DIY BIOMECHANICS

@NYU ITP

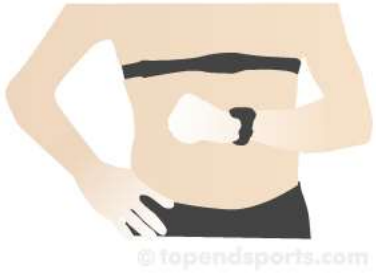
Key: closed source open source

Health & Fitness Monitoring

Heart rate monitors & pulse sensors:

A heart rate monitor is a personal monitoring device which allows one to measure his or her heart rate in real time or record the heart rate for later study. It is largely used by performers of various types of physical exercise. The heart rate is measured by detecting the electrical signal transmitted through the heart muscle when it beats.[1]

HRMs are usually in form of chest straps that continuously measure heart beats (even while exercising) and wirelessly transmit the rate to a receiver (like your phone/ wrist watch).[2]



1. Chest strap (source: topendsports.com)

An alternative to HRMs is a pulse sensor. It optically senses pulses to determine the heart rate. It comes in easy to use clip-on forms and is usually quite cheap, but is less accurate than a chest strap; and you've to be stationary to measure your pulse.[3]

> *Note: Pulse detectors are often confused with pulse oximeters. Oximeters are devices that non-invasively measure the oxygen level in blood- by using similar optical technique (photoplethysmography) as that of the pulse detectors. Look here for example. An oximeter can provide pulse measurement too but a pulse detector cannot measure blood oxygen level.*

Some devices and tools for heart rate measurement:

1. Heart Sensor: State of the art sensor devices ranging from low cost sensors for consumer applications to medical grade ECG sensors. They provide their own SDK along with the products.
2. Garmin's HRM. (They've some heart rate measurement based fitness monitors too)
3. NuMetrex..has speacial apparel (tank / shirt/ sports bra) that have sensors embedded in the fabric to measure heart rate!
4. Polar fitness products: provide heart rate & activity monitors in form of wrist watches and chest straps with features like GPS, calorie counter and activity monitor.
   - In collaboration with Sparkfun, they've developed an interface board to receive data from their HRM chest strap (Wearlink+). Tutorial on using Sparkfun interface+ Arduino for Polar HRMI: http://bildr.org/2011/08/heartrate-arduino/
   - Adafruit, too, has an experiment kit for interfacing to Polar HRM: http://www.adafruit.com/products/1077
5. Sparkfun's simple pulse sensor . A complete DIY-from-scratch of this pulse sensor.
6. Another DIY pulse sensor: http://embedded-lab.com/blog/?p=5508.
7. DIY ECG + Optical pulse sensor

(Also, seems like the Wii Vitality sensor (a pulse oximeter that connects through Wii Remote) needs some more time to prove itself)

Cool applications for heart rate monitors and pulse sensors:

BioBeats: Smartphone App that detects heartbeat through camera & generates music accordingly!

http://www.geek.com/news/hacked-heart-monitor-changes-tempo-of-music-according-to-heart-rate-1528892/

http://www.lozano-hemmer.com/pulse_park.php

http://www.mariapaulasaba.com/heartpillow.php

http://www.phanv.com/#connected-heartbeats (Used stethoscope)

http://artandprogram.com/butterflydress/index.php?mov=1

Daily activity monitoring:

The major products available in market for fitness monitoring are:

1. Nike Fuelband
2. Fitbit
3. Body Media
4. Jawbone Up
5. Basis

..all of them work more or less on similar principles- they have sensors that measure parameters like body movement, heart rate, body temperature during an activity and combine the sensor data with user's physique to give out an analysis of fitness activity of the user. (A lot of the heart rate monitors mentioned previously provide activity analysis as well but are mostly only based on heart rate data.)

There are a lot of GPS based fitness apps for smartphones:
Here's a nice compilation of such apps for iPhone.
The Google play store has quite a lot of fitness apps for Android

More info:

- Here's a nice comparison of all the four wearables: http://www.getgrok.com/2013/01/a-comparative-review-28-days-with-the-fitbit-one-jawbone-up-nike-fuelband-and-bodymedia-link/
- Another quite good comparison of a few more (Striiv Play, LarkLife, MotoActv) fitness monitoring wearables: http://www.pcmag.com/article2/0,2817,2404445,00.asp
- Here's a selection guide for HRMs used for activity monitoring

Weighing scales:

- An idea for DIY weighing scale: We can use an array (or grid) of FSRs with a platform/ plate placed on top of it to distribute weight to measure the total force on it. We can calibrate the FSR output to give out actual weight measurement

- Wii Balance board as a weighing scale

- Hacking a digital bathroom scale

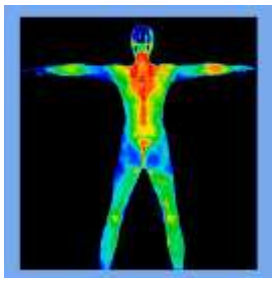
- Weight sensor

Temperature sensors:

- TMP102: Digital sensor with a resolution of 0.0625^{0}C & accuracy upto 0.5^{0}C. Getting started guide for TMP102 with Arduino
- TMP35: Very easy to use sensor that provides output voltage proportional to temperature. Accuracy in normal weather conditions is +/- 1^{0}C
  Tutorial
  (Both TMP sensors need to be in contact with the body to measure temperature)

➔ **Thermal imaging**:

..is a very useful tool for non-invasive monitoring of overall health of a person. It works on the principle of detecting IR emissions by an object above the absolute zero temperature. Under this temperature condition, a body is constantly emitting IR radiation; the amount of radiation being proportional to the temperature of the body[4]. [How it works]



2. Thermal image of IR radiation emitted from body (source: Wikipedia)

Here's a nice article on uses of thermal imaging

Thermal imaging is performed using special, very expensive cameras. FLIR ($5,000- $8,000) and FLUKE ($1000 - $6000) are the major manufacturers of hi-end thermal imaging cameras.

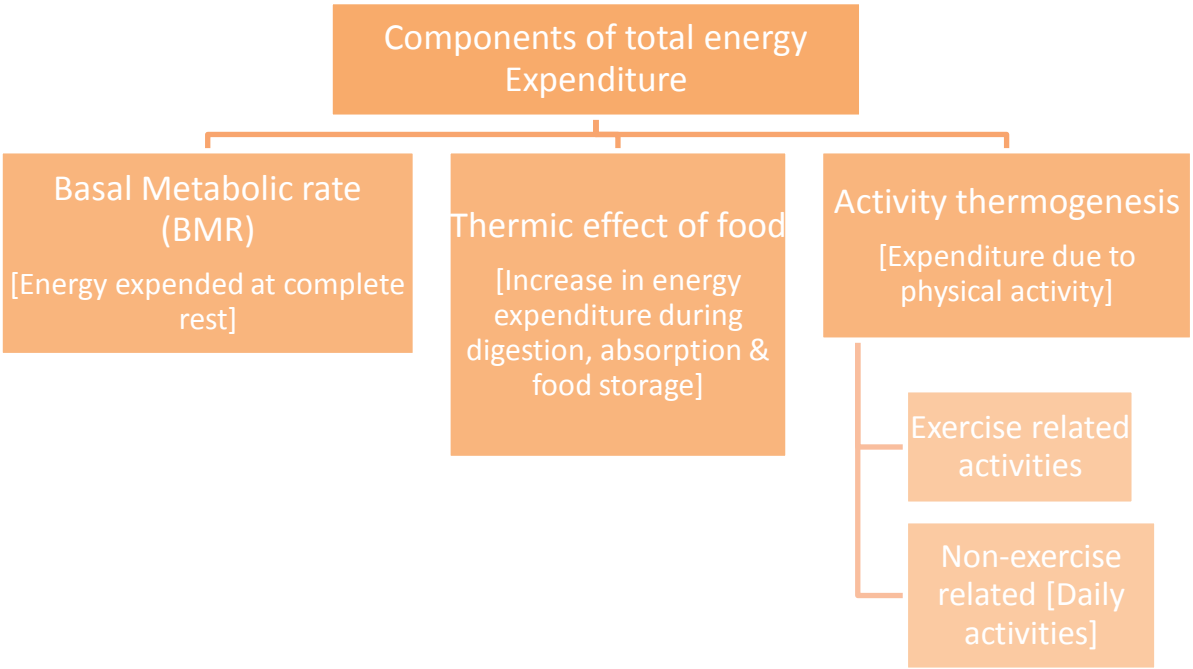
AND, some clever people have come up with very affordable solutions to thermal imaging..

- DIY Thermal imaging camera (~$200)
- IR Blue: Thermal imaging smartphone accessory
- Thermal flashlight

Recently I got to know about this: e-Health sensor kit for Arduino & Raspberry Pi!
It contains a shield for Arduino & RasPi that connects to 9 different bio-sensors! (included in kit) The sensors:
Pulse, blood oxygen level, breathing/ airflow, body temperature, ECG, glucometer, galvanic skin response, blood pressure & position. The whole kit costs $485. You can buy just the shield for $98.

Make Magazine has a nice article on Biosensing

HUMAN ENERGY EXPENDITURE MEASUREMENT



Methods of measuring EE:

1. Direct calorimetry: Rate of heat loss from the subject to the calorimeter(thermally isolated chamber) is measured to determine the EE. This method is pretty accurate but very cumbersome & costly. A low cost alternative would be to monitor local heat loss (e.g., by a sensor on arm band) and calculate EE. [Intro video]

2. Indirect calorimetry: Oxygen consumptioin &/or carbon dioxide production is measured and converted to EE using formulae (because the body's energy production is directly related to O_2 consumption). It's the most commonly used method. [Intro video]

Figure 3. EE at rest

Figure 4. EE while walking

A paper here describes very nicely how this method is used to measure EE.

Maybe, we can use O2 & CO2 sensors from hobby stores to build our own system!

3. Non calorimetric: EE determination using HRMs, thermal imaging & kinematic measurements

   Here's Dustyn's short description of various EE methods
   Here's a technical paper describing EE measurement in detail

References:

[1] "Heart rate monitor," *Wikipedia, the free encyclopedia*. 07-Jul-2013.
[2] "Heart Rate Monitors - How They Work?" [Online]. Available: http://www.topendsports.com/fitness/equip-monitors.htm.
[3] "Heart Rate Monitors: How to Choose." [Online]. Available: http://www.rei.com/learn/expert-advice/heart-rate-monitor.html.
[4] "Thermography," *Wikipedia, the free encyclopedia*. 29-Jun-2013.
[5] J. A. Levine, "Measurement of energy expenditure," *Public Health Nutr.*, vol. 8, no. 7A, pp. 1123–1132, Oct. 2005.