

A simple controller for neutron computed tomography that interfaces nearly every camera

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Abstract

High-end precision neutron computed tomography requires a considerable investment in quality components. To get it right, it makes sense to make feasibility tests with cheaper components. A simple tomography controller was built that can drive a tomography sequence on two stepper motors, and interface with any camera even without a hardware trigger interface by simulating the mouse in the camera control software by interfacing to the mouse on the camera control computer.

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Peer-review under responsibility of the organizing committee of ITMNR-8.

Keywords: Neutron Radiography; Neutron Imaging; Neutron Computed Tomography; CCD Camera; Tomography

1. Introduction

Neutron computed tomography is now being introduced even at smaller and older reactors. Operators are often faced with a Hen-and-Egg problem: First, they have to show that they can do tomography before they can obtain a budget to build a tomography system. In other cases, a setup has to be installed in an environment with such high radiation levels that the expected lifetime of the camera is rather limited. In both cases, the use of cheaper components is preferred.

For these cases, a cheap tomography controller was developed that can drive two stepper motors (a rotation table and an optional translation table) and control an external camera with a trigger signal that either interfaces a hardware trigger input on the camera if available, or simulates the mouse in the camera control program to start each image capture by mouse click.

A stepper motor was fitted with a toothed belt and a pair of toothed-belt wheels to create a simple gear reduction, since the typical 200 steps per rotation of a single stepper motor are insufficient for computed tomography. The system is operated by a simply Python script.

It must be stressed that the system described here is NOT a professional system for computed tomography, it is a hack to get a test setup working quickly. There is no replacement for a precision rotation table, and proprietary camera control software.

2. The Hardware

The controller is based on the popular Raspberry Pi mini computer (1) (Model B, B+ or 2 – Model 3 will work, but needs a non-standard power supply and some modifications) and the add-on board called 'Gertbot' (NOT gertboard – that is a different board), which are both available by the official

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distributor Farnell (2). The Gertbot board provides its own processor for driving two stepper motors with high-level commands, two open-collector outputs, several digital I/Os as well as ADCs and DACs. Two two-phase stepper motors can simply be connected to screw terminals. End switches can be connected to the multi-pin connector, which are only required for the optional translation table.

Alternatively, the serial port of the Raspberry Pi can be used to control any existing motor controller.

The Raspberry Pi has 5V on the board, but operates with 3.3 V logic levels. For a full galvanic insulation from the camera PC, a small reed relay is driven by one open collector output (against 5V on the board) to pull the trigger output of the camera to ground – or to simply perform a mouse click in the control program on the camera PC. Fig. 1 shows an overview of the complete setup.

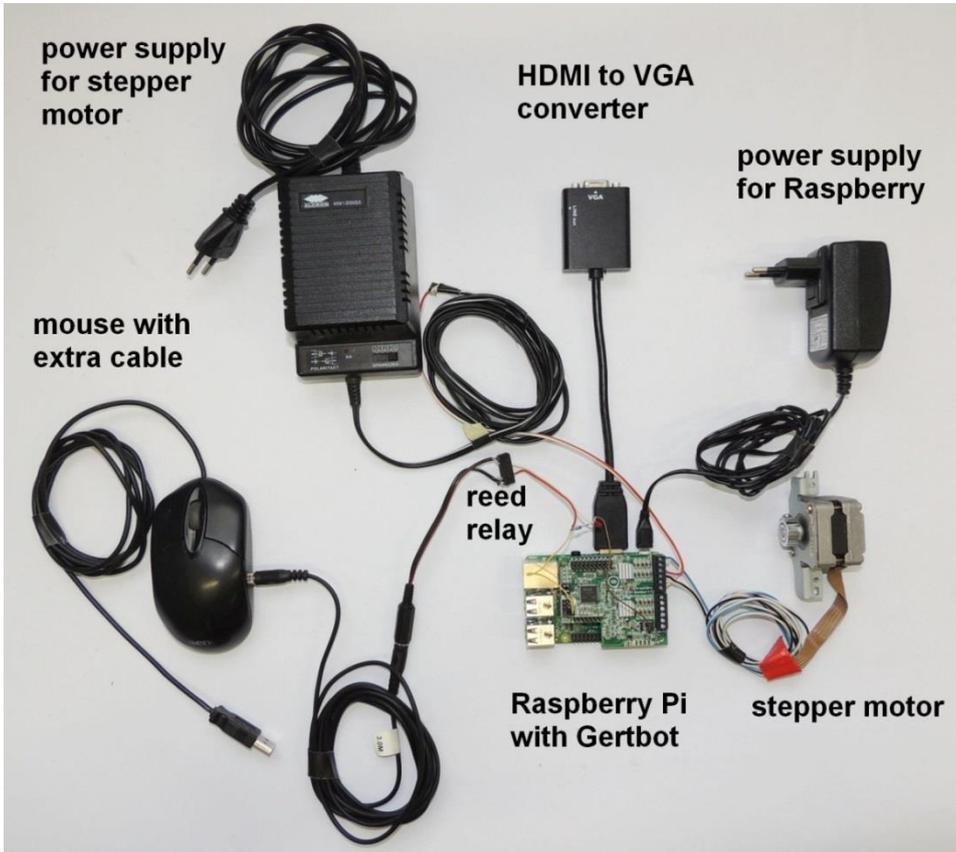


Fig.1: Overview of all components for the controller. The mouse in the picture plugs into the camera PC. Mouse, keyboard and network plug into the left side of the Raspberry board. The HDMI to VGA converter allows for the use of an old monitor.

For this, two extra wires are simply soldered in parallel to the left mouse button, and connected to the relay contacts (Fig.2). To control a tomography sequence, the camera control program must be set for an image sequence with individual trigger by mouse click, and the mouse pointer positioned on the start button. The raspberry Pi can then initiate each single exposure by mouse click.



Fig.2: Extra connection to the left mouse button.

Fig. 3 shows the connection of the reed relay to the open collector output and the +5V connector on the unused serial port connector of the Gertbot. For testing, a LED and resistor have been connected in parallel to the relay.

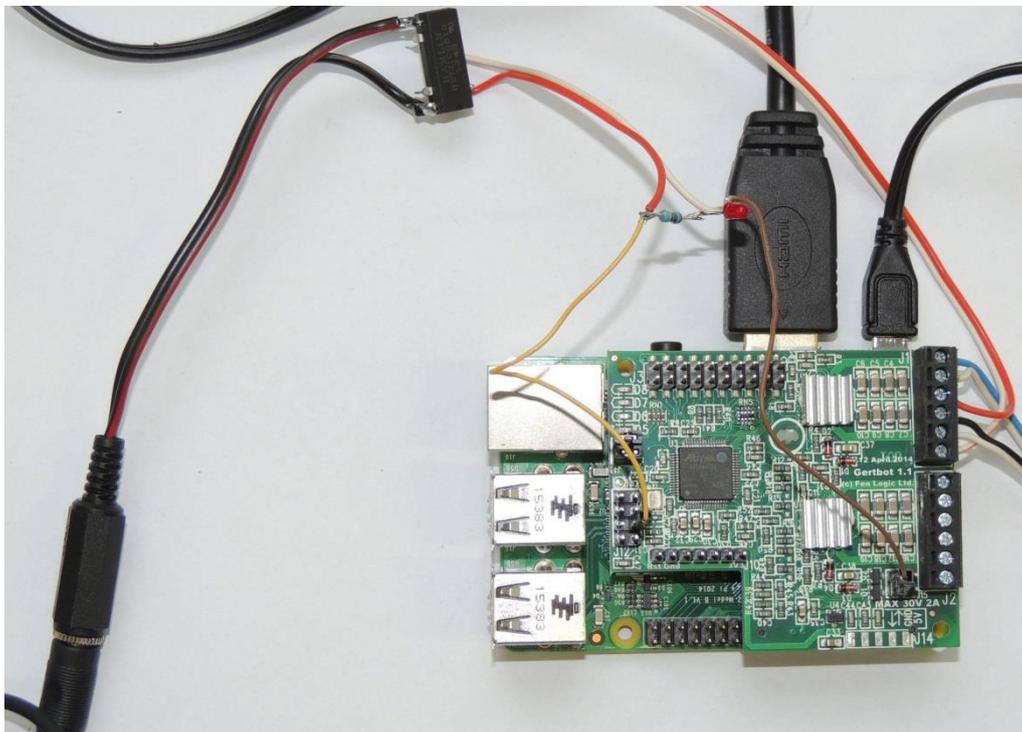


Fig. 3: Connection of the reed relay to the open collector output +5V .
For testing, a LED and resistor have been connected in parallel to the relay.

To obtain quick results, a rudimentary rotation table was built with the stepper motor shown above, a toothed belt and two cogwheels with a 5:1 reduction ratio, as shown in Fig. 4. This allows for 1000 steps per full rotation, sufficient for a good quality tomography. The belt tensioner is simply made from a ball bearing. The bearing for the rotation table can support 10 kg. However, it must be stressed again that this is a quick-and-dirty solution, with no adequate precision whatsoever. Its sole purpose is to obtain first results that may support a grant application for funding of advanced components like a precision rotation table.

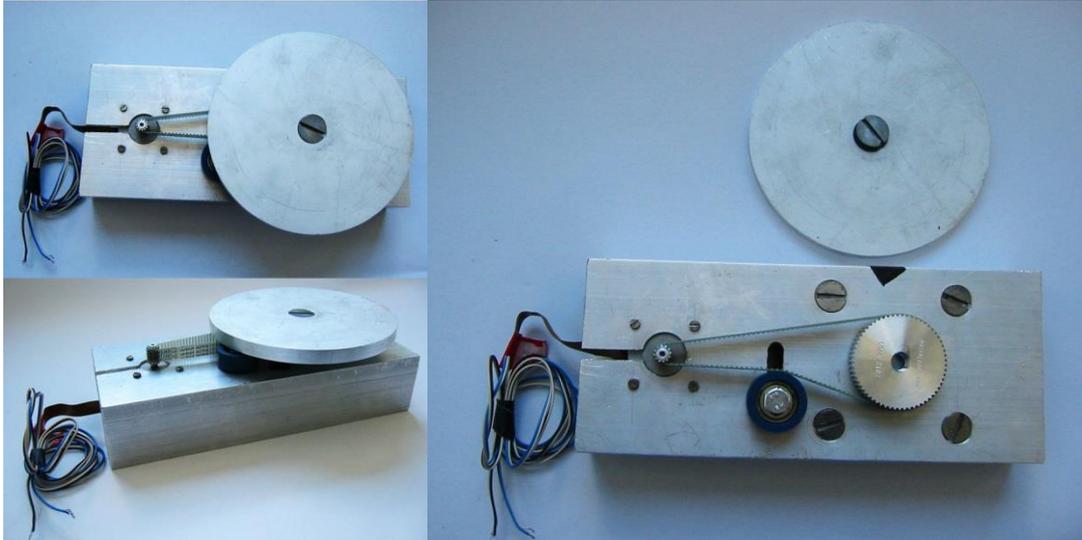


Fig.4: Rudimentary rotation table with 5:1 reduction ratio built with a stepper motor, a toothed belt and two cogwheels.

3. The Software

The tomography sequence is simply controlled by a Python script on the Raspberry Pi.

Since the Gertbot accepts high-level commands for motion sequences, very few commands are required. The user only has to define parameters for gear reduction of the rotation table, the turnaround time of the camera from one image to the next without the exposure time, the angular range (180 or 360 degrees), the exposure time and the number of projections.

The script calculates the required angular step width for the given number of projections. For a low gear reduction of the translation table and thus a relatively small number of steps for a full rotation, there will be rounding errors, so the script calculates the total number of steps required to reach the current angular position starting from the zero position, and adds up all previous steps. The previous steps will be deducted from the currently required number of steps from zero, and the result will be used to reach the current position from the previous position, in order to minimize the rounding error.

After sending the rotation command, a mouse click (or trigger signal) is initiated, and a waiting command issued for the turnaround plus exposure time of the camera, before the next rotation command is sent. For a camera with hardware handshakes, the waiting time can be replaced by waiting for the 'camera ready' signal to be connected to one of the digital inputs of the Gertbot board. Once the whole setup works, the extra monitor, keyboard and mouse for the Raspberry Pi are no longer required, since it can also be accessed via a SSH shell through the network running on the camera PC. In that case, a five second wait must be included in the control script to allow the operator the time to move the focus of the mouse from the SSH window to the camera software and its start button.

The author will provide the control script and a complete working image of the Jessie (formerly Raspbian) operating system with installed script and drivers on request. A more detailed manual with instructions and necessary adaptations for the Raspberry Pi model 3 as well as documents about free

software for Image processing, CT reconstruction and 3D rendering are available for download on the website of the International society for Neutron Radiology (3).

4. Optional Extensions

The second stepper motor output can be used to drive a translation table that moves the rotation and sample table into and out of the beam, so the recording of open beam images can be added to the control script. In that case, it is essential to connect and read proper end switches as well.

The second open collector output can easily be used to drive the beam shutter.

Instead of the Gertbot, the serial port of the Raspberry Pi (requires an add-on for correct voltages) can be used to drive any existing motor controller with its proprietary commands.

5. Outlook

As has been stated in the introduction, this setup and controller hack gets you a working tomography setup with minimal effort, but it is NOT a professional, high-end solution, and should not be used as such, especially not the crude rotation table. It is meant to produce first results that demonstrate basic capabilities and can be used to apply for funding for further development.

The mouse hack can be used on any control program that does not provide a programming interface to other control software.

In full purpose, only the minimum working software solution for the controller is provided for download, so that the control script remains transparent and easy to understand. It is up to every individual user to program additional controls, fancy GUIs, and to build a nice housing for the controller.

Cheap (<\$500), but high-quality cameras have recently become available from a new manufacturer⁴, mostly intended for astronomy. The only crucial item is the neutron scintillation screen. That must be bought from a special supplier.

In a different publication (5), a software path from image recording through tomographic reconstruction to 3D imaging and analysis is shown with free software. Building your own first inexpensive tomography system will help to understand the method in detail, so a professional system can be planned and built once appropriate funding becomes available, and the new understanding will help to control and master the new system to the maximum possible extent.

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