The Educational Value of Grand Challenge Problems

Alan Wassyng, Mark Lawford & John Hatcliff

Grand Challenge Problems

- **Grand Challenges** *
  - Potentially have a major impact in the domain
  - Ambitious but achievable
  - Compelling and motivating
  - Focussed – must know when they have been achieved
  - Drive innovation and advance technology

- **Research Intensive**
  - If you look at the definition of a grand challenge it should be obvious that the emphasis is on the research involved in the challenge

- **Education?**
  - So why consider grand challenge problems in education?

Possible Challenge Problems

- We have a number of challenge problems in the medical device domain, and we are going to look at those in some detail later

- We need challenge problems in other domains

The PACEMAKER Grand Challenge

- Boston Scientific (through Brian Larson) released into the public domain a sanitized requirements document for a 10 year old pacemaker

- Brian also worked with an ECE Capstone class at U Minnesota to design a hardware reference platform

- Mark Lawford manufactured & sold 50 modified units

- The challenge was to use the natural language spec as the basis for a formal approach to building a pacemaker

- Currently more than 10 different prominent institutions tackling the challenge

- A Dagstuhl Seminar on the PACEMAKER Challenge has been approved – Feb 2-7, 2014.

PACEMAKER Lessons

- I think it has all the attributes of a Grand Challenge as suggested by Kalil, but one:
  - It is not focussed enough
- The lack of focus has hurt us, and we must make sure not to repeat the mistake in future challenges
- The challenge does not run itself – there are real resourcing issues
- The PACEMAKER Challenge has been unexpectedly successful as an educational vehicle
  - Capstone class at McMaster (Mark Lawford)
  - 3rd year class on software development for ECE and Mechatronics Engineers (Alan Wassyng)
  - SCORE project at ICSE – 4 groups, one of which won the prize for best use of formal methods

Using PACEMAKER in Classes

- **Material provided**
  - Natural language requirements
  - Hardware platform
  - Instructions for use in lab
  - Example low level interface code
  - Access to links on SQRL website – timing diagrams primarily, Wiki including FAQ
- **3rd year class (single semester)**
  - Formal requirements for VVI mode
  - Class had to design, implement, test VVI mode

Instructions for PACEMAKER in Lab

The PACEMAKER hardware is shown below.
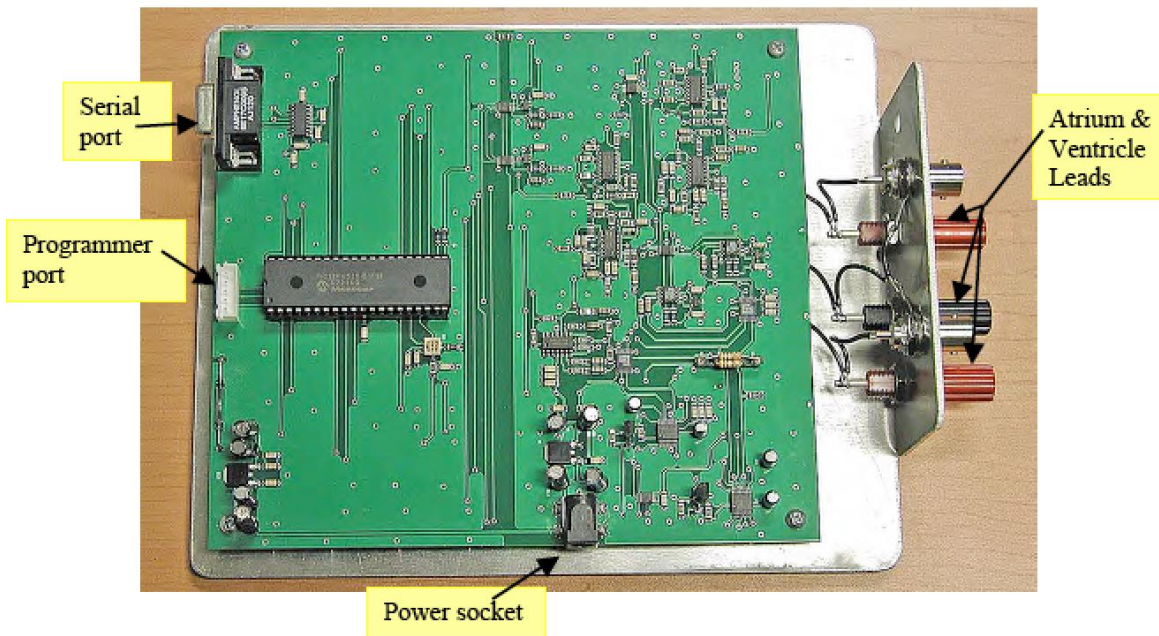
You should try and identify components on the board. The Atrium and Ventricle leads can be connected by coax or by simple wires with a common ground. We suggest using simple wires.

There are some really important points in connecting this hardware to the equipment in the lab. Make sure you understand these instructions and that you always follow them. If in doubt – ask your TA. *NOTE: Connecting the power supply incorrectly can permanently damage the PACEMAKER hardware.*

The picture below shows the general layout at a lab station. The major components are:

1. The PACEMAKER itself. Note the onboard PIC controller (computer) shown clearly in the figure above.
2. The power supply.
3. The PIC programmer.
4. The PC.
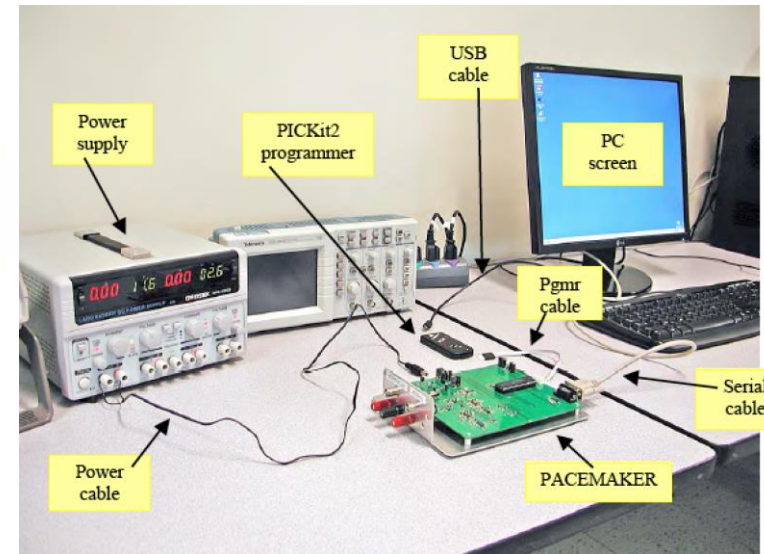
The PACEMAKER leads are used for input and output. Both the coax and screw terminals can be used. In the photo below, we have used the coax cables for input from the PC, and the screw terminals for output to the oscilloscope.
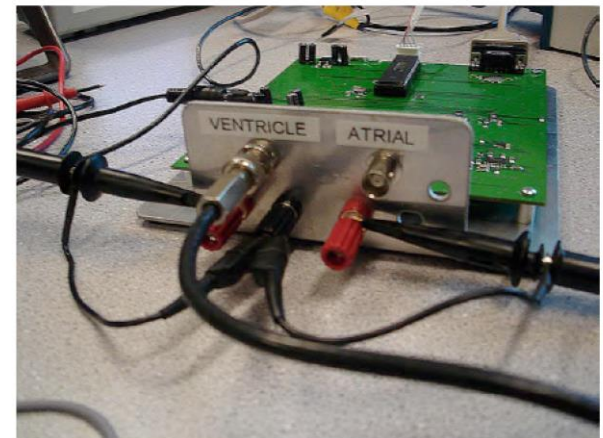
Why Use Challenges for Education?

- There are major components of these grand challenges that are reflective of state of the art and do not require the final research breakthrough that is being sought in the Grand Challenge

- They typically involve hot topics in their specific domains

- Tremendous effort is being expended in tackling these problems, and we can borrow from that effort to reinforce our education components in these domains

- *We think we can bridge the gap between state of the art/practice and general practice by disseminating these problems with guidance material*

Relationship to SCC Goals

- Recall that the basic themes of SCC are to advance certification / regulatory science by championing
  - evidence-based certification techniques
  - tool-supported rigorous (formal) methods
  - rigorous approaches to reasoning / argument based on mathematics and logic
- All these can be targeted through challenge problems
- Who is the audience?
  - students in safety/security-critical systems
  - industry engineers who we want to orient to "new/improved" techniques that we are proposing
  - regulatory / certification agencies
  - SCC members working on research topics to advance the state of the art in certification / regulatory science

Required Attributes of the Problem

- Complex enough to require sound techniques for their solution

- Complex enough to need groups rather than individuals

- Need both hardware and software components

- Can be "solved" in 8 months

- Can be scaled down so that a subset can be solved in 4 months

- Have an adequate/good requirements spec

What **Should** We Offer?

- Requirements spec (natural language or formal?)
- Dependable hardware platform at reasonable cost
- Hardware manual(s)
- Goals
- Guidance for development of solutions
- Mechanisms for evaluating solutions
- Domain specific background material
- Certification related background material
- Details on a slice through the system
- Wiki with FAQ & discussion groups
- Competitions

Benefits to Students

- Tackle a project that is representative of "real" projects
- (Hopefully) excellent support material
- Guidance on how to "do it right"
- They are excited to have it appear on their resumes

Benefits to Instructors

- Details of a "case study" given to them with all supporting material including availability of a hardware platform

- Support through Wiki

- Common problem tackled in many countries, support group should grow

- Evaluation guide

- Limited help with evaluations – probably through contests

Benefits to "Us"

- Feedback from many groups on the support material and evaluation guide
- Should help reduce the gap between state of art/practice and general practice
- Visibility & reputation
- Materials submitted for evaluation
  - We can evaluate our evaluation process
  - We get to see & compare alternative methods & techniques
- The challenge problems provide a reasonably contained universe in which we can identify the BoK required to solve these problems
- They also identify gaps in the BoK which feed into the research aspect of the Challenges

Analogous Challenge

But...but...

...I don't know what puzzles is

LOLCATS.COM