1st QTB PBR Hack‘a’thing

Soldering for and by beginners.

March 2–4, 2016

Contents

1 Program

1.1 March 2 <12:00 : Building Bioreactors

Talks, 30-60 min:

- Rob's DIY Reactor - The Beginnings: `NinjaPBR` - Arduino-controlled mini PBR
- Dougie's DIY Reactor - 20 yrs Later
- Avantes - Spectrometry: Spectrometry applications, incl. NIR for metabolite measurements and OD; software interface to Avantes spectrometers
- CellDeg - Optimizing Photosynthetic Growth: Introduction to CellDeg's 2.5 k Euro algal growth setup (30 g/L cyano biomass in three days)

1.2 March 2 >13:00 : Hack‘a'thing I

- Introduction to the `Gas‘o'meter`: connecting sensors with Arduino, making an autonomous measurement device via Sainsmart's Touch Screen
- Introduction to Rob's reactor: complete setup for photosynthetic growth
- Introduction to 3D printing with QTB's `ultimaker`[2]
- Self-organizing into teams: lab hardware (tubing etc.), control hardware (soldering etc.), software and/or by by projects (3.1–3.7)

1.3 March 3 : Hack‘a'thing II

- Hardware I: soldering, tubing & 3D printing
- Software I: probe/sensor/pump ⇔ arduino/raspi interfaces
- Visit HHU's fine mechanics and glas blower work-shops, place orders

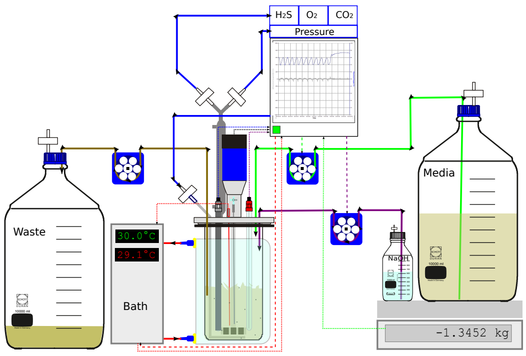
1.4 March 4 : Hack‘a'thing III

- Hardware II: Integrate projects 3.1,3.2&3.3 into a simple DIY reactor and/or with PSI FMT150 or Multicultivator
- Software II: arduino/raspi ⇔ master/server interface; data formats and interfaces
- Brain storming: relation of data and models and beer

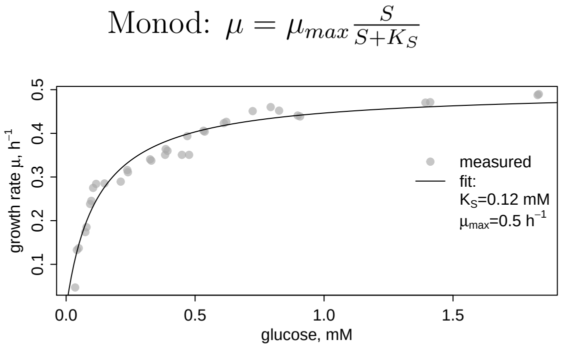
Resources - Materials, Designs and Ideas

Please see the Hack'a'thing Wiki for link lists of DIY bioreactors, DIY lab ware, 3D printer designs, general DIY websites, and electronics suppy shops.

This program and all code is at the HHU git project.



(a) Dougie's Reactor



(b) Snoep *et al.* 2009

Figure 1: Bioreactors

$$\frac{dX}{dt} = (\mu_{ab} - \phi)X$$

$$\frac{dS}{dt} = \phi(S_{in} - S) - (\mu_{ab} + \mu_{cd})X \qquad \mu_{ab} \equiv f(S, atp)$$

$$\frac{datp}{dt} = (n_{cd}\mu_{cd} - n_{ab}\mu_{ab} - \mu_m)\frac{C_c}{V_c} - \mu_{ab}atp \qquad \mu_{cd} \equiv f(S, G, adp)$$

$$\mu_m \equiv f(S, ROS) n_{cd},\ n_{ab} \quad \equiv f(S)$$

$$\frac{dG}{dt} = k_L a(G^*_{in} - G) - n_g\mu_{cd}X$$

$$adp = a_{tot} - atp$$

Figure 2: Growth in Continuous Culture: liquid and gas flux equations

2 PBR Hack‘a’thing Awards

- The “most creative Arduino fry” Award, inspiration at youtube: 5 ways to destroy
- The “red soldering iron” Award
- The “chip monkey” Award

3 PBR Hack'a'thing Projects

3.1 Gas Flux: `Gas'o'meter`

Project: Extend existing setup (co2meter's O_2 and CO_2 sensors with Sainsmart's Arduino Mega+Touch screen) by our brand new digital mass flow meter Aalborg XFM; write calibration routines for all sensors; build water trap and tubing to connect to the PSI or our DIY reactor and increase gas transfer (smaller bubbles) and decrease overall gas flow so that we can measure cellular activity. Perhaps add valve control to measure multiple reactors in series.

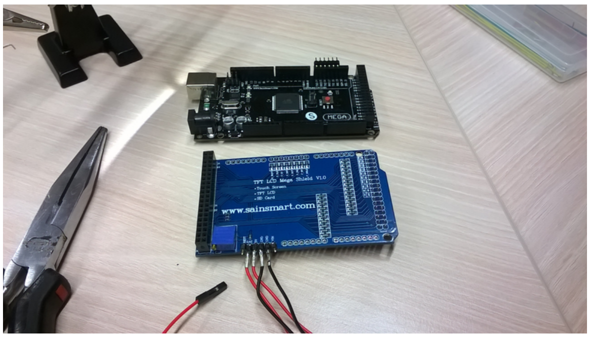
1. **build** water trap, tubing path from reactor, and casing for sensors and Arduino; **build** improved gassing system (glas blowers!) to allow lower flow
2. **code** sensor calibration routines via touch-screen (use PSI gas mixing system)
3. **build** & **code** interface to Aalborg XFM digital mass flow meter: connect the Aalborg's RS 485 interface to Arduino hardware serial Tx3/Rx3, and Ground
4. **build** & **code** valve control to measure several reactors; connect via Arduino software serial connections; perhaps attach to PSI Multicultivator

Resources:

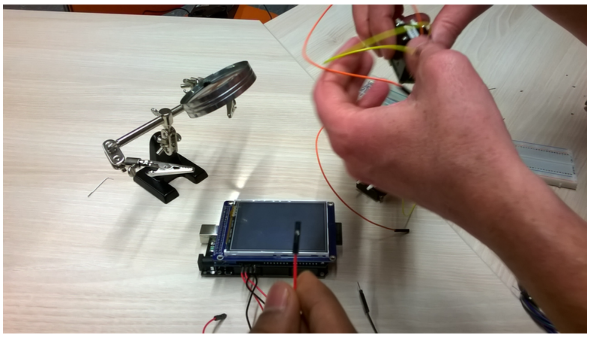
- Sensor manuals in `code/manuals/offgas/` at the PBR git: `Manual-CM-0201-UV-Flux-Oxygen.pdf`, `Manual-GSS-Sensors.pdf`, and `A_XFM_Manual_TD0701M[...].pdf`
- Code in `code/offgas/arduino/` at the PBR git

Materials:

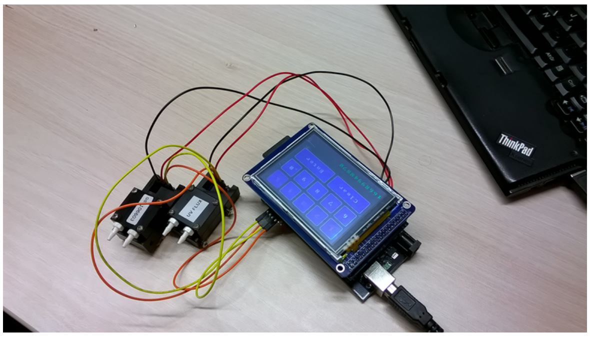
- Existing setup: **available**
- Aalborg XFM, with RS 485 interface: **available**
- Valve system for gas tubing, controllable *via* serial interface: **obtain**



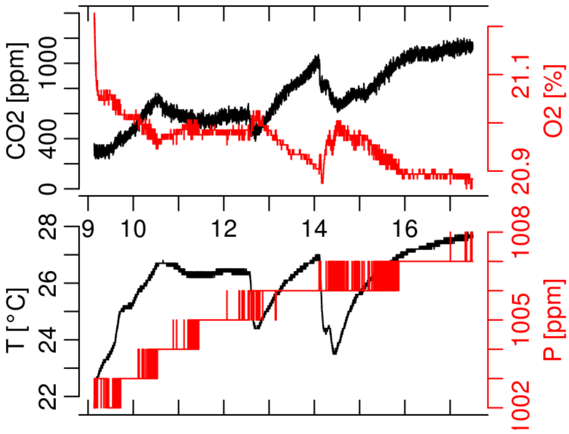
(a) The Gas‘o’meter: making of



(b) The Gas‘o’meter: making of



(c) The Gas‘o’meter



(d) Room 03.30, 2016-01-13

Figure 3: **Gas Measurement Module.**

3.2 Light Flux: Spectrometer

Project: Simple spectrometric measuring tool based on AvaSpec-Mini2048l-V25

1. Basic: Connect to Rasperry Pi, using drivers provides by Avantes; **code** simple interface with display and/or recording functions
2. Advanced: use LED for absorbance, reflectance, or fluorescence measurements; **build** light paths and perhaps a reactor probe for online recording

Resources:

- AvaSpec-Mini data sheet in `code/manuals/light/` at the PBR git
- The AS5216 microprocessor board - lib for Rasp. Pi 1 B+ at `code/light/`
- Tsuda *et al.* PLoS ONE 2015: 3D printed casing for OD measurement

Materials:

- AvaSpec-Mini2048l-V25, Minispectrometer: **available**
  Mini spectrometer, 2048 Large pixels, grating-MN0600-0.50 (350-885nm), OSC, 25µm slit, USB2 interface, AvaSoft-Basic
- Fiber optic cables, VIS/NIR: 1 m, 200 µm VIS/NIR and 1m, 600 µm: **available**
  SMA terminations, metal protection sleeves
- Raspberry Pi Version 1 Model B+: **obtain**
- LED system: use PSI LEDs or **obtain**
- Reactor probe: **build**; 3D print and/or fine mechanics and glas blowers

(a) AvaSpec-Mini 2048

setup sketch here
(b)

Figure 4: **Spectrometer Module.**

3.3 Liquid Flux: Continuous Culture & Turbidostat

Project: build a module consisting of media and waste bottles, a reactor vessel, peristaltic pump(s), and a scale; pump and scale are controlled *via* serial interfaces from an Arduino+Touchscreen. The flow rate is controlled *via* the pump motor speed and recorded *via* the scale; the flow rate is recorded or can be set after a setup-specific (tubing) calibration routine

1. **build** a simple reactor vessel (Schott bottles) with liquid media flow, from media bottles through reactor vessel and out to waste bottle
2. **code**: calibration routine for the weight sensor module
3. **code**: analog control of peristaltic motor speed and recording of weight loss and/or gain to record mass flow (g/min)
4. **code**: routine to calibrate pump speed to weight loss/gain for a specific setup; store calibration on SD card, which allows to also set pump speed in g/min, or if provided with a culture volume, as culture dilution rate (h^{-1})
5. **build** & **code**: combine with 3.2 to make turbidostatic control
6. **build**: add gassing system of project 3.1 to make a first simple bioreactor

Resources:

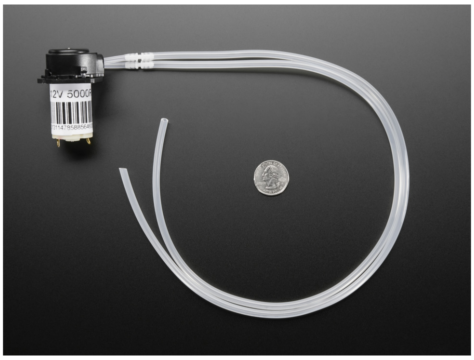
- Arduino tutorials for Adafruit peristaltic pump and general DC motor control and Adafruit motor shield
- Arduino library for Elecrow weight sensor kit 3 kg
- HX711 24-bit analog-to-digital converter (ADC) for load cells

Materials:

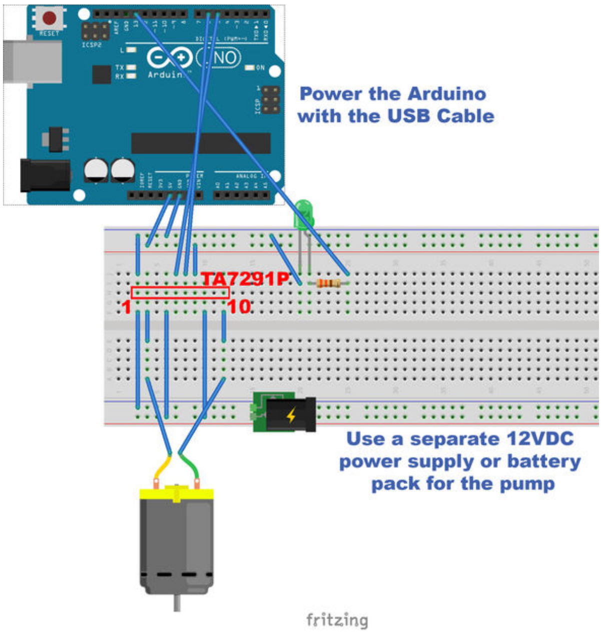
- Bottles, screw caps with inlet/outlet openings, and tubing: **available** & **obtain**!
- Scale - **ordered**
  fancy: Mettler Toledo, PBK785-3XS/f
  cheap: Elecrow Weight Sensor kit 3kg for Arduino ← **ordered**
- Peristaltic pumps - **ordered**
  fancy: Longer Pump LP-BT100-2J, DG-2(10)
  cheap: Ismatec Ecoline VC-MS/CA4-12
  cheaper: Welco WPM or cheapest: Adafruit ← **ordered**
- Toshiba TA7291P Bridge Driver - **ordered**

- Sainsmart Arduino Mega + Touchscreen - ordered

(a) Elecrow Scale Module, 3 kg



(b) Adafruit Peristaltic Pump



(c) Fritzing scheme for the Pump

Figure 5: **Continuous Culture Module**. The elecrow scale module is based on the HX711 load-cell amplifier (24-bit analog- to-digital converter) and connected to 5V, Gnd and two analog pins of the Arduino and comes with an Arduino library. An Adafruit peristaltic pump (12 v) is run by a "geared down DC motor" and requires a Toshiba TA7291P Bridge Driver (0-20V 1A; 2A peak) to control pump direction and speed *via* Arduino's PWM pins, see the *instructable* tutorial.

3.4 The Server

Project: a master software running on a (detachable) linux desktop that synchronizes and speaks via a comon interface to all Arduino and Raspberry Pi modules; the modules themselves can interpret get, set and act impulses (use arguments only when absolutely necessary).
During an initializiation the server may inquire what an attached module provides (*via* data IDs and SI units, meaningful time resolution) and handle it automatically.
Variable higher order control or processing logics can be built using defined data and control IDs. Ultimately, a direct integration with mathematical models may be desirable. For example, measured O_2 and CO_2 levels may be used to estimate metabolic activities, such as catabolic ATP/ADP turnover; required data and equations can be loaded and interpreted *via* SBML encoded models.

1. **build** combine of gas (3.1), liquid (3.3) and light (3.2) modules into a bioreactor
2. **code**: master program to synchronize and record data from the three modules
3. **code**: combine e.g. 3.2 & 3.3 to implement turbidostat control
4. **code**: higher order data evaluation logics, *eg.*, estimate metabolic rates from gas exchange measurements

Materials:

- `setTime(time_t` t`)`: sets the current master time to all modules
- `get(..., time_t` t`)`: get all values, currently available (with a time stamp), or from a previous time t
- `act(..., time_t` t`)`: act (switch on and off, set to a specific value), now or at future time t

3.5 Heat Flux: Water Bath Thermostat

Project: build a water bath for growth vessels, control T, read-out energy required for maintaining constant T and estimate the amount of heat withdrawn or administered

1.

Materials:

- Jacketed reactor vessel: **build** or **obtain**
- Julabo water bath, e.g. F25-ME
- Arduino and/or Raspberry Pi

3.6 The `Kaiten Eppi`: Automated Sampling Device

Projects: build sterile and automated sampling device; using a controllable syringe pump, sampling into the `Kaiten Eppi` (automated: pump sample into tubes, potentially pre-filled with chemicals, vortex, and transport them into liquid N_2 or other storage containers)

Materials:

- Sterile sampling device by HHU glas blowers: **available**
- Syringe pump: **obtain**
- `Kaiten Eppi`: **build**
- Sainsmart Arduino Mega & Touchscreen: **obtain**

3.7 Single Cell Biology: Microfluidic Device

Project: Basic microfluidics and live-cell imaging device; scratch growth chambers and liquid flow channels into microscope slide; attach 2–3 pumps; and control *via* arduino/screen

Resources:

- Tsuda *et al.* PLoS ONE 2015: 3D Printed 'Plug and Play' Millifluidic

Materials:

- Ilka's lab microscope: **available**
- Microscopy slides: **available**
- 2–3 peristaltic pumps for microfluidics: **obtain**
- Sainsmart's Arduino Mega + Touchscreen: **obtain**

3.8 Participants & Teams

type	name	e-mail	team
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Table 1: should we have skill badges, `https://www.adafruit.com/products/2857?q=skill%20badge&p=0&` or 3D-printed awards, like the "red soldering iron", "the blue tube", "the green chip"?

4 Outlook: 2nd QTB PBR Hack'a'thing

4.1 Growth Dynamics: Photobioreactors in Research

Talks, 30-60 min:

Nir Keren, Hellingwerf, Jan Cerveny, Dougie Murray, something microfluidics?

4.2 Single Cell Dynamics: Microfluidic Devices

Integrate project 3.7 with the simple microscope in Ilka's lab, or a more advanced system (CAi?)

4.3 Omics: Sterile and Automated Sampling Devices

Proper sampling for high-throughput data acquisition (mass spectrometry, sequencing) - the `Kaiten Eppi`