Immediate Medical Response (iMr) System:

Fast, Cheap, Comprehensive, and Effective Medical Assistance for Anyone, Anywhere

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Abstract:

According to the World Health Organization (WHO), the top two causes of death in the world are ischaemic heart disease (IHD) and stroke[1a], both of which require immediate medical attention. This translates to over 13 million deaths worldwide[2a] , many of which could be saved by quick medical attention.

Our technology, the Immediate Medical Response, iMr, is a 3-part system: a Mtach bio-sensor that can detect an emergency; a GPMS positioning and monitoring system that locates emergencies; and a Mrotor mini Unmanned Aviation Vehicle (UAV) that responds to the emergency alerts and acts as a first responder system that will deliver elementary, life-saving treatment. iMr will cut the time it takes for medical attention to reach the patient, a critical issue in developing nations and, hence, save many lives. IMr is also cheap, comprehensive, and versatile making it attractive in developed countries to deliver fast emergency response at low cost.

1/30/2014

Submitted to the Toshiba ExploraVision competition

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Cardiovascular diseases (CVDs) are diseases related to the circulatory system and the heart. IHD involves the clogging of the coronary arteries with plaque, which can result in a heart attack. Many CVDs require immediate medical assistance for survival; tragically, this is not a reality for many[2a]. Even with the major advances in medical attention today, from response to treatment, over 17 million lives are claimed by stroke, IHD, and CVD medical emergencies---every year[2a]. Even more are being lost annually from other medical emergencies that lack prompt, appropriate medical attention. A better solution to save these lives is critically needed.

Present Technology: **[***Detection:]* After an emergency occurs, usually another person who finds out calls Emergency Medical Services (EMS). Slow detection, however, results in severe damage to brain which occurs due to no blood flow, revealing the need for more effective and faster detection. *[Before the hospital:]* An Automated External Defibrillator (AED) checks heart pulse and sends an electrical shock to the heart through metal leads attached to the chest in order to restore regular heartbeat. Sudden cardiac arrest, often the result of irregular electric activity of the heart (heart arrhythmia), can be treated with an AED. Chest compressions, in conjunction with assisted respiration, are always performed for CVD emergencies to maintain blood circulation of nutrients and oxygen with cardiopulmonary respiration (CPR). AEDs and people trained in CPR, however, are not present in many locations, particularly in developing nations. Even when nearby, if immediate attention is not received in a few minutes, a patient will often die, as seen in sudden cardiac arrest[3a]. Whereas pacemakers and implantable defibrillators are recent technology that keeps contains heart arrhythmia with minor electric pulses, they're limited to those (1) willing to restrict major life activities with implanted devices and (2) able to pay for such an expensive surgery of over $20,000[4a]. In America alone, 130,000 of the 800,000 patients who have stroke, die[5a]. The worst damage from a stroke often occurs during the first few minutes after a stroke[6a]. Clearly a quick, omnipresent solution that is accessible to anyone, anywhere right when the emergency occurs is necessary. *[To the hospital:]* Land and helicopter "air" ambulances are current methods to respond to medical emergencies. Land ambulances, however, are susceptible to circuitous routes, traffic jams, and limited access to certain areas such as trails. The EMS response is worst in developing countries, which range from 2 hours and 42 minutes in West Azerbaijan[14c], to 1 hour in Pakistan[15c]. Air ambulances, while flying to the patient directly, can only access areas with flat land for landing. Air ambulances also come with astronomical costs: the Essex Air Ambulance, for example, costs over $45,000 per trip[7a]. A cheaper, faster response mechanism which is accessible to any terrain or area is required. *[At the hospital:]* Once at the hospital, a patient with IHD is given a CT scan[8a], as with other CVDs, to detect the location of blood blockages. Different procedures to clear the clog are performed. A metal mesh known as a stent is used to compress and hold the plaque to the sides of the arterial walls[8a]. Angioplasty, encompasses the use of a small balloon to compress the plaque all the way to using diamond-headed rotors to cut away hardened plaque[8a]. New coronary arteries are constructed if the blockage is too extensive and medications are often used for treatment as well, such as aspirin, an anti-clotting medicine[8a], to improve blood flow. Other cardiovascular diseases involving vessel blockage may use similar anti-clotting medications as well, such as tissue plasminogen activator for stroke[6a]. These methods, while comprehensive and effective, are only available at the hospital. Before reaching the hospital, the body is susceptible to much harm. A way of bringing some of these procedures to the patient at the scene of the emergency is needed. *[Future Outlook:]* Clearly a cheap, quick-responding, comprehensive, omnipresent solution that is accessible to anyone, anywhere, is required to resolve the crisis posed by IHD, stroke, and other CVD medical emergencies. Such an innovation would save millions of lives that are stolen by ineffective medical responses.

History: The beginnings of IHD can be traced back to the ancient Egyptian pharaohs of 1200 BC[1b]. It was only until the 1800s, however, that the first explanation of IHD was formulated by the University of Halle's Dr. Gregory Thomas: the "reduced blood passage within the coronary arteries[1b]." Finally a century later, a group of physicians, later known as the American Heart Association, embarked on a journey to treat IHD[1b]. They began exploring catheters, thin tubes, as a way to clear blocked arteries[1b]. Only until the 1960s-70s, however, did IHD treatment gain momentum, with the inception of clinical treatment of IHD using bypass surgery and angioplasty[1b]. The stent quickly followed[1b].

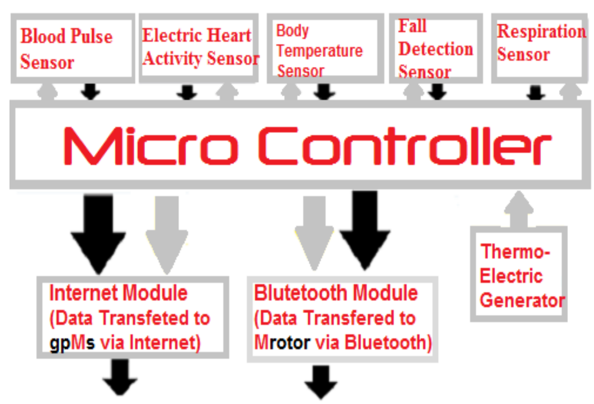
Today, non-invasive treatment techniques for IHD have advanced, such as enhanced external counterpulsation[8a]. Anti-clotting medications have also been developed[8a]. First response mechanisms, such as CPR, are now used to increase chances of survival[8a].

The ambulance also advanced during this time period. Starting as far back as the ancient Romans, wagons laden with medical supplies trailed behind battle lines to help treat the wounded[4b]. In the 11th century, the Knights of St John, recognized by their Maltese "red" Cross on their tunics, provided medical help to soldiers on the battlefield during the Crusades[5b]. In the late 1800s, hospitals began employing horse-drawn carriages for civilians in America and England, followed by the replacement with motor vehicles for transportation in the 1900s[4b, 5b]. National ambulance networks began to be laid out from then on out, resulting in the current mobile land and helicopter "air" ambulances of today[4b, 5b]. Medical records have evolved from hand written documents to Electronic Medical Records (EMR).

Future Technology: Our technology, the iMr, focuses on treating CVD medical emergencies, such as stroke and IHD-induced heart attacks, as well as other medical emergencies, by cutting the time it takes for the patient to receive comprehensive medical treatment. iMr combines quick response time, current treatment concepts, and advancements of the future to yield a cheap, comprehensive, versatile, and easily-usable system that will track recent medical history, detect symptoms of impending conditions, and respond more quickly than current EMS. In addition, it will be a personal doctor. The iMr system consists of three parts: 1) Mtach; 2) gpMs; 3) Mrotors.

|**1. Mtach:**| Mtach will be a small, versatile, external, portable biosensor that tracks the health of the user. *[Monitoring function]* The Mtach will detect aberrant behavior, which can be analyzed for impending medical emergencies through continuous monitoring of:

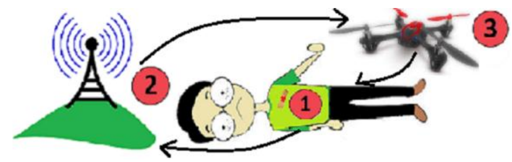
1) Blood pulse with the Cardiocam , developed at MIT, by detecting fluctuations in light absorbance by the blood corresponding to each blood pulse [1c]. 2) Electrical heart activity with the Holter monitor by construction of an electrocardiogram[2c]. 3) Body temperature with an electronic thermometer[3c]. 4) Respiration rate with an electronic thermometer by detecting brief, small spikes in body temperature[5c]. 5) Fall detection and severity measured with accelerometers that track displacement angle and fall impact[6c]. Adhering to the body with painless, removable microneedle adhesion[7c] or strong, removable adhesive substance[8c], the Mtach will be attached, like a band-aid, over the heart (on the chest). With an external body of durable and light carbon fibers, the Mtach will maximize comfort and be suitable for people with allergies.



The Mtach will be powered by a 1 inch squared battery, developed by a Department of Energy research lab, which uses thermoelectric generator to convert body heat to electricity[8.5c]. This provides a sustainable, clean, and renewable power source.

|2. gpMs:| The Global Positioning and Medical System (gpMs) will be a secure online-based system to store, analyze, track, and respond to medical emergencies in conjunction with the Mtach using computers such as IBM's Watson, an artificial intelligence computer. By using the global internet, the gpMs will have worldwide coverage. *[Data Analysis & Storage Function]* The Mtach will continuously send its data to the gpMs for analysis and storage through its internet module to the internet infrastructure and nearby regional routers. (1) The gpMs will continuously analyze incoming data for possible symptoms of IHD and common medical emergencies, such as rapid or irregular blood pulse[9c] and shallow breathing[9c] for IHD. (2) As a database, the gpMs will store Mtach data up to 15 days old, as well as all abnormal data points deviating from the preset norm. In the case of an emergency, this data will help a doctor decide on appropriate treatment methods for the condition. The Mtach will also include an optional feature of updating a smart phone app with current data through the Mtach Bluetooth module. History from the past 15 days, as well as all abnormal data, will be available, allowing the patient to monitor his or her own health for free. *[Detection and Response Function]* The gpMs will alert the patient, the patient's doctor, and the EMS in the case of an emergency, and the patient's emergency contacts. A loud alarm through the Mtach will be issued to alert those around the patient. An alert will be issued to the pre-designated doctor's phone, as well. The EMS will also be notified of the emergency. The Mtach will include a Global Positioning System (GPS) module which will be tracked by the gpMs to help the EMS find the patient. Before alarming everyone, the patient will first be notified. If, after 30 seconds, the patient does not turn off the alarm as a false alarm, the alarm will be officially dispatched to everyone. The gpMs alarm can also be configured to alert people close to the patient, so they can provide assistance and additional information will be sent to the EMS and doctor regarding the patient.

3. Mrotors: The Mrotors will immediately be dispatched upon detection of an emergency. Mrotors, pairs of small quadrotors that complement each other, are mini Unmanned Aviation Vehicles (UAV) that responds to the emergency alerts and act as a first response system that will deliver elementary, life-saving treatment and hence will increase the chances of survival. *[Locating Patient function]* Navigation technology from the University of Pennsylvania that can guide quadrotors through obstacles, such as a home or forest, will help the Mrotors arrive to the patient safely. To call attention to the emergency, the Mrotors will emit emergency lights and sirens. Upon nearing the patient, the Mrotors will connect their Bluetooth modules to the Mtach's module. This will be a key to the patient's private gpMs medical records, and give the local hospital and pre-designated doctor access to this data for better diagnosis of the condition in preparation for treatment. Using thermography detection based on greater blackbody radiation from the patient in relation to his or her surroundings, the Mrotors will be able to identify the position of the patient. Mrotors will be positioned every few miles at cell phone towers for immediate medical assistance. Mrotors will dock on a platform at iMr Stations (like fire stations) and be powered by solar panels. Mrotors can reach their destination by flying in a straight line (aerial speed is 6 minutes per mile, which is expected to improve over next 20 years).



[Diagnosis and Treatment function] The Mrotors will be connected to an emergency shift doctor at the hospital through live cameras. Carrying different equipment, the Mrotors will provide elementary treatment procedures upon landing. Using data from the Mtach, as well as input

from the doctor about the suspected condition, the doctor will instruct the Mrotors on what to do. A bystander (untrained layman) will help the Mrotors perform these procedures by following voice instructions given by the Mrotors: (1) The patient will be reoriented in a face-up position, flat on the ground; (2) Through a noninvasive transdermal ultrasound drug delivery method developed by MIT[23c], relatively harmless anti-clotting drugs such as aspirin will be sprayed as solution and absorbed through the skin. A low and high frequency ultrasound combination will painlessly churn up the gas in the skin, creating partial vacuums to effectively suck in medication on the skin into the bloodstream[23c]. Other medications could similarly be absorbed this way. (3) A positron emission tomography and computed tomography (PET-CT) scan will be performed to check for the exact location of plaque in the coronary arteries of the heart[22c]. Using this scan, the hospital can prepare for the surgery in advance. (4) Chest compressions can be given at 100 compressions per minute to sustain blood flow with the LUCAS chest compression device[21c]. An artificial oxygen mask will be secured and suctioned over the mouth and nose to provide the critical oxygen needed for the body.

The Mrotor will be very versatile. Current quadrotors can land on the bottom of stable objects, such as ceilings and on inclined surfaces very well and stably. Quadrotors are also very agile, as they can fly through many obstacles such as small openings in broken windows and various environments. Given this quick flight time and adaptability across all terrains, Mrotors are an ideal first response system, arriving on the scene from traffic-less air before the ambulance can navigate through indirect and often circuitous routes, faced with the possibility of being further delayed in a traffic jam.

Breakthroughs: Certain technological advances (already happening in other fields) lay before the inception of the iMr. The various sensors of the Mtach must shrink, as well as the equipment carried by the Mrotors such as the PET-CT scanners. This has already happened for the mobile CT scanner[0.9d]. As all technologies do so over an extended period of time, we have confidence that these technologies will shrink and drop in cost, too. A system that can integrate all the components of the Mtach must also be devised.

Secure internet servers, as well as a gpMs network, must be designed and tested to insure maximum functionality and security. This could be modeled on health management systems such as the University of Texas MD Anderson Cancer Center's Oncology Expert Advisor[0d], which utilizes IBM's Watson.

For the Mrotors, durable quadrotors that can withstand varying weather need to be designed. Mrotors that are designed to fly with medical equipment connected on them must also be designed. The battery life of quadrotors, which is almost 30 minutes[0.5d], needs to be extended for effective emergency response trips. Faster quadrotors need to be developed to shorten response time. As quadrotors are a recent innovation, they will naturally undergo major advancements and be refined and improved over the next 20 years.

Our current technology assumes that the patient will be in a location accessible to the Mrotor. To reach a patient at home with a locked door, more breakthroughs are needed. A code transmitted by the Mrotor that can unlock a patient's door, given their prior consent, is necessary, as quadrotors are already able to turn door knobs. This breakthrough will primarily be needed in the developed world, where more people live alone.

Future research needs to be conducted to encompass restructuring coverage areas of the Mrotors, adding more measurements for the Mtach to monitor, and redesigning the gpMs for better analysis. Effectiveness will be measured by the number of lives saved. Operations management research regarding the optimal location and deployment of Mrotors would also be conducted, just as prior studies have been conducted on fire station[3d] and ambulance[4d] location and deployment. The results will be measured by the decrease in ambulance trips.

Design Process: After deciding to focus on CVD, our team built on different ideas to reach our current one. The first idea, which concentrated on heart arrhythmia and sudden cardiac arrest, involved a monitoring device which tracked electrical heart activity. This device responded to minor heart arrhythmia by electrically stimulating the vagus nerve, which significantly reduces painful heart arrhythmia symptoms[1e]. In the case of a sudden cardiac arrest, a small AED was also incorporated in the device to restore the heart to normal pumping. Immediate detection and response was thus achieved. There were certain problems, however: misreading the data would result in deleterious and unnecessary electrical pulses to the heart and vagus nerve. To stimulate the vagus nerve, the device would need to be implanted in the body through an expensive surgery, reducing its accessibility and appeal to many people.

After much pondering, drafting, and many other related ideas, we finally arrived at our current idea: the iMr. Originally, however, we planned on using an octorotor, instead of quadrotor pairs, as the Mrotor since an octorotor can fly 3min/mile which is half that of qudrotor. But octorotors, are much larger than quadrotors, reducing their agility and navigation abilities in the narrow confines of a home, an office building, a hiking trail, and the like. With 2 quadrotors, however, which can carry different equipment, these restrictions would not be present, making first response more effective[2e].

We also considered establishing several central iMr headquarters with specially-trained personnel who would guide the Mrotors and monitor their location and status, while connecting the gpMs, local EMS, police, physicians, and Mrotors. This would be similar to the U.S. Army, which controls its global missions from one central military base in the American desert[19c]. But we concluded that training these professionals and having one central location was not feasible.

Consequences: CVDs are the number 1 cause of death worldwide[1f], and the number 1 cause of death in each income group worldwide[3.5f], accounting for over 17 million deaths every year[2a]. By 2015, 3 million more will have joined this tragic plight of death[2f]--equivalent to wiping out the entire populations of Greenland, Bermuda, Guam, Iceland, the Bahamas, Luxembourg, Fiji, Cyprus, Kuwait, Jamaica, Mongolia, Uruguay and Puerto Rico combined---every single year[3f].

The *low cost* of Mrotors--$100 every quadrotor[0.6f]--makes them easily distributable and *omnipresent*. In conjunction with navigability across any terrain, Mrotors can access *any patient in any area of the world*. Patients will not need to find an available doctor after waiting in the Emergency Room for an average of 6 hours anymore, as in America[0f]. Rather, Mrotors will allow doctors to directly address the patients' emergencies before it is too late. *Wider medical coverage* will save more lives. And as unnecessary doctor visits fall, the *quality* of each will *increase* with less stress upon the doctors. Less unnecessary ambulance trips will *save costs*, as well. As mobile doctors with a broad emergency coverage, Mrotors will deliver more comprehensive medical assistance than any CPR-trained professional or AED. Currently, CPR can only be given for 2 minutes by one person and after one minute, the ability of a CPR trained person to deliver effective chest compressions falls dramatically[11f]. As a result, *95% of the patients* who survive a cardiac arrest are permanently impaired with neurological problems[12f]. In contrast, the LUCAS Chest Compression system provides 100 compressions per minute continuously[13f], pumping the blood more regularly and quickly[12f]. The life of a CVD patient will not be dependent on a CPR-trained bystander or nearby AED, with the iMr. *Comprehensive first* *response and treatment* will not only save more lives, but also increase the quality of life for those surviving by preventing brain damage from inadequate CPR. Mrotors will not only address IHD; with its equipment, many other CVD emergencies, as well as emergencies in general, can be addressed. As an example, ischemic stroke, like IHD, can be treated with anticlotting medicine, such as aspirin[6a].

Developed countries are faced with the high costs of EMS services today. An ambulance trip costs up to $2204 by land[1d], and over $45,000 by air[7a]. Quadrotors cost very little, usually only $100[0.6f], in contrast with the cost of an ambulance, over $180,000[0.5f], which excludes average annual paramedic salaries of $66,000[0.5f]. The low cost of a Quadrotor will make wide coverage of EMS services feasible, including rural areas, in developing countries.

The iMr is needed in developed countries, but even more in *developing countries*. One of the biggest issues is slow EMS response times, which can be as high as 3 hours in many nations. Ambulatory and treatment costs are even higher than in developed countries, and the doctor-to-patient ratios are astronomical, ranging to 1500:1 even among the more developed countries like India[10f]. Mrotors' omnipresence will enable them to respond in a few minutes. Mrotors will provide wider coverage, saving more lives before reaching the hospital. As a new way of delivering medical care, our innovation will provide global and higher-quality medical coverage at a faster rate with lower costs that will be available to anyone, anywhere.

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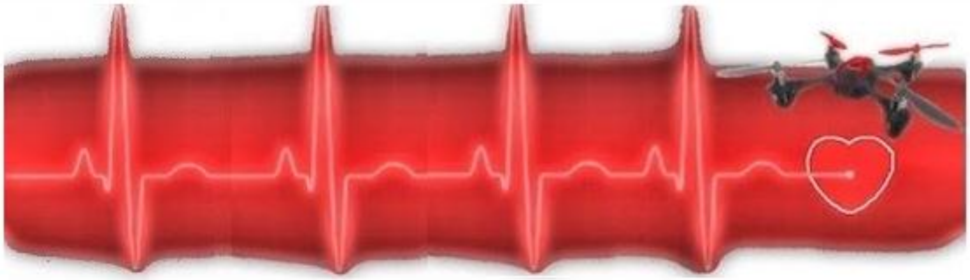

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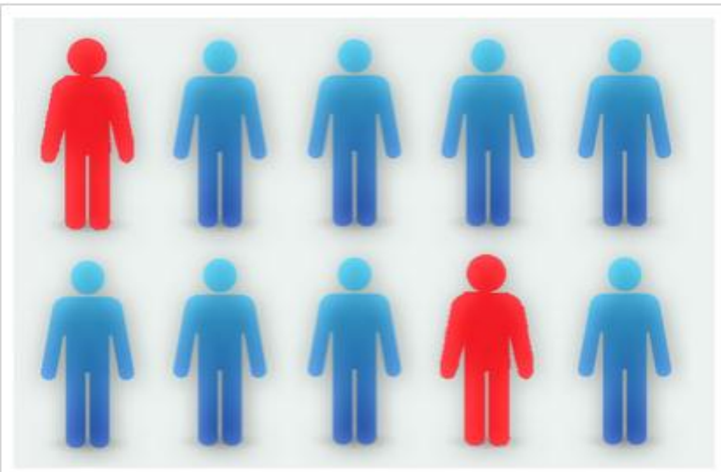
According to the World Health Organization (WHO), the top two causes of death in the world are ischaemic heart disease (IHD) and stroke, both of which require immediate medical attention. This translates to over 13 million deaths worldwide, many of which could be saved by quick medical attention.



By 2015, 3 million more people will have joined this tragic plight of death equivalent to wiping out the entire populations of Greenland, Bermuda, Guam, Iceland, the Bahamas, Luxembourg, Fiji, Cyprus, Kuwait, Jamaica, Mongolia, Uruguay and Puerto Rico combined every single year.

This calls for a system that will cut the time it takes for medical attention to reach the patient, a critical issue in developing nations and, hence, save many lives. This system must also be cheap, comprehensive, and versatile making it attractive in developed countries to deliver fast emergency response at low cost.

Click on tabs to navigate

Acces the live website at https://sites.google.com/site/medcopter2

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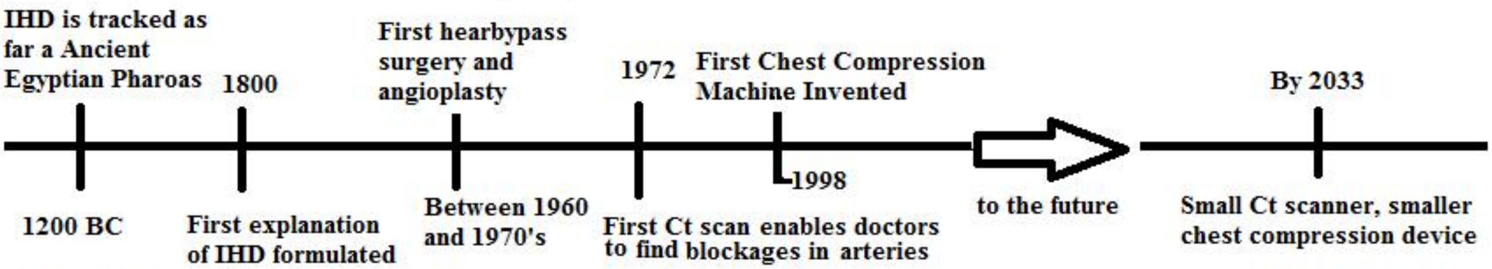
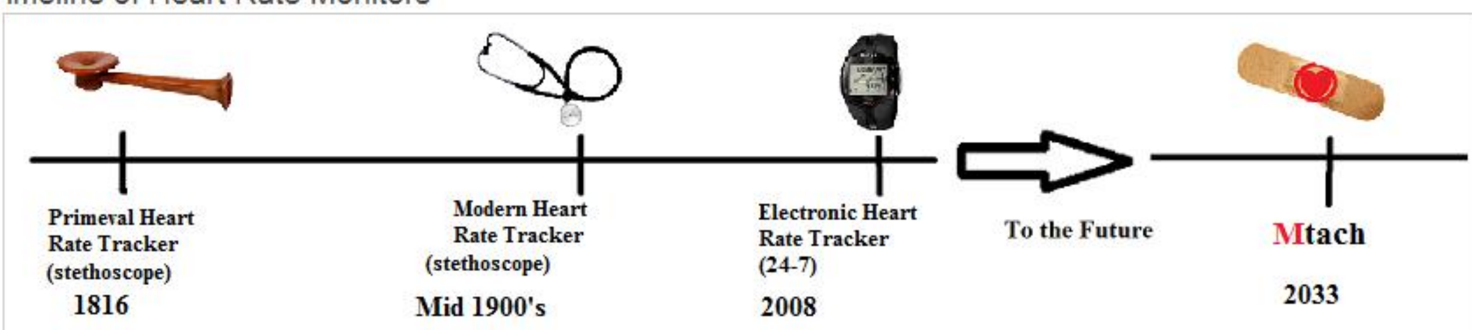
Timeline

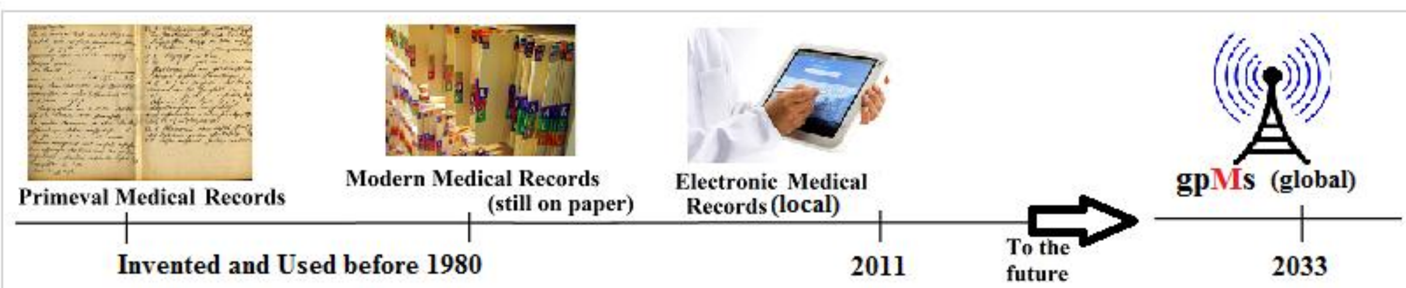
Timeline of Ischemic Heart Disease(IHD) and devices that make treatment easier:



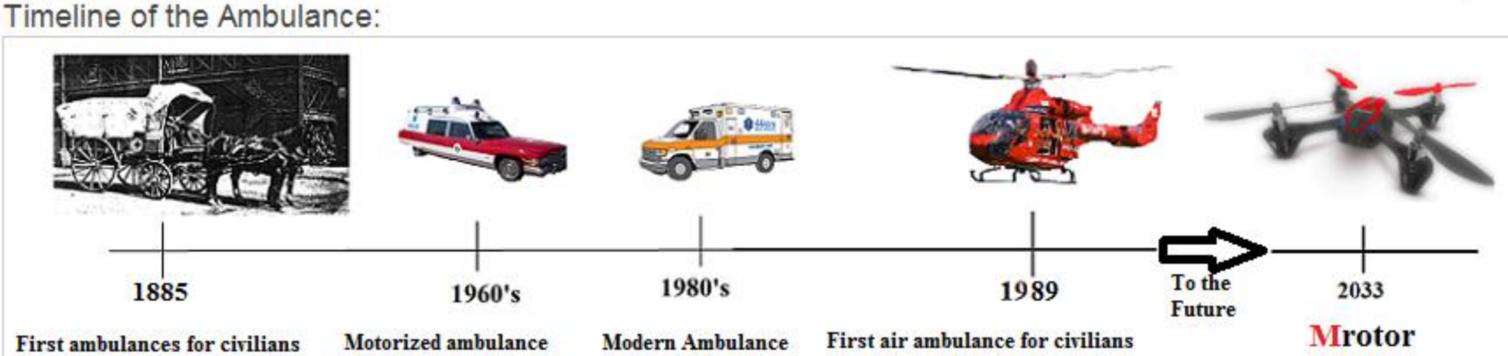
Timeline of Heart Rate Monitors



Timeline of Medical Records:



Timeline of the Ambulance:



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The Solution

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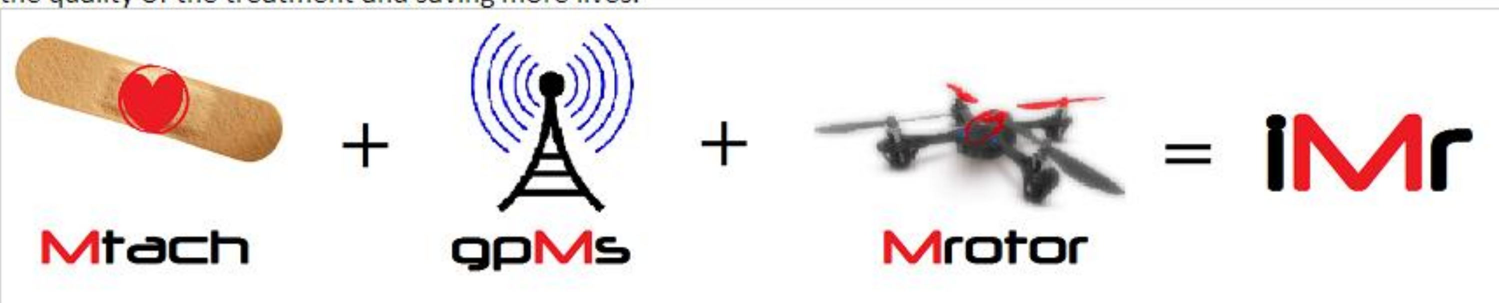
Our solution, iMr, detects and locates medical emergencies, and then delivers diagnostic and elementary treatment procedures to the patient. This cuts the time it takes for medical attention to reach the patient, while also improving the quality of the treatment and saving more lives.

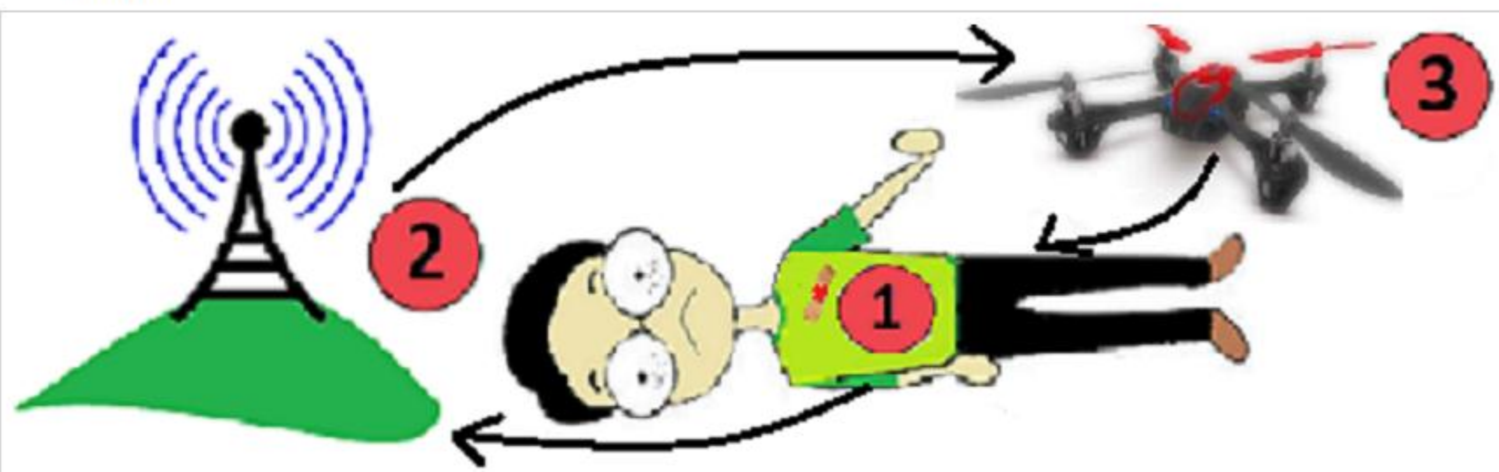


1)Mtach
Mtach is a small, versatile, external, and portable device that contains bio-sensors that keep track of user's vitals. Medical emergencies can be detected by aberrant behavior in general health. The Mtach will continuously monitor:

- blood pulse
- heart's electrical activity
- body temperature
- respiration rate
- fall impact

2)Global Positioning and Medical System (gpMs)-
GPMS is a secure online-based system that will function as an international medical database, analysis network, patient location tracker, and emergency response system. The GPMS continuously analyzes incoming data from the Mtach for deviant behaviors that are characteristic of certain medical emergencies.

3)Mrotor:A mini Unmanned Aviation Vehicle (UAV) multi-rotor that responds to the emergency alerts transmitted by the GPMS and Mrotor Centers. As a first responder system, it will deliver elementary, life-saving treatment and perform non-invasive diagnostic tests, bringing critical preliminary medical attention to the patient while cutting the time it would takes for complete medical treatment to reach the user.



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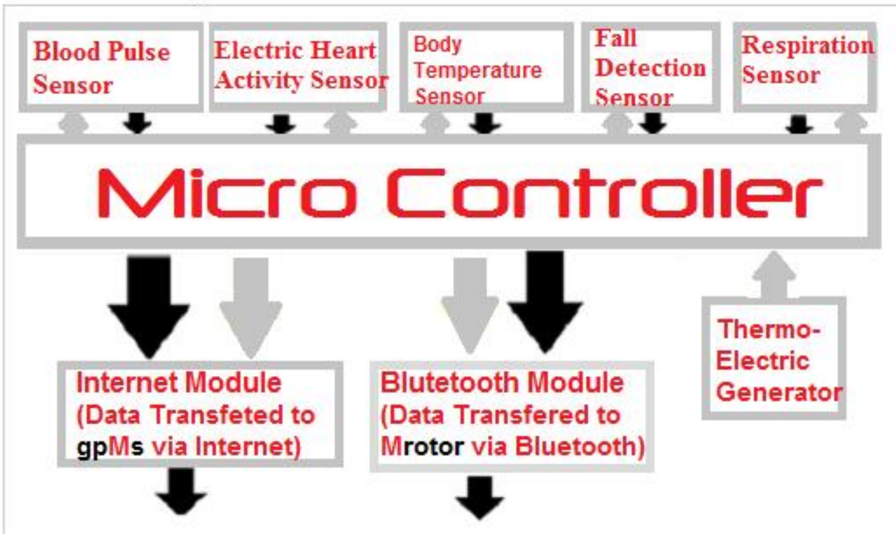
The Solution Part 2

Block Diagram for **Mtach**



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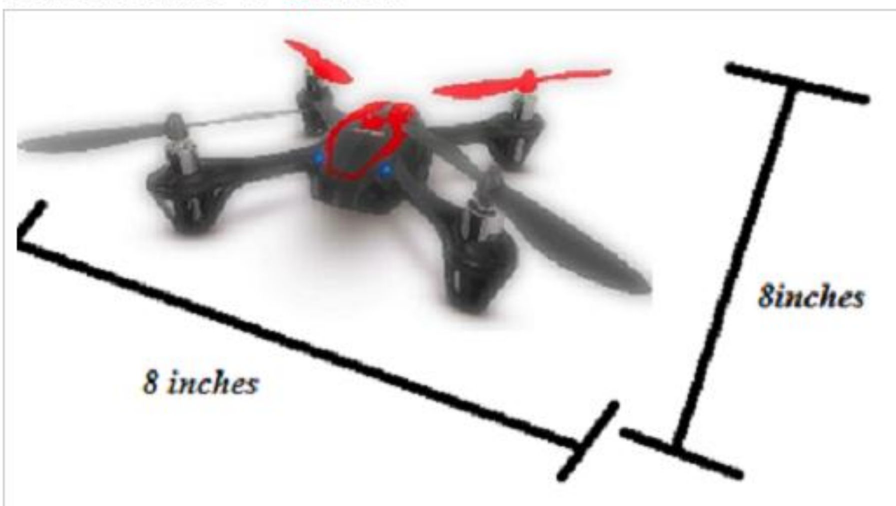
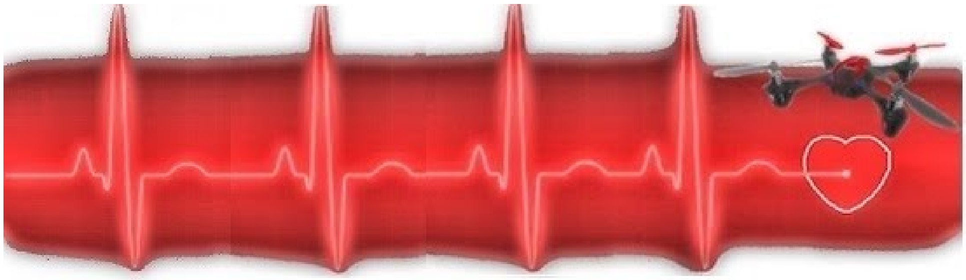
The diagram on the left is a block diagram that shows the interaction of the mirco-controller and its sensors on the Mtach.

Dimensions of **Mrotor**



Mrotor is a quadrotor that is fast, small, cheap, agile, and sustainable vehicle that is the perfect canditate for being the next generation of emergency medical response vehicles. Although the quadrotor currently can fly at a speed of 6.5 minutes/mile which is slower than the modern ambulance, it can fly over all buildings and other obstacles and thus can fly to its' destination in a straight line. This allows to be faster than the modern ambulance which have to stick to roads. This makes it take long detours that add extra time that are avoidable with quadrotors. Another positive point is that the quadrotor is smart enough to recognize its gyroscopic readings and reorientate itself which allow it to fly in severe conditions that are unnavigable with the modern air ambulances.
The quadrotor has a shockingly cheap price of only $50(not including medical equipment) while the modern air and land ambulance cost more than a few thousand not including the medical equipment.



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The Impact

The primary impact of iMr will be to provide **fast detection, diagnosis, and response system for medical emergencies**. This will result in:

- **Many lives saved among patients who currently lack access to fast response**
- **Improved quality of life for patients who are saved due to fast response as it prevents long-term brain and heart damage**
- **Provide wider coverage of emergency services that are currently unavailable due to resource constraints**
- **Lower emergency response costs due to avoided unnecessary ambulance and doctor visits**

Developed countries are faced with high costs of EMS services today. Also they do not have wide coverage of EMS in rural areas. An ambulance trip can cost as much as $2204 by land, and over $45,000 by air in developed countries. The impact of iMr in developed countries will be to:

- Provide an omnipresent EMS due to the low cost of a quadrotor (Quadrotors cost very little, usually only $100)
- Allow doctors to directly address the patients' emergencies before it is too late
- Comprehensive first response and treatment resulting in many lives saved
- less unnecessary ambulance trips will save costs
- 95% of the patients who survive a cardiac arrest are permanently impaired with neurological problems. LUCAS system of iMr will improve quality of life for surviving patients

Developing countries face the challenge of lack of fast EMS care with EMS response times greater than 2 hours in many nations. Patient to doctor ratios are also astronomical, ranging to 1500:1 even among the more developed countries like India. The impact of the iMr in developing countries will be to:

- provide global and higher-quality medical coverage at a faster rate with lower costs to anyone, anywhere
- access any patient in any area overcoming traffic congestions in big cities and lack of medical staff in remote villages
- Patients will not need to find an available doctor after waiting in the Emergency Room for an average of 6 hours
- Reduced reliance on trained personnel to administer CPR or AED since they are not readily available. LUCAS Chest Compression system provides 100 compressions per minute continuously, pumping the blood more regularly and quickly
- increase the quality of life for those surviving by preventing brain damage from inadequate CPR.