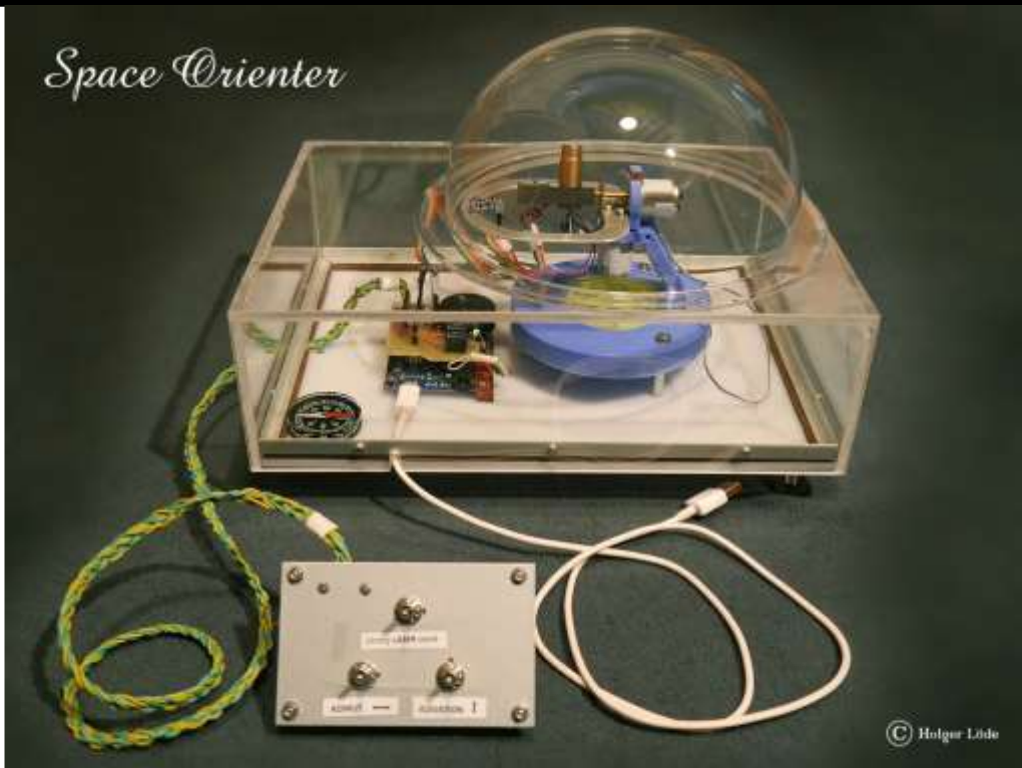
2017

Space Orienter



Laurin Kettner, Justin Ebert

Jugend forscht

12.03.2017

Abstract

As soon as an astronomer trys to explain the sky to an audience, he will direct his finger in a certain destination to show stars and constellations. But not all participants can follow him and look from a bit other destination (parallax) and are uncertain to what is shown. The astronomer will use a laser pointer and is careful not to direct it to the eyes or airplanes. The laser beam can be seen over some kilometers and the parallax is perfectly avoided. Meanwhile it is possible to use appropriate mobile apps, but this is not the real sky, which is in the field of view but a display only. The aim of the Space Orienter is to develop a tool, which automatically finds stars and constellations in the sky. To this end we mounted a small laser pointer on a goniometer. The two positions of the goniometer, elevation and azimuth is measured by two sensors, an accelerometer and an electronic compass, and controlled by microstepping gear motors. The sensors and the motors are directly controlled by an Arduino, requiring no additional power supplies. The stars are selected from an Excel sheet and using the internet time the respective star position is computed, requiring as additional parameters only the GPS position of the experiment.

The Space Orienter can potentially be used to determine its own position by directing the beam on a known object.

Inhalt

Introduction

Since the beginning oft he history mankind was fascinated by the sky, one can say magically attracted. Beginning from Stonehenge, which is directed to the solstice, over the Maya calendar to various depictions of the Egypts, they all had a problem. So the modern astronomers too, which since 500 years try to follow stars and planets. Seafarer has been faced with the problem to aim stars, planets, the moon and the sun to find their own position and the vessel course. With the help of the nautical annual book the can find their course and finally their aim. We can help them to aim certain stars, constellations, planets, moon and the sun.
Showing a group stars with the help of laser pointers nearly excludes the problem of parallax and each participant will see essentially the same.
To automize this process we use a nonhazardous laser pointer, two small gear motors and an acceleration sensor for elevation and a magnetic sensor for azimuth. The laser pointer should have a good visibility and so we use a frequency doubled green laser with 50 mW power. The position values are computed in an Excel sheet and are than passed by the program TWedge from TEC-IT to an Arduino Leonardo, which regulates the position on the right values.
In the following the setup is explained.

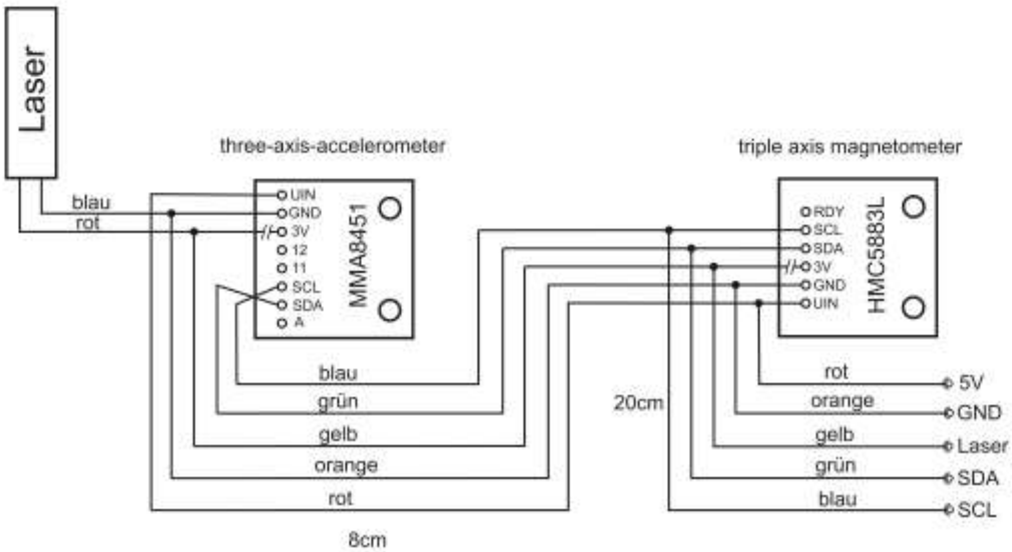
Setup, materials and method

The goniometer

The goniometer should enable to aim the laser pointer to each direction of the upper halfspace. It consists of some parts, which were 3D printed in a fablab of the TH Wildau. With the help of two motors, one with a vertical rotation axis and the other with a horizontal rotation axis, the goniometer is driven. The motors type was GM22 298:1 of Watterott and drain a current of about 30 mA at 5 V. To screen their magnetic field, the motors were surrounded by mumetal caps.
The goniometer consists of a stand, which is equipped with a spirit level. On the stand is mounted the motor for the azimuth and it carries the elevation motor, which finally aims the laser pointer. In the plane of the azimuth is mounted the magnetic sensor (triple axis magnetometer HMC5883L) and on the adjustment of the elevation the force sensor (three axis accelerometer MMA8451). Both sensors are connected via an I2C bus to the Arduino Leonardo. The motors are connected to digital outputs of the Arduino and the voltage is switched to be present for some milliseconds only, to enable small steps.
On the baseplate of the instrument a small simple compass is mounted to enable the crude alignment. It turned out, that it is not useful to use the azimuth over the full 360 degrees and the elevation from zero to 90 degrees, since this had not allowed to establish limits for the movement. So we decided to address all points on the upper half sphere by using an azimuth of zero to 180 degrees and an elevation of zero to 180 degrees.

The sensors

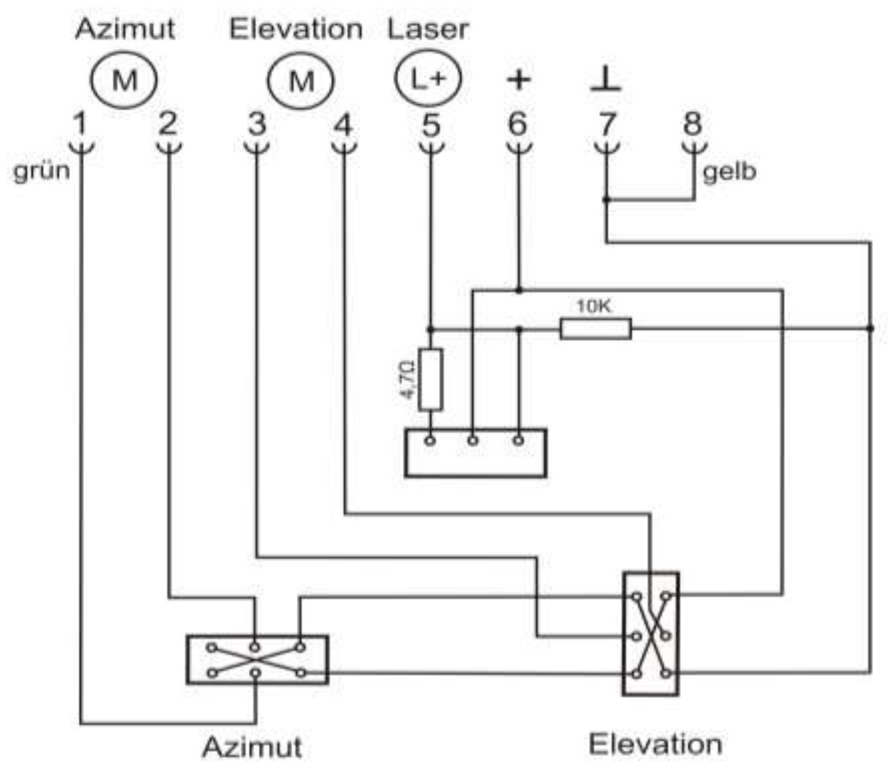
The magnetic field of the earth has a strength of 0.5 Gauss in Berlin and its horizontal component is directed to north, what is not perfectly fulfilled. It has a resulting angle of 3.8 ° to the pole of the celestial sphere. These data are used to adjust the azimuth by using the two horizontal axes of the HMC5883L. The sensor is set to highest sensitivity (0.73 mG/count).
The accelerometer MMA8451 should be called a force sensor, since it measures the force on the sensor with a minus sign involved. The electrical scheme is shown in the following. The laser is switched by a relais, since it drains a current of about 200 mA.
The electrical scheme is depicted in the following graph:



Verschaltung der Sensoren

Manual control

The manual control is realized with bidirectional toggle switches. It is not directly connected to the motors or the laser pointer, but uses logical inputs of the Arduino Leonardo. The open laser input is pulled down to zero by a 10 kOhm resistor as long as the corresponding switch is not activated.
The scheme of the manual control is as follows:

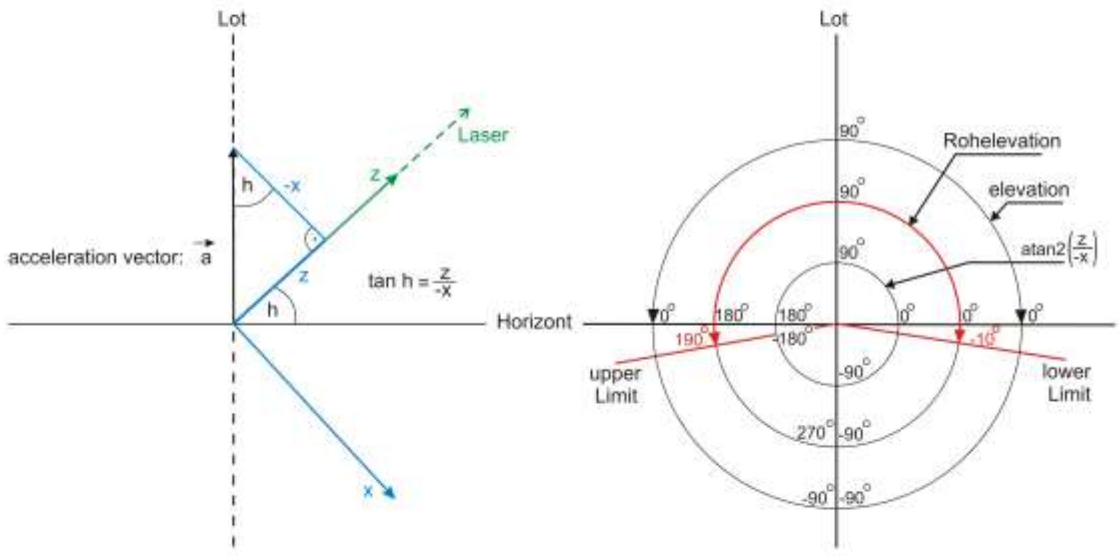


Handsteuerung

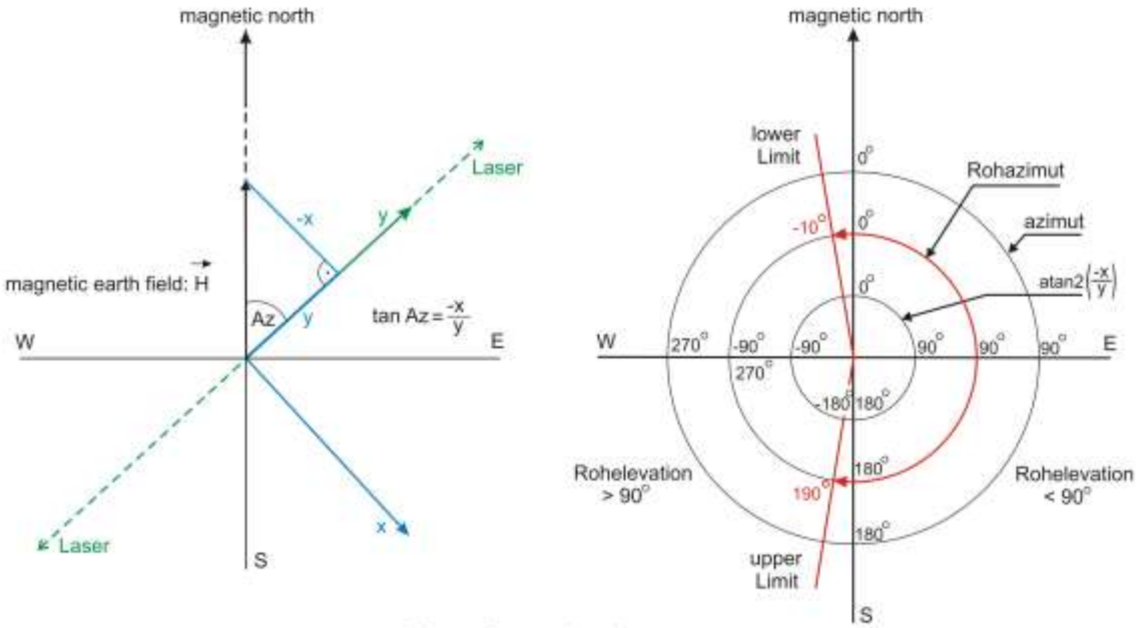
The application of the Arduino Leonardo

The microcontroller Arduino Leonardo communicates via Serial Interface in this manner, that it transmits the actual azimuth and elevation separated by am semicilon and it receives the setvalues for elevation and azimuth, also separated by a semicolon. Internally it works with the so called raw values (Rohelevation and Rohazimuth).It is organized in this manner, that the raw values have both a range from -10 to 190 degrees, enabling the operation without jumps of the values, which otherwise would occur for the azimuth at 0 to 360° and for the elevation at 180°. The introduction of the raw values enables to respect limits for the movements, so that the regulator and the manual control cannot force the device to turn around and around.
We show in the following, how to get from the true elevation and azimuth the raw values.
When the inputvalues are elevationIn and azimuthIn, than the raw values are found by setting them first equal:
Roh_elevationIn = elevationIn
Roh_azimuthIn = azimuthIn

And if azimuthIn > 180° the operations
Roh_elevationIn = 180 –elevationIn
Roh_azimuth -= 180
Are performed.
Internally the Arduino gets his raw values in the following manner from atan2, which is ranging from -180° to 180°. First we consider the elevation for which the z-axis and the –x-axis of the MMA8451 are responsible. The raw elevation is first set to the arctan2 in the following manner:
Rohelevation = atan2(z/-x)*180/π
If this is < -90°, we perform
Rohelevation += 360.
Now we can set
elevation = Rohelevation.
If the elevation is bigger than 90° we have to correct
elevation = 180 – Rohelevation.
This is than the true Rohelevation and elevation computed.
Now we consider the azimuth. It is first set to arctan2 with the axes –x and y of the HMC5883L:
Rohazimuth = atan2(-x/y)*180/π
If this is < -90°, we perform again
Rohazimuth += 360.
Now we can set:
azimuth = Roazimuth
and if the Rohelevation is bigger than 90°, we have to perform
azimuth += 180.
The following graphs visualize the relationships:

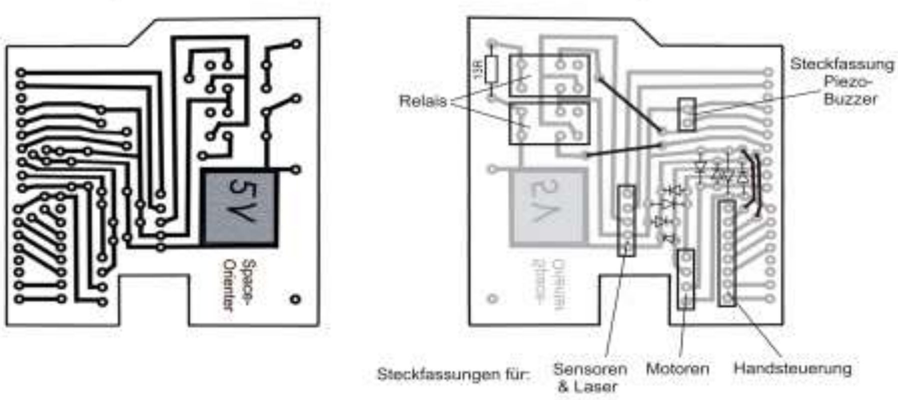


Elevation Determination
(Side view MMA detector, looking towards vertical rotation axis)

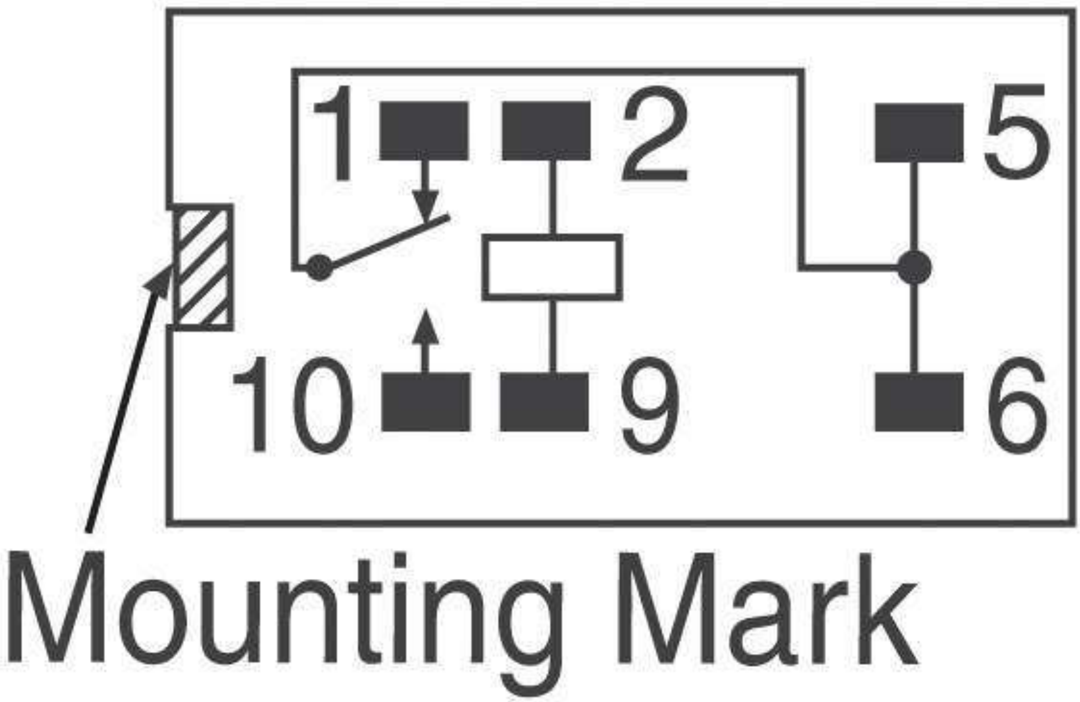


Azimut Determination
(top view HMC detector)

For the Arduino a shield has been designed, which contains the protecting diodes for the outputs, the connector for the manual control, piezo buzzer, which gives a warning signal before switching on the laser, the connector for the sensors and the laser and two relais for switching on the laser in strong or weak mode.



The relais are from Omron of the type G5V-1, 5 VDC and have the following pinout, seen from the pins side:


1
2
5
10
9
6
Mounting Mark

Combination with Excel

The Excel sheet has the actual internet time, which is refreshed with the command JETZT() on every CR. The longitude and latitude has to be input according to his own position, which can be get by GPS data or Google Maps. The actual vernal equinox is derived from the year 2016. From a star table, which is stored in an additional table, the actual elevation and azimuth for the respective object is computed. Selecting one star from the table, the Excel Sheet transmits the actual elevation and azimuth to the Arduino and it positions the goniometer and switches the laser for three seconds on.
The data transmission is realized by the program TWedge of TEC-IT in Austria, so that in the Excel sheet are displayed the actual data for elevation and azimuth.

The ephemerides

A drawback of the Space Orienter was, that it cannot address planets, the moon and the sun, for which so called ephemerides hold. We could find an Excel Add In from PlanEph, which works not perfect, but is usable. When Excel is closed and opened again the Add In starts not correctly and must be deactivated and activated again. On other computers it was even necessary to reinstall it.

Testing

The Arduino position regulator hat a settling time of some seconds, what is tolerable. The accuracy is one to two degrees. It turned out that the laser is very temperature sensitive, requiring a warming up of up to one minute. Also the motors are so weak, that the cables should be very flexible.

Conclusions

With the help of our Space Orienter it is possible to find unknown objects on the sky without any further knowledge. The implementation of Excel enables a simple user interface and is very simple to operate. In principle it should be possible to determine his own position by manually aiming on a star, what is of importance for celestial navigation.
With simple means we realized a device, which easy to build and cheap and uses technologies of microcomputing and 3D printing.