with any new method, we need to remain somewhat skeptical until conclusive evidence over a prolonged use period confirms the methods as satisfactory. Similarly this non-invasive delivery of medication is also a technological must for the success of the project. The recent introduction o not only the dispensing of medication through a skin particle but with a controllable method of dosing the dispensing also is a technology that is critical to the project.

Description of Product's Required "New" Technology

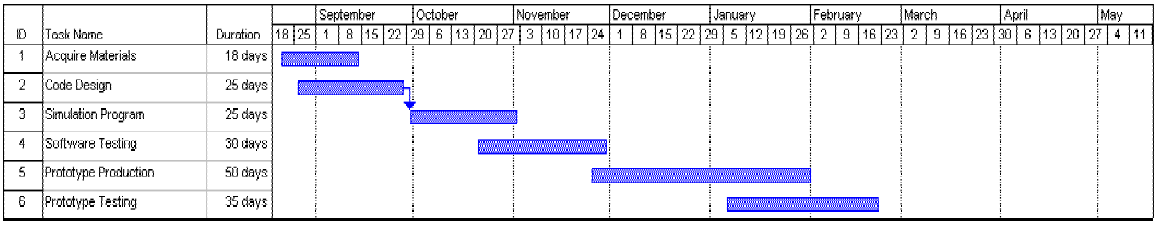
The incorporation o a digital control device (microprocessor) to act as both the interface and the automated decision making is the technological innovation of this project. The utilization of these two technological advances (non-intrusive blood sampling and non-intrusion controllable medication dispensing) remains as critical elements of the overall AGRID system.

17 Milestones

The following are our milestones in successfully tracking our success and also a tool to monitor our progress. The following is described in the pert char sequence with some graphics, which exactly describes how many days are involved in completion of each milestone.

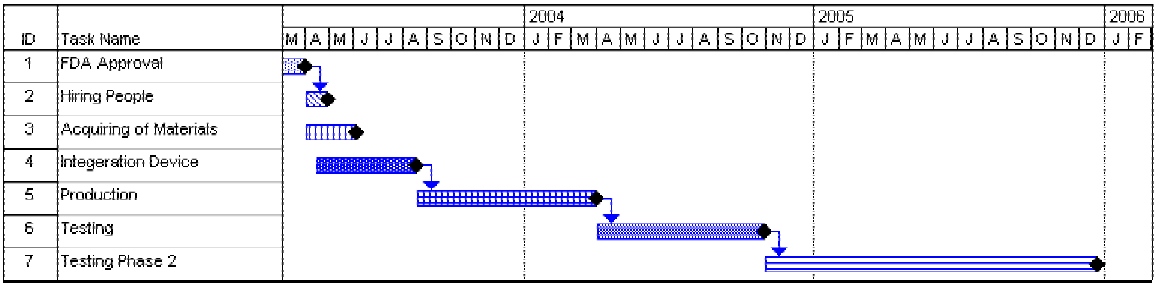
17.1 Graphic for Prototype Development

This displays the number of days taken for each milestone and the project starts from August 20 and ends on March 20, 2003.



17.2 Graphic for Initial Production Period

This displays the number of days taken for each milestone and the project starts from 2003 March and successfully completes its testing phase in December 2005. By the year 2006, we hope to be in long time production and successfully launch our product.



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