A Pneumatic Excavator as GBC Module

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Next to MINDSTORMS, Pneumatics are one of my favourite LEGO® elements. They may not appear to have much in common, at least at first sight, but building this Pneumatic GBC module has taught me that they are more similar than I imagined.

Inspiration

When I first started building GBC modules I looked to the internet for inspiration and started off by rebuilding a couple of Philo's modules [1]. I also scoured Brickshelf for modules and had a good look at the videos available at Steve Hassenplug's GBC website [2]. One of the modules that stuck in my memory was a back hoe [3] that used two pneumatic cylinders to raise/lower the arm and open/close the bucket.

I liked the idea, but the module used an RCX to control the valves and the motor in charge of turning the back hoe. I wanted to add another movement to the arm and therefore needed a way to control four movements (bucket, bend arm, arm up/down and rotate) but an RCX only has three motor ports.

Then I remembered the turning mechanism of the 8868 Claw Rig: two pneumatic cylinders that work in opposition to turn the cabin on the back of the model. That meant I could do all movements using pneumatics and wouldn't need any motors at all. The secondary model of that set uses a closed loop circuit that continuously alternates two actions. After learning a bit more about pneumatic sequences [4] I started working on the sequence I'd need for this particular module.

Pneumatic programming

An RCX (or NXT) is a programmable unit that can switch motors on and off as a result of either timing or inputs [5]. A pneumatic cylinder/ valve combination can do something very similar. It can be used as a timing mechanism. It can respond to the input of another valve. It can even be use to create logic control circuits. And finally, by adding these functions in the right sequence, you can 'program' a pneumatic control circuit.

I started out by creating a type of test board: on a 32x32 baseplate I placed a number of cylinder/valve sets and started building parts of the circuit in order to combine them later. The four movements of the module are the following:

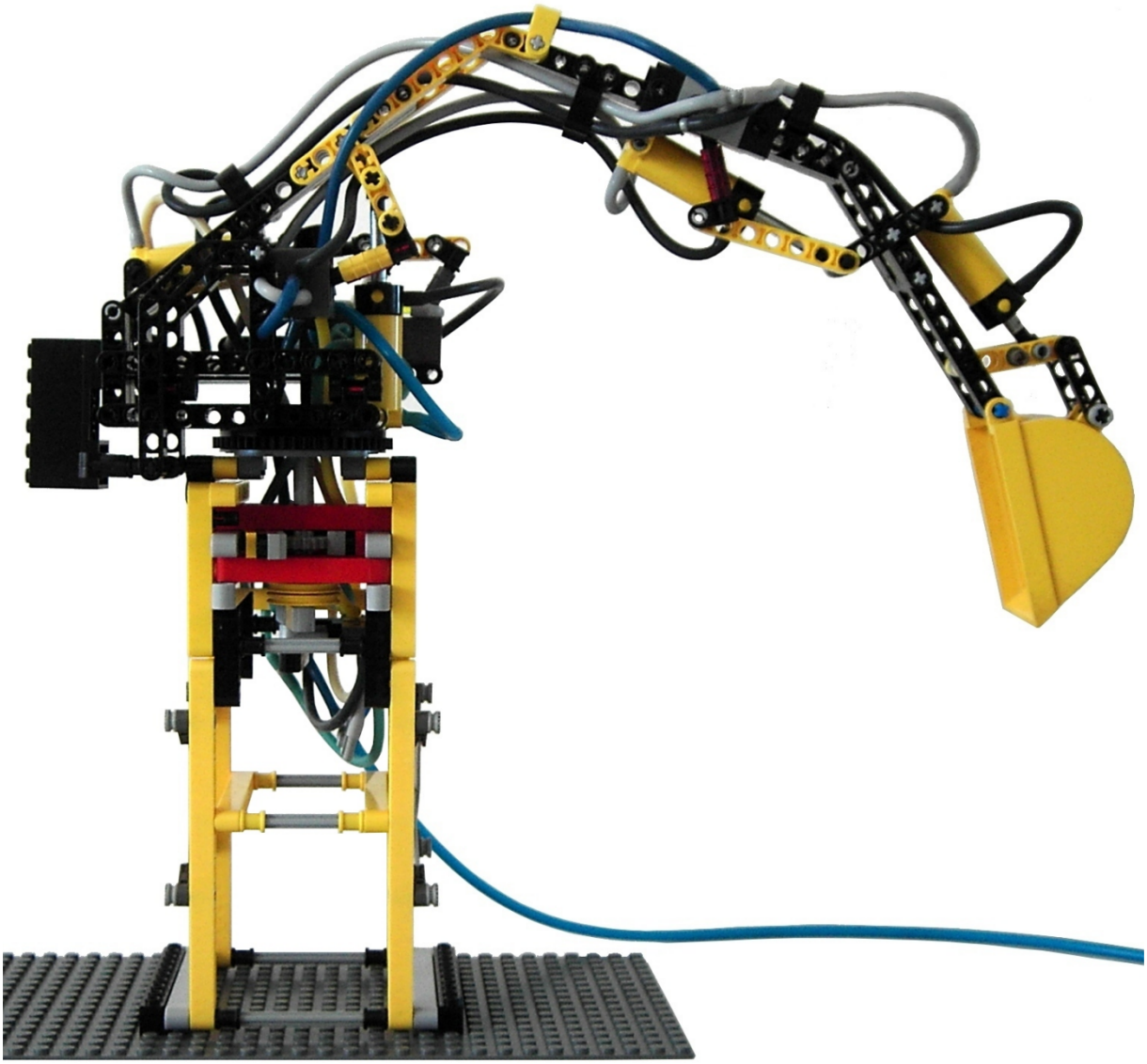
Arm up/down
Arm close/open
Bucket close/open
Turn

In order to describe the movement of the cylinders I'll use the convention proposed in Kevin Clague's article about pneumatic sequences: A^C = close/contract A and A^X = open/expand A. The sequence that is necessary to make the excavator module work is not a straightforward A B C D, but rather the more complex A^C B^C C^C A^X D^X B^X C^X D^C[6]. As can be seen B and C always follow the same order. The other sequences however are not that simple. Both A and D act on B, but they also act on each other. This meant that I had not only to include more valves, but also an extra cylinder order to prevent one of the cylinders receiving pressure on both the bottom and top port at the same time.

My first intention was to have a control circuit on the baseplate and parallel working cylinders inside the excavator. However, I quickly realised that due to the effort this second group of cylinders had to make they could not work in parallel to the cylinders acting on the valves because those moved much faster and the cycle was never correctly executed. This meant I had to include the vales inside the excavator. Finding the right geometries was an interesting challenge that has taught me a lot. In the end I decided that the cylinder acting on the bucket did not need to finish its stroke completely before the arm draws it closer to the base of the module. As a result, this is the only working cylinder that has no valve attached to it and works in parallel to a control cylinder on the cab of the excavator.

Studless design

I started building the module using Technic bricks with the traditional studded building techniques, but I kept running into problems with geometries for the arm and couldn't seem to find a satisfactory design in terms of functionality and aesthetics. Then I



decided to make a radical change and virtually started from scratch again, only this time I used only liftarms. I was surprised to see how easily things fell into place and although I still had to rebuild the model several times the result was quickly both reliable and reasonable good looking. The only studded parts I used in the cabin were the counterweight and some plates to keep it in place.

At first I didn't find a satisfactory solution for the valves controlled by the cylinders in charge of turning so during the first official run of this module at the HispaBrick 2008 the valves were operated by a parallel control cylinder. This worked well for a couple of hours, but after that I started having problems with the synchronicity of the control cylinder and working cylinder.

In the initial design I used a studded base. In the second version this base has been changed for a studless design which is not only more robust but has also allowed me to include two valves in the bottom of the module so the working cylinders act on the valves directly.

If you want to see the model in action there's a video of the first version on YouTube [7], and you can see it live at HispaBrick 2009.

[1] www.philohome.com/
[2] http://www.teamhassenplug.org/GBC/
[3] http://www.brickshelf.com/cgi-bin/gallery.cgi?f=121269
[4] http://www.kclague.net/Sequencer/index.htm – You can find a translation of part of the article at HispaLUG: http://www.hispalug.com/foro/index.php?topic=6763.0 - and the webpage of C.S.Soh's http://www.fifth-r.com/cssoh1/contents.htm
[5] Of course a RCX (or NXT) can do much more than that, but these are the basics tasks that a lot of robots built with MINDSTORMS do
[6] Of course D represents two cylinders that work in opposition, but I have considered just one in order to make the description easier.
[7] http://www.youtube.com/watch?v=4diUt7yXBMs ■