IPRO 497 - 324

Spring 2009

Power Measurement for Road Bicycles: Towards a Universal Solution

Project Plan

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Team Members:
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1.0.Objectives

- Mechanical Team Objectives
  - Obtain more data from previous crank set
  - Define a setup using strain gauges that would obtain the best results on the new crank set
  - Apply strain gauges on a new crank set
  - Design an experiment that would accurately measure the output of the strain gauges at different loads
    - Crank angle
    - Direction of applied force
    - Point of force application
      - Left pedal
      - Right pedal
      - Both left and right pedal
  - Analyze data and implement an algorithm to calculate torque
- Electrical Team Objectives
  - Implement an algorithm to calculate the applied torque at the bicycle crank set
  - Transmit the data wirelessly to the Garmin Edge 705 using the ANT+ protocol
  - Improve power efficiency
- Overall Team Objectives
  - Packaging System
    - Must work under realistic conditions
    - Needs to conform to the space requirements associated with a bicycle
  - IPRO Deliverables

2.0. Background

- The goal of the IPRO is to try to find an inexpensive, but accurate way of measuring the power output of a rider on a bicycle. Problems with systems currently available are: some products are not compatible with all bike systems causing the need to purchase new parts, the cost of the available products is expensive, and some of the available measuring systems are not very accurate.
- There are four main ways in which systems measure the power output of a rider. They include crank set, free hub, chain, and opposing force systems. The crank set system uses strain gages to measure the strain in the crank set which can be related to torque from which the power is calculated. The free hub system works in much the same way except the strain gages are attached to the rear wheel of the bicycle. Chain systems detect the vibration and the speed in the chain and convert that to a power reading. Opposing force systems calculate opposing forces to the rider and bicycle including: gravity, drag, acceleration of the bicycle, and wind speed. The system takes all this information and calculates the power using Newton's Third Law.
- The crank set is what the pedals are directly attached to on the bicycle. The crank set includes the spider, which is attached to the crank arm, and the chain rings, which drive the chain. The freehub is used to connect the chain to the rear wheel.
- The crank set systems can be very complicated systems and therefore are very expensive. Not only are the systems themselves expensive, but the system requires a new spider, causing the replacement of an expensive part of the bicycle. The Quarq CinQo has an accuracy of ± 2%, but costs $1159.
- The free-hub systems have similar problems involving the crank set systems. Their measurement accuracy is diminished because the power output of the rider is not directly measured. The PowerTap Pro made by Saris has an accuracy of ±1.5%, but costs $899.99 with the computer.
- Inaccuracy is a bigger problem with the chain systems because of power loss from the crank to the chain as in the free-hub systems as well as vibration in the chain caused by other factors including terrain. The Polar CS600 cycling computer with Power Output Sensor has an accuracy of ± 5%, and is less expensive than the crank set and free-hub systems at $679.95 which also includes the bicycle computer.
- While cost is not as much a factor in the opposing force systems as in the crank set systems the accuracy can be far less. The inaccuracy can be caused by drag which is affected by rider position, weight fluctuation of the rider, as well as the roughness of riding surface. The iBike Pro claims to have accuracies comparable to those of high end models, like the crankshaft and free-hub systems, but it becomes more inaccurate in sharp turns or long stretches of rough terrain. The cost of the iBike system is $399.99.
- The other side of the project is the interaction with the rider. This is done through the bicycle computer. The

computer processes the information from the power measurement systems and displays it for the rider to see. Problems faced with the computers involve finding a way to relay the information wirelessly. The Garmin Edge 705 bicycle computer will be used to communicate the information to the rider. The ANT+Sport system will be used for communication between the computer and the rest of the system.

- During the last semester (1st of the IPRO), the team was able to implement the strain gauge system in a crank set. However they did not attain accurate results and found that the crank angle needed to be figured into the algorithm that allowed calculating of the power. A method of testing was also achieved, but will be improved in order to speed up the process. For the electrical side they were able to come up with a power circuit as well as make great progress on a reading circuit as well as a start on the wireless communication needed from the system to the bicycle computer.

3.0. Brainstorm and Work Breakdown Structure

We would like to develop a system that measures the applied torque at a bicycle crank set. In contrast to current solutions, we want to be able to retrofit our system to existing crank sets, obviating the need to abandon parts that the bicyclist already owns. In principle, according to preliminary tests performed at the MMAE department, this can be done using sets of quite inexpensive strain gauges. However, being able to get accurate torque measurements will require some advanced signal processing from the strain gauges. These signals can then be transmitted wirelessly to a bicycle computer like the Edge 705 that the global positioning system corporation Garmin released last year. There is a defined wireless protocol, called ANT+Sport, which has been developed specifically for the purpose of transmitting exercise data, such as power output or heart rate, to small computers. Chipsets and development kits for this protocol are also available commercially. Therefore, our task will be to find an optimal configuration of strain gauges that will be attached to the crank set, and to develop an algorithm to process the strain gauge data in order to isolate a signal that is proportional to the applied torque. This signal will then be transmitted to the bicycle computer for display and storage.

1. Electrical Team
    a. Improve Power Supply Circuit
    b. Build Circuit to Interface with Strain Gauges
    c. Design Circuit to Obtain RPM
    d. Develop Algorithm
    e. Implement ANT+ Communication
    f. Improve current Circuit Board
    g. Minimize Electrical Packaging

2. Mechanical Team
    a. Strain Gauge Testing
        i. Apply Strain Gauges
        ii. Acquire Strain Data
        iii. Preliminary Analysis of Strain Data
    b. Final Analysis of Strain Data
    c. Develop Algorithm

3. Entire Team
    a. Program Hardware
    b. Test Product
    c. Design Final Product Package

4. IPRO Deliverables
    a. Project Plan
    b. Code of Ethics
    c. Midterm Presentations
    d. Final Report

e. Exhibit/Poster
f. Abstract/Brochure
g. Presentation
h. IPRO Day

4.0 Expected Results

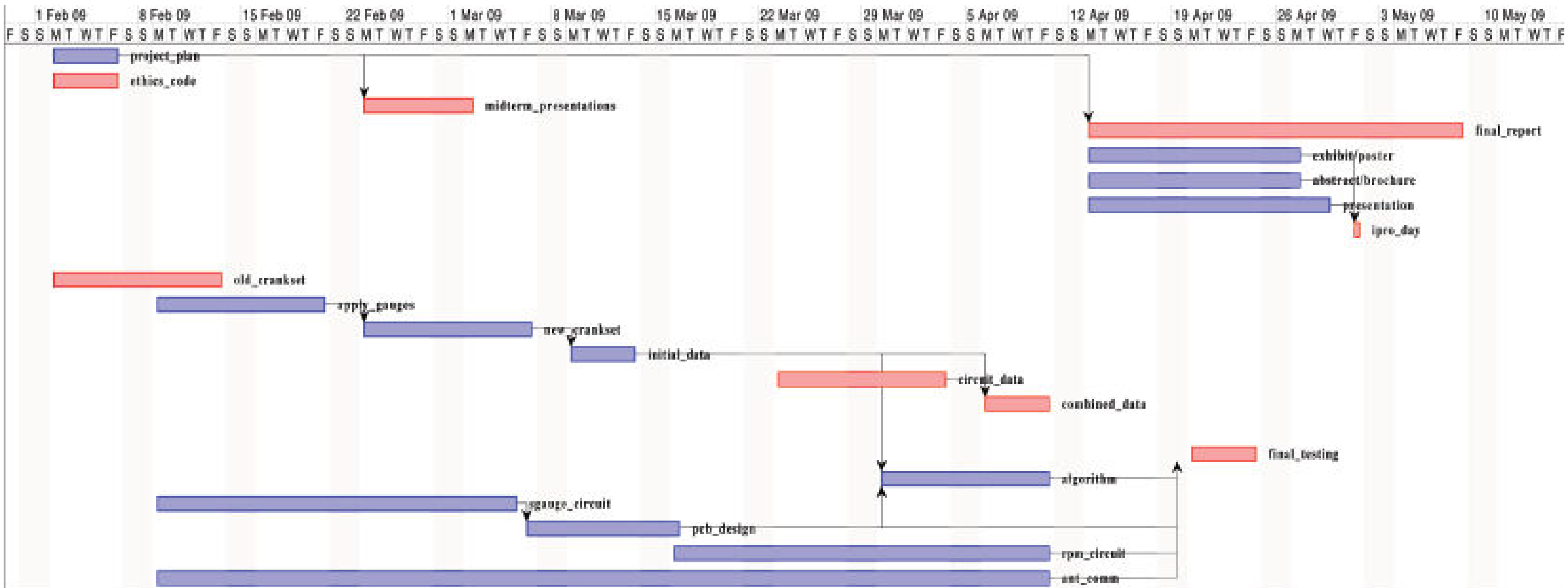
The team anticipates improving the current system from last semester's IPRO based on the learning experience from old members as well as new ideas from the new members. As planned, a final product that is able to measure power output of a rider will be developed that will cost a whole lot less than that of currently available systems. The system will be available to all bikes with no need to replace parts or buy expensive equipment and replacements. If the development of the product is successful, the market potential of a commercial product in a follow-up ENPRO may be likely.

5.0 Project Budget

ITEM	UNIT PRICE	QTY	PRICE	PURPOSE	Vendor
Electrical					
MSP430 Dev Kit	20	1	$20.00	Wireless	Multiple
INA 122 (Amplifier)			$5.00	Amplifier	
Voltage regulator			$5.00	Regulate Voltage	
Switches ADG 801	4	4	$16.00	Switching Bridges	
Support Components			$54.00	Batteries & other electronics	
Soldering tips	6.15	4	$24.60	Soldering	HMC Electronics
Mechanical					
Crank Set	142.9	1	$142.90	R & D	Shimano
Hard drive/Software upgrade			--		Vishay
Extra			--	FEA (Craig)	IIT Machine Shop
Adhesives, applicators	100	1	--	Strain Gage application	Vishay
Half Bridge Gauges (5 pack)	50.00	6	$300.00		Vishay
Final Presentation, Materials					
Refreshments and food			$100.00	Team Building	Multiple
Total			**$667.50**		

Bold items already purchased

6.0. Schedule of Tasks and Milestone Events



		Name	Duration	Start	Finish
1		Project Plan	5 days?	2/2/09 8:00 AM	2/6/09 5:00 PM
2		Code of Ethics	5 days?	2/2/09 8:00 AM	2/6/09 5:00 PM
3		Midterm Presentations	6 days?	2/23/09 8:00 AM	3/2/09 5:00 PM
4		Final Report	20 days?	4/13/09 8:00 AM	5/8/09 5:00 PM
5		Exhibit/Poster	11 days?	4/13/09 8:00 AM	4/27/09 5:00 PM
6		Abstract/Brochure	11 days?	4/13/09 8:00 AM	4/27/09 5:00 PM
7		Presentation	13 days?	4/13/09 8:00 AM	4/29/09 5:00 PM
8		IPRO Day	1 day?	5/1/09 8:00 AM	5/1/09 5:00 PM
9		Old Crankset Testing	10 days?	2/2/09 8:00 AM	2/13/09 5:00 PM
10		Apply Gauges	10 days?	2/9/09 8:00 AM	2/20/09 5:00 PM
11		New Crankset Testing	10 days?	2/23/09 8:00 AM	3/6/09 5:00 PM
12		Initial Data Analysis	5 days?	3/9/09 8:00 AM	3/13/09 5:00 PM
13		Circuit Data Acquisition	10 days?	3/23/09 8:00 AM	4/3/09 5:00 PM
14		Crankset/Circuit Data Analysis	5 days?	4/6/09 8:00 AM	4/10/09 5:00 PM
15		Final Product Testing	5 days?	4/19/09 8:00 AM	4/24/09 5:00 PM
16		Develop/Implement Algorithm	10 days?	3/30/09 8:00 AM	4/10/09 5:00 PM
17		Develop Strain Gauge Interface	19 days?	2/9/09 8:00 AM	3/5/09 5:00 PM
18		Design Circuit Board	7 days?	3/6/09 8:00 AM	3/16/09 5:00 PM
19		Design RPM Circuit	20 days?	3/16/09 8:00 AM	4/10/09 5:00 PM
20		Implement ANT+	45 days?	2/9/09 8:00 AM	4/10/09 5:00 PM

7.0. Individual Team Member Assignments

Name	Major / Year	Skills and Strengths	Experience and Academic Interest	Subteam	IPRO Assignments
Tarun Anupoju	Computer Engineering 4th Year	C and python programming and circuit analysis	Work experience with BME professor Philip Troyk - coding in C and Python for micro controller chips.	Electrical	Wireless Communication
Stephanus Halim	Computer Engineering 3rd year	Java programming, circuit building, and circuit analysis.	Interested computer hardware and circuits.	Electrical	Wireless Communication
Bryan Kaminski	Electrical Engineering 4th Year	Previous IPRO 324, Familiarity with lab equipment, circuit design and goals. Various computer languages, EagleCAD, MPLAB	Familiarity with programming microcontrollers, soldering	Electrical	Electrical Team Leader, Gauge Interface
Brian Lam	Mechanical Engineering/Physics 4th Year	C++, MATLAB, Microsoft Office, Instrumentation experience	Rapid-prototyping & manufacturing internship at USC. Interests in Engineering design.	Mechanical	Testing, MATLAB
Brandon Marcellis	Aerospace Engineering 3rd Year	MATLAB, AUTOCAD, Some electronic instrumentation experience.	Interest in using equipment and solving problems.	Mechanical	Mechanical Team Leader, Strain Gauges Testing
Rebecca Martin	Mechanical Engineering 4th Year	Mechanical design and analysis. Good communication and writing skills.	Interests in sustainability and energy concepts.	Mechanical	Apply Strain Gauges, Testing, Scribe
Edumaregbemiro Odunaiya	ECE 4th Year	Java and C++ Programming language skills; Team skills; Experience in hardware design, circuit building and software design	Intern at Cummins Inc. in IT Department and also as a Controls Engineer	Electrical	Gauge Interface
Stefan Stevanovic	Mechanical Engineering 3rd Year	Java programming, SolidWorks, CosmosWorks, AutoCAD, and MATLAB.	CAD finite element analysis, assisted with prototype assembly, and some machining experience.	Mechanical	Testing, Apply Strain Gauges
Henrietta Tsosie	Mechanical Engineering 4th Year	Pro/E, Solid Works, MATLAB, C++. Practical experience with instrumentation.	Internship at Argonne National Lab (research in enhanced heat transfer). Academic interest in hybrid vehicles, heat transfer applications, engine efficiency, and alternative energy.	Mechanical	Apply Strain Gauges, Testing
Ivan Voukadinov	Mechanical/Aerospace Engineering 4th Year	ProE, Adobe Photoshop	Internship at Zebra Technologies	Mechanical	Pro/E, Apply strain gauges, Testing
Arkadiusz Ziomek	ECE 4th Year	SolidWorks, AutoCAD, MATLAB, Simulink, C, Assembler of AVRAtmega16/32	Experience in design and construction of four legged walking machine. Interested in mechatronics, robotics, electronics, and control systems.	Electrical	Gauge Interface

8.0 Designation of Roles

Team Leader
- Henrietta Tsosie

Mechanical Sub-team
- Brandon Marcellis

Electrical Sub-team
- Bryan Kaminski

Scribe
- Rebecca Martin

IGroups Moderator
- Rebecca Martin

Sub-team Responsibilities

Mechanical
- Apply and test strain gauges on various areas of the bike's spider
- Analyze results of strain gauge testing

Electrical
- Develop microcontroller and circuitry for strain gauges and RPM measurements
- Interface standard bike computer with measurement circuitry
- Refine previous circuitry
- Optimize footprint
- Wireless Communication between gauges and Garmin

9.0 Sources

Quarq CinQo: www.quarq.us
iBike: http://www.ibike.com.ar/faq.html, http://www.bikyle.com/PowerMeters.asp Polar
Polar CS600: http://www.bikeradar.com/gear/category/accessories/gadgets/cyclecomputers/product/cs600-cycling-computer-with-power-output-sensor-17033?_brc=1,
Saris PowerTap: http://www.saris.com/p-328-powertap-pro.aspx
Garmin: www.garmin.com
ANT+: www.thisisant.com