

The SMERTbike
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My entry for the Parallax MicroMedic contest is a device which I call the SMERTbike. SMERT is an acronym for Smart Medical Exercise machine for use in Rehabilitation and Therapy. The SMERTbike is designed as the internal electronics of a smart stationary bike. The system is capable of measuring a patient's vital signs (body temperature, ambient temperature, heart rate and respiratory rate) and automatically adjusting the bike's performance based on the sensor information, patient information, and user adjustable settings. The project that I am submitting is just the electronics and sensors; it is NOT mounted in a stationary bike even though it is designed to be. In replace of the sensors and electromechanical hardware that would be inside of a standard stationary bike, I am using variables to simulate them and the remote to manually adjust them.

In terms of hardware, the SMERTbike system uses a Parallax Propeller microcontroller as its beating heart. The propeller is mounted in the PropBOE PCB. There is an 8GB MicroSD card inserted into the PropBOE's slot. The SD card stores 10 text files which contain the patient profiles. The PropBOE outputs video through the VGA connector. Mounted on the PropBOE's breadboard is the Polar Wearlink heart rate receiver. The rest of the circuitry (mounted on an external breadboard) includes a 38Khz IR remote receiver, the LM34 temperature sensor, a LED, a jumper that will enable/disable output to the Parallax Serial Terminal, and a connector leading to the body temperature sensor (AD592). The pressure (breath) sensor, PropBOE, external breadboard, and the piezo buzzer are mounted onto a metal base.

There are 2 main software programs; SMERTbike_Main.spin contains all the code necessary to make the bike run normally and Write_patient_data.spin contains the code to write information to the MicroSD card. The main program initializes the sensors, and then displays the menu screen. There are three options on the menu: Individualized Workout, Simple Workout, and Diagnostics. You navigate through the menus using the infra-red remote control. If you select the simple workout, it will prompt you to put on the sensors. After that, it will start a simplified program that will display the sensor data on the screen and allow you to manually adjust the bike's resistance. If the patient is working out too hard (abnormally high heart rate for example), it will beep the speaker and tell them to slow down. They can exit out of the program at any time by pressing the 'exit' button on the remote. The advanced mode is a bit more complex. The patient is prompted to select their 'profile', which contains basic information such as their age and resting heart rate. If the profile is empty (all values at 0), they are prompted to try again. When they have selected a profile, they are prompted to put on the sensors. The individualized workout will then begin.

The individualized workout display screen is divided into two regions. The upper area displays data such as bike speed, bike resistance, the workout mode selected, and how hard you are working out. The lower area displays the data from the sensors. There are four workout modes; Default, Rehabilitation, Stamina, and Speed. The modes control what speed of pedaling the program considers too slow, just right, and too fast. They are tailored to specific uses: rehabilitation is purposely set quite low for people whose goal is to just get their legs moving (useful for medical rehabilitation); Stamina mode is also set low (designed for people who are trying to pedal slowly but for longer periods of time than normal). In

addition there is the Speed mode, which is set quite high (for people training for a triathlon, for example). Finally there is Default mode. Default mode is somewhere in-between all of the modes.

The SMERTbike system is smarter than normal stationary bikes in that it is able to determine exactly how hard you are working out and is able to adjust the workout to suit your needs. It does this by taking the speed values set by the workout mode compared to the patient's speed; as well as the patient's calculated target heart rate zone compared to their heart rate. The SMERTbike system has four exertion levels. Going from least to greatest we have *Slacking*, *Just Barely*, *Perfect*, and *Slow Down*. Depending on the exertion level which is active, the bike's resistance will automatically adjust itself up or down (you can manually adjust it as well). The exertion level is *Slow Down* if the patient's heart rate is greater than their target heart rate zone's upper limit or it is larger than their maximum heart rate. The exertion level is *Perfect* if the heart rate is larger than the target heart rate zone's minimum limit and is smaller than the target heart rate zone's upper limit or the speed is smaller than the maximum speed (set by the workout mode) and the speed is larger than the target speed (set by the workout mode). The level is *Slacking* is active when the patient's heart rate is below their heart rate zone's lower limit and the bike's speed is below the minimum speed (set by the workout mode). The level is *Just Barely* if none of the other conditions are met (doesn't work on paper but works in the real world). If the exertion level is either *Slacking* or *Just Barely*, the bike's resistance will slowly tick up. Similarly, if the level is *Slow Down*, the resistance will be slowly ticked down. Finally, if the level is *Perfect*, the resistance value will stay the same. Again, the resistance value is manually adjustable as well.

The final mode available in the main menu is the Diagnostics mode. It displays all of the sensor data as well as a few extra variables which are useful for debugging the hardware. While in the debug mode there are a few additional things that you can do: a few of the buttons on the remote allow you to test certain features of the device, such as the speaker and VGA screen.

The second program, `Write_patient_data.spin`, is a small widget that I created that allows the reading, writing, and deleting of patient information on the MicroSD card.

My design is far from ready to be manufactured and contains a few known glitches. First of all, when the 'exit' button is pressed (to go back to the main menu) while the advanced workout is running, the device will crash and needs to be reset for operation to resume. Second, after the MicroSD card is mounted, the Parallax Serial Terminal object will fail to send data to the computer (if one is hooked up). Finally, the first time a program is run after the device is powered up, the PropBOE's onboard ADC will fail to measure accurate values; this can be fixed by reloading or resetting the program. There are also a few areas for improvement in the device's design. One of the ideas I originally had was to use a pair of Xbee wireless transceivers; one mounted on the SMERTbike and one or more connected to external devices such as a data logger/monitor or an automated paramedic dialing system if there is a problem. Another thing on the to-do list is to add a GUI to the device (the User Interface on the VGA screen is all in text with no additional graphics). Also, the AD592 temperature sensor that is used for measuring the body temperature is very inaccurate (± 4 °F is the approximate inaccuracy) and therefore cannot be used to determine if the patient's body temperature is high enough to be a concern. Substituting a more accurate sensor would be a necessity for a production-ready device. I originally had an idea for a sensor

that would measure how much the patient had sweated during the workout, but this idea was scrapped because it conflicted with the mounting position of the AD592 temperature sensor.

The SMERTbike system is designed for use in the medical rehabilitation and therapy fields, though it can be used for so much more. The SMERTbike's incredible workout flexibility makes it able to adjust to a wide range of uses: from gently working out an injury to training for a cross country biking race, it is able to adjust nicely to almost any therapy or training exercise. I know from personal experience that a device similar to this is needed in the medical therapy field. A little over a year ago from the time of me writing this (it's currently July 2013); I suffered from a serious spinal injury. I was in physical therapy for about four months. About halfway through my time in therapy, they started me on the stationary bike. The therapists did not make use of any of the programs on the machine (they were all too intense of a workout for therapy); instead I pedaled at about 15 RPM on the least resistance setting for about 10 minutes per session. There was no program on the bike that was designed for therapy. None of the programs were customizable enough to where they could be used for therapy. So no programs were used during my therapy. The need for this kind of a stationary bike is the main motivational reason behind the creation of the SMERTbike system.