The Brilliant Balance

Things That Think
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1.0 Abstract

The Brilliant Balance is a demonstration of what can be done with embedded computation and simple machines to produce educational aides. It consists of a simple wooden balance, a series of sensors, various masses (2* 50 gm, 1* 100gm, and 3* 1gm), a cricket, and a LED display. The brilliant balance does not need to interact with another computer and in a "real" version the computational elements would be incorporated directly into the structure. Assuming a weight is placed on the right side of the balance the LED will display what weight is needed at one of two positions on the left hand side when the reflectance sensor is engaged at the appropriate position. It also displays a value that shows the total torque applied. A student will note that the total torque will not change but the weight needed will go down the farther away you place the weight on the left hand side. In this way the balance helps to reiterate the fact that there is an inverse relationship between weight and distance when calculating a torque on a lever.

2.0 Design

The original design called for a balance that was permanently weighted on one side and could sense the location of weights on the other side. It would then compute the minimum weight needed to raise the weighted side if the weight was placed at this position. Given this design we decided to concentrate on the balance first and work on the sensors and display after the balance was acquired or built.

We were encouraged to find and purchase an already fabricated balance or lever from an online scientific supply store. Collectively we spent many man-hours searching the Internet to no avail. Most sites were geared towards the needs of teachers and possibly school administrators. On average they were not well organized and short on specific information. Dimensions and photographs were virtually non-existent. We even spent time going through catalogs for scientific equipment. (catalogs.google.com is an excellent resource.) After spending a week trying to find what we needed we decided to just build the balance.

We purchased from the lumber store a singe 2 x 1 pine plank and cut it into shorter pieces. One piece was used for the actual lever, two pieces made the vertical support and a final provided the base. Since our first design called for a lever more than a symmetric balance we drilled a series of holes along the lever piece for a wooden dowel axle to pass through.

It soon became apparent that this design wasn't very engaging because couldn't be used as a balance in its own right. We then decided to make the whole thing a simple see-saw balance by drilling a hole in the dead center of the lever. After sanding the dowel and the hole the balance worked reasonably well.

We then worked on mounting the sensors to the balance. The use or pressure, light, and reflectance sensors were considered. The LEGO pressure sensors weren't adequate because of their large size and weight. Light sensors would probably have worked if mounted properly but we were concerned that the need for good external light might be a hindrance. We therefore chose to use reflectance sensors because they are light, easy to work with, and only dependent on their own components.

We mounted two reflectance sensors on the left hand side of the balance on short dowels. In this way the detected anything placed on top of the balance at the specified position. The locations were 10 and 20 centimeters from the center pivot. We chose the positions because the mass needed at the 10 cm position would be twice that of the 20 cm position.

The integration of a cricket to read the sensors and display the data on an LED was fairly trivial once we discovered how to output to the LED. Because we were dealing with known masses and positions we hard coded our output based on the detection of something on the balance by the reflectance sensors. (See Appendix A for the code.) We output the needed mass at the position and torque produced.

To finish up fabrication we painted the balance and placed Velcro for the masses to attach to. We also placed Velcro on the bottom of the masses so that they would adhere to the balance. (Without the Velcro all the weights would slide off.) We used Velcro and one gram weights to balance the device.

The total cost of materials was around $4 to $5 if you don't include the mass set. The use of Velcro, free paint, and cheap wood kept our costs down. Also it was surprisingly easy to make the whole device and actual fabrication time was less than 8 man hours.

3.0 Evaluation / Improvements

Our prototype version is limited in several ways. First the prototype is unable to differentiate the various weights. It can only sense that something is engaging the reflectance sensors and is unable to differentiate the various masses. One solution to this would be to have a weight and sensor design that allows the cricket to sense which mass has been placed where. Another improvement would handle multiple weights at the same time on either side.

A better display could be incorporated to show more information simultaneously. The crickets have limited display capabilities and are a little overpowered for this application. A smaller cricket would be nice.

The device should be made rugged and safe for use in a classroom. The prototype looks like a science fair project from 5th grade. The use of a sleeker aluminum frame, flush sensors, and hidden cricket would produce a device that could survive in a classroom.

4.0 Education

The potential for this type of learning aid is immense. After searching many websites in search of a balance we can tell you that there are very few products that incorporate computation. There is no reason why a whole set of “intelligent' simple machines couldn't be made. Inclined planes, pulleys, springs, and screws are all machines that could be incorporated into a “smart” experimental aid.

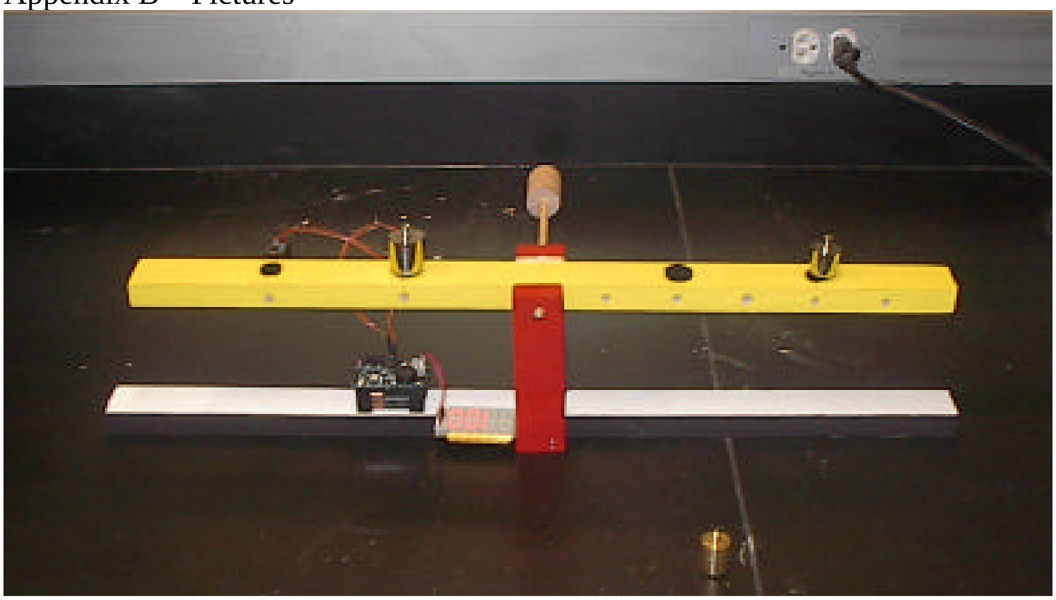
We assume that in the future these sorts of devices will find their way into the classroom. Currently a lot of people place an emphasis on software experimental aids. We believe though that a “virtual” machine is less informative than a “computationally enhanced” machine. This will probably remain the case until good VR systems come into use. In short there is now reason why in the 21st century classrooms shouldn't be equipped with intelligent construction kits and demonstration tools.

Appendix A - Code

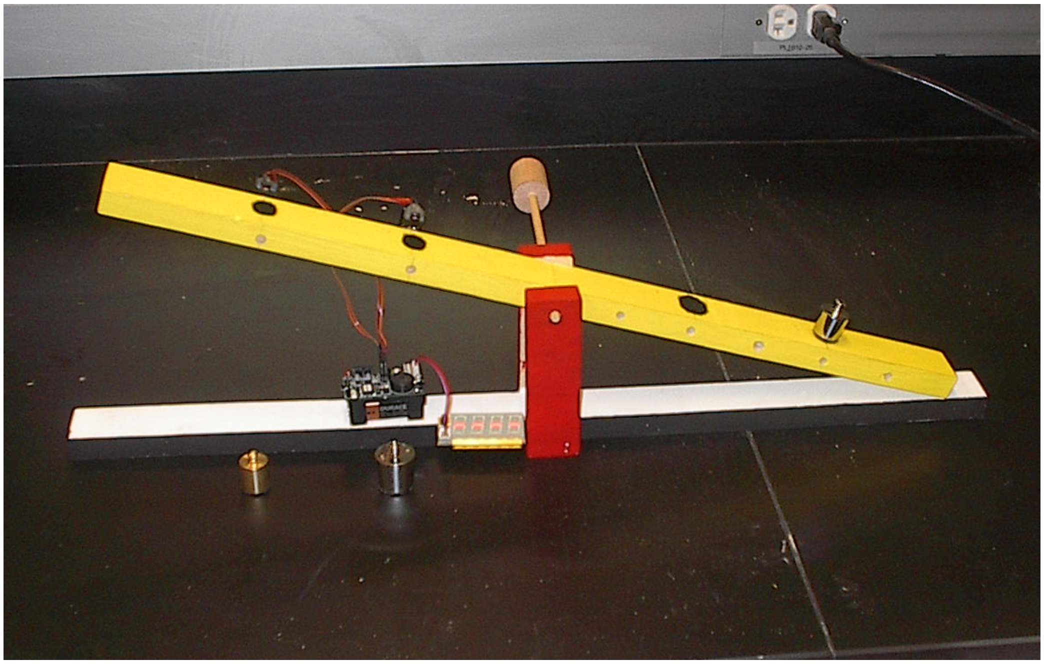
```
to Touch

  DisplayBlank

  loop
  [
    if sensora > 90
    [
      DisplayBlank
      Display 50
      wait 50
      Display 1000
      wait 50
    ]
    if sensorb > 90
    [
      DisplayBlank
      Display 100
      wait 50
      Display 1000
      wait 50
    ]

    DisplayBlank
 ]
```

```
end

to Display :n
   bsend $170
   bsend (:n / 256)
   bsend (:n % 256 )
end

to DisplayBlank
   bsend $170
   bsend 8888
end
```

Appendix B – Pictures



The brilliant balance at work.



A not-so-balanced brilliant balance.