Virtual Reality Treadmill "Crosswalk"

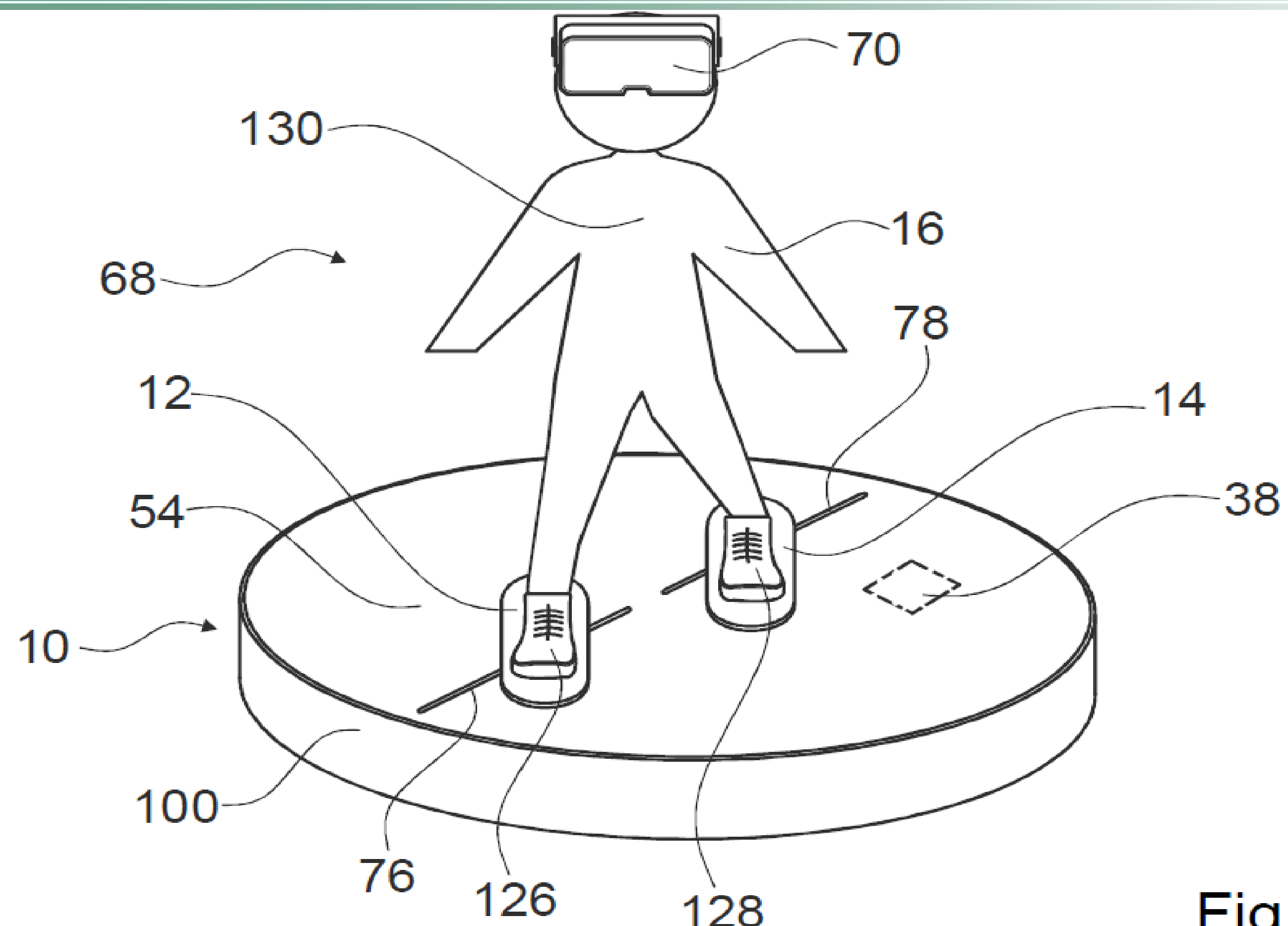


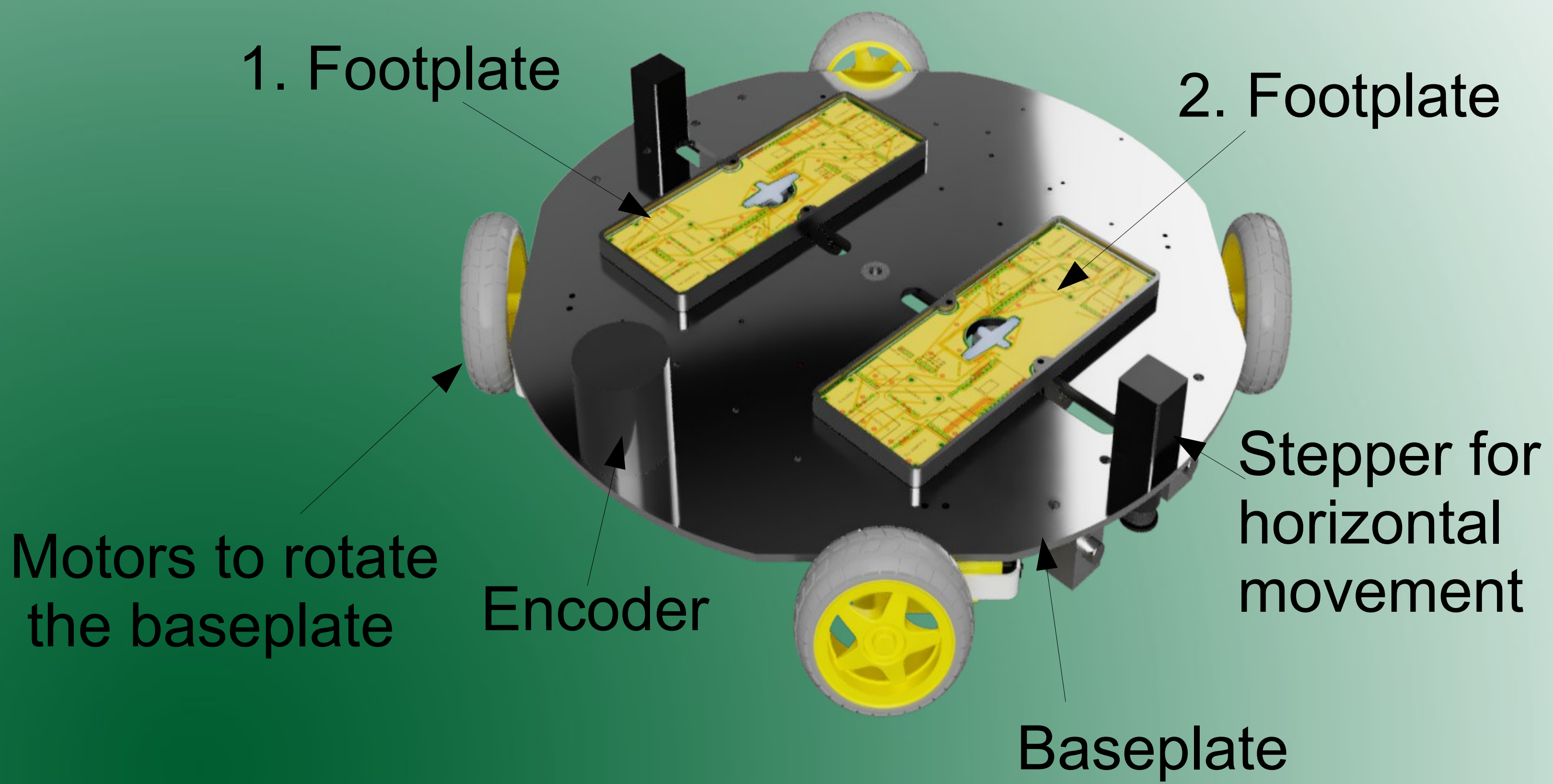
Fig. 5b

Foot following device

Virtual Reality Treadmill "Crosswalk"

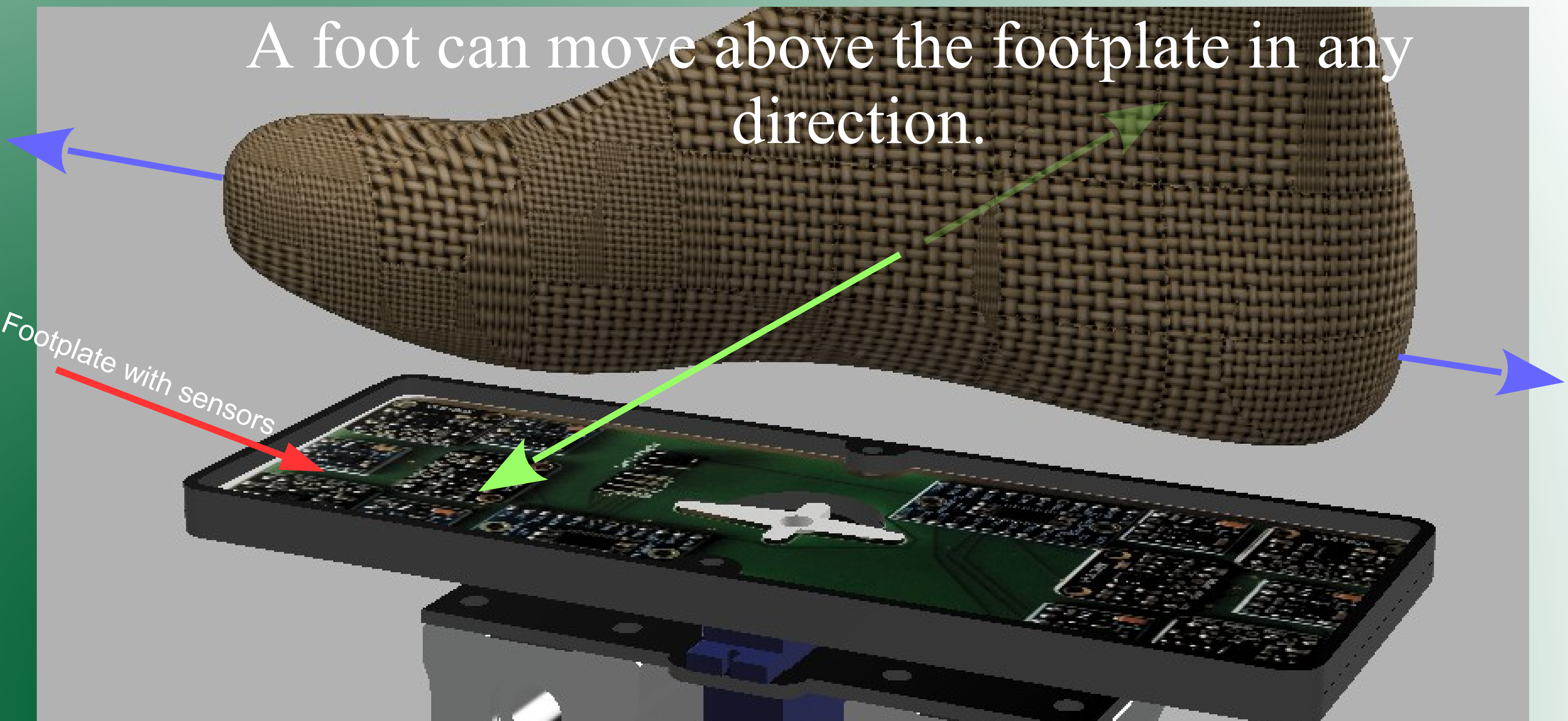
This document will decribe the math stuff to figure out where the foot is located above a footplate by using magnetic field sensors and a magnet.

Overview of "Crosswalk-Mini"

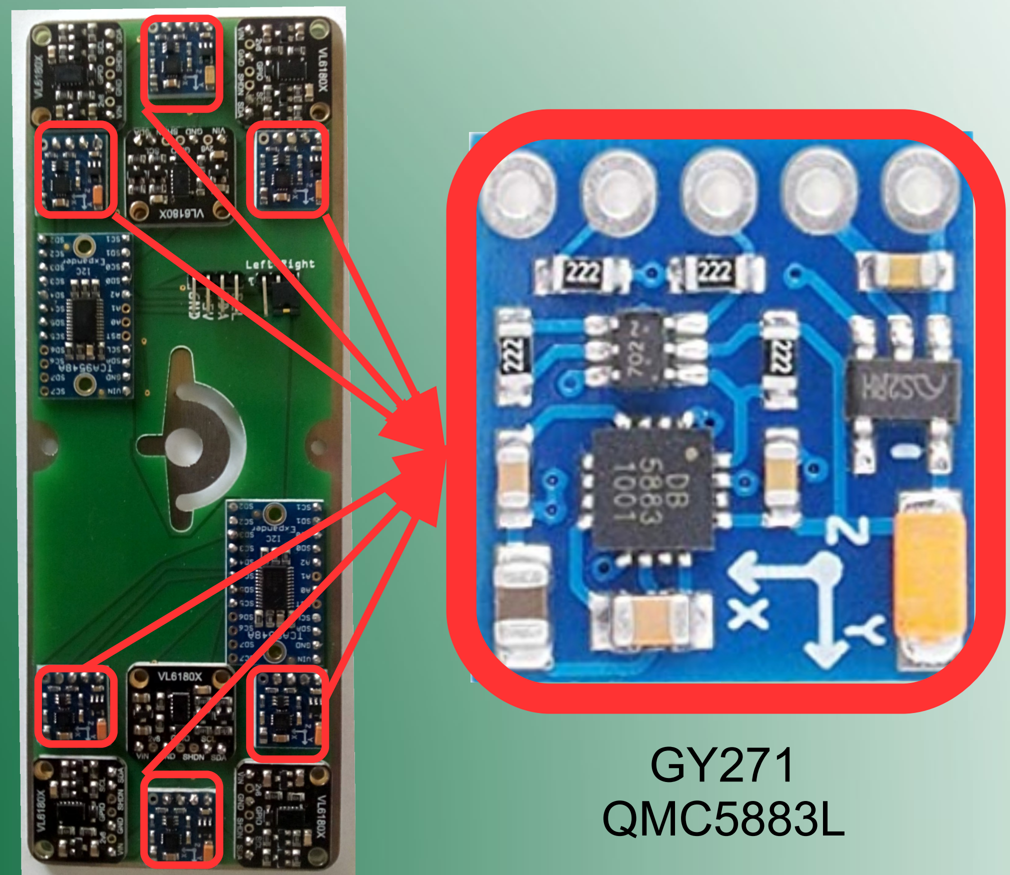


Where's the foot?

A foot can move above the footplate in any direction.



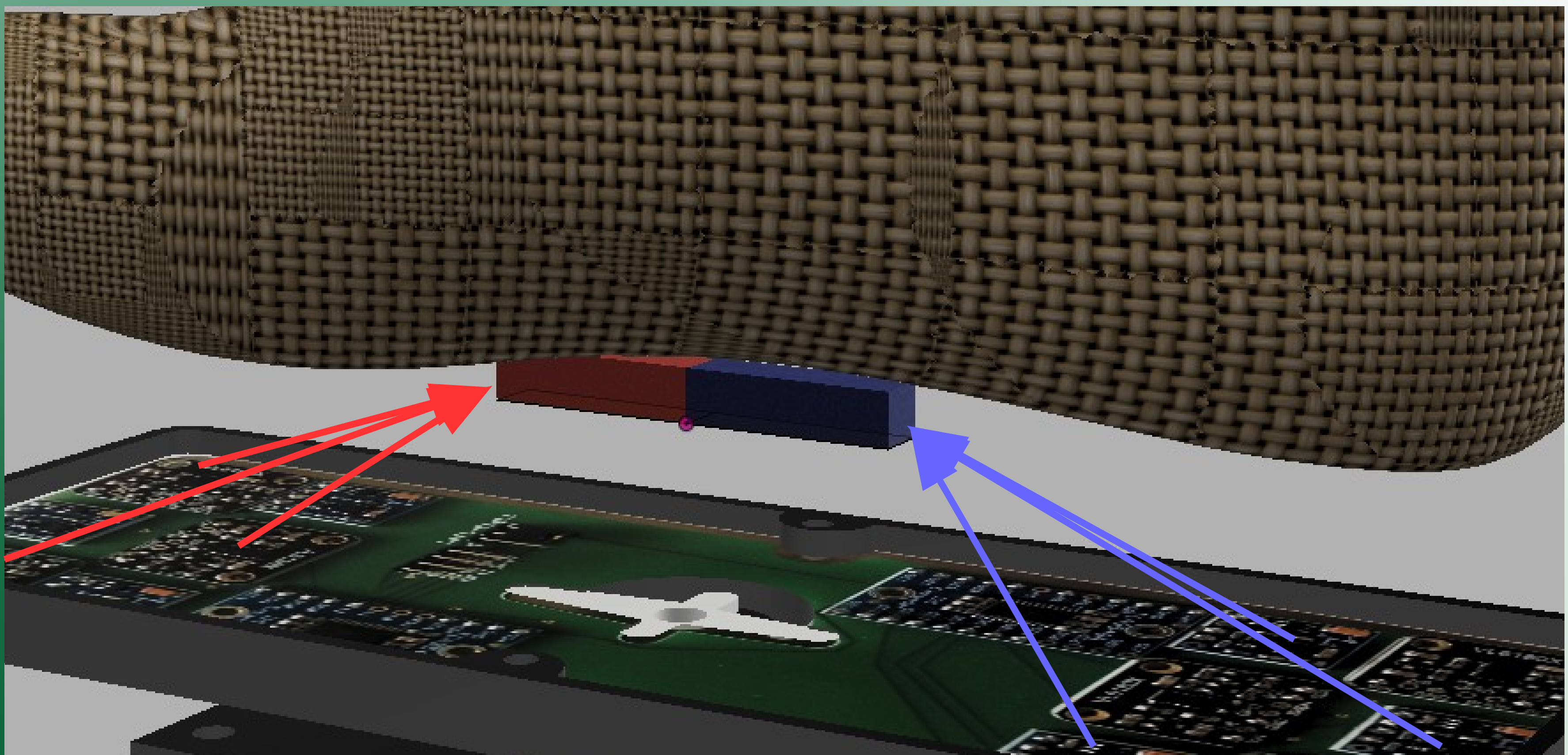
Footplate with magnetic field sensors



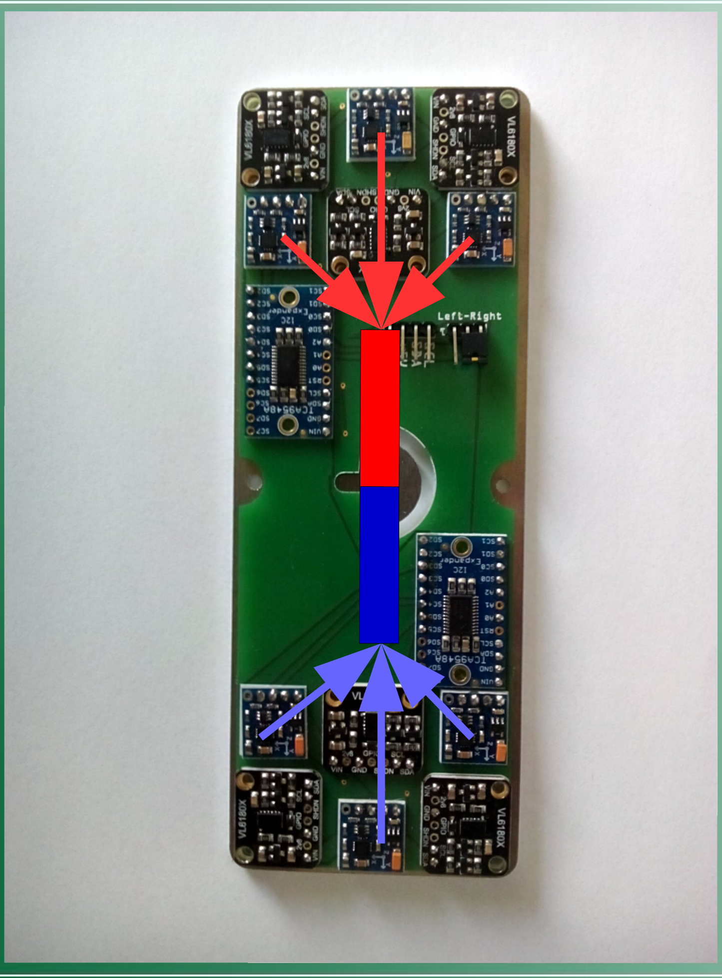
GY271
QMC5883L

Magnet in each foot orthosis

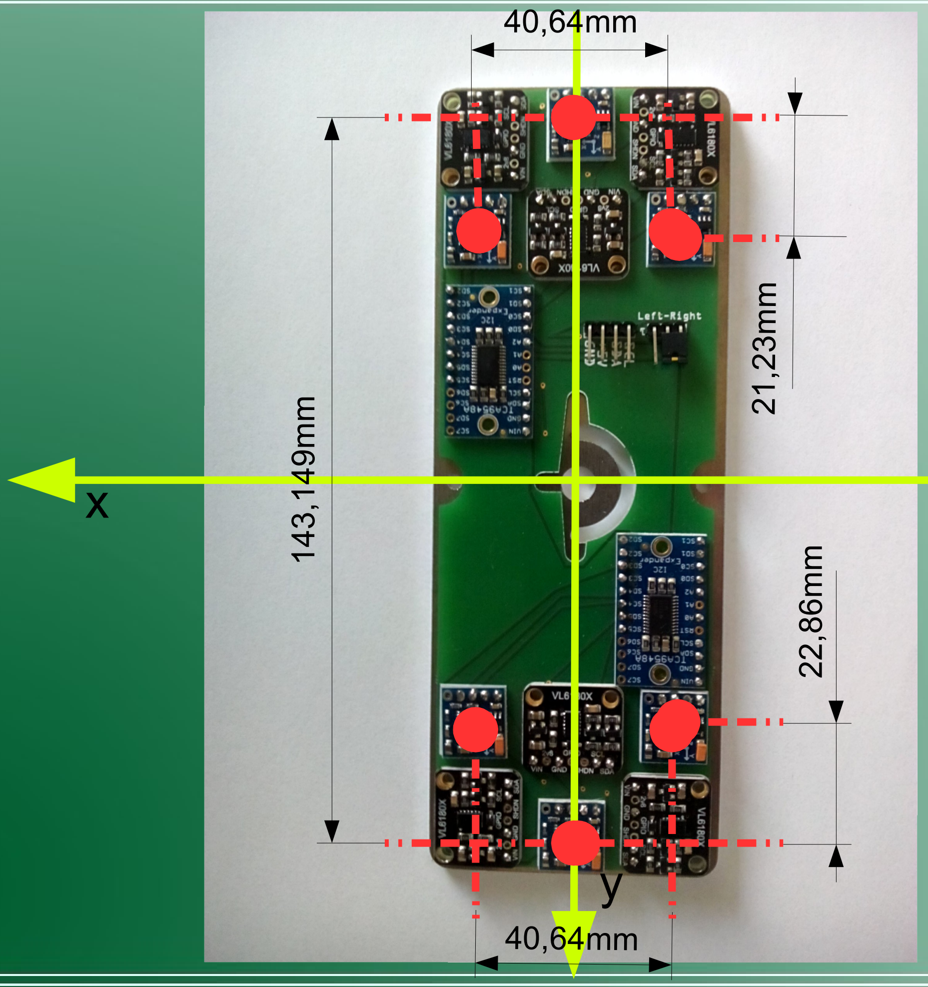
Looking for north and south pole 1/2



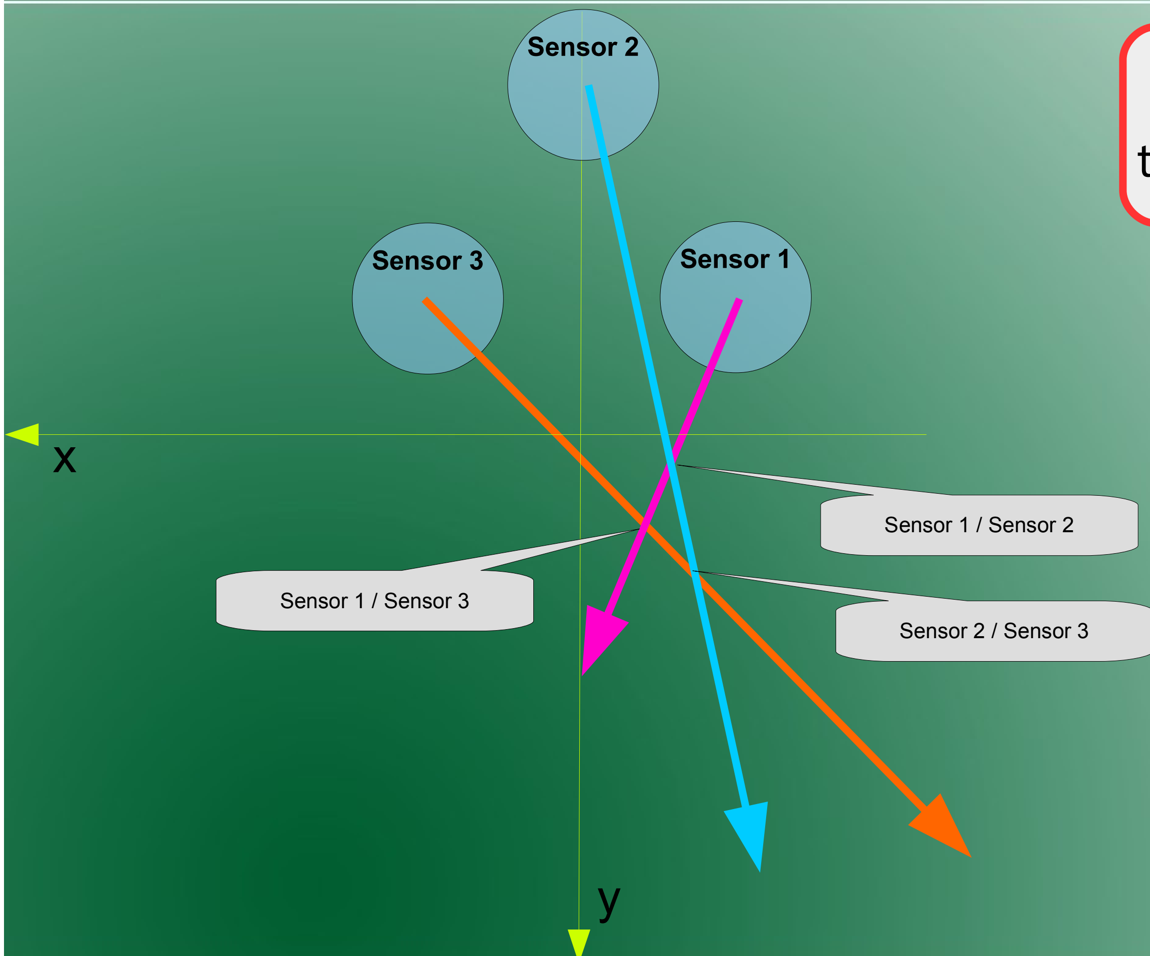
Looking for north and south pole 2/2



coordinate system of the footplate

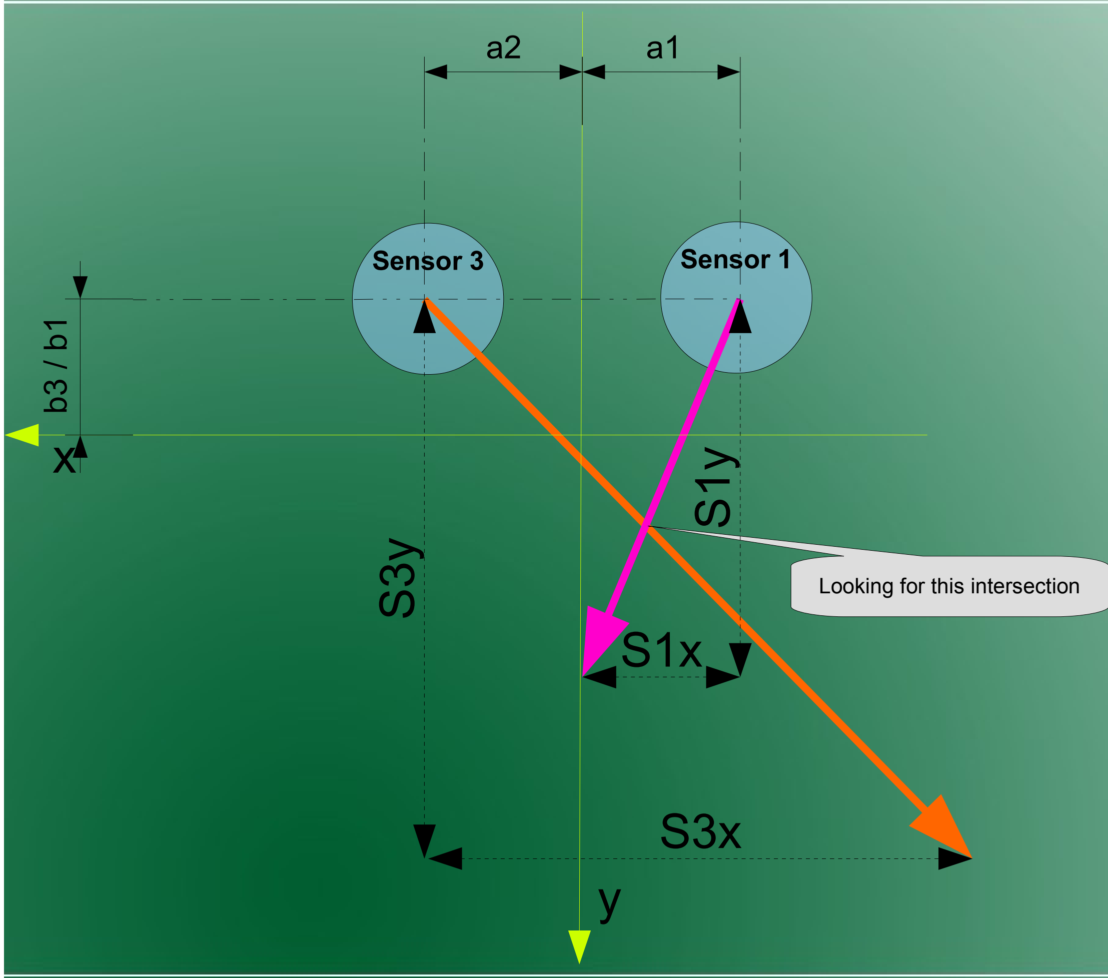


up to three Intersections:



Depending on the sensor accuracy, there can be up to three intersections.

Intersection of Sensor 1 and 3

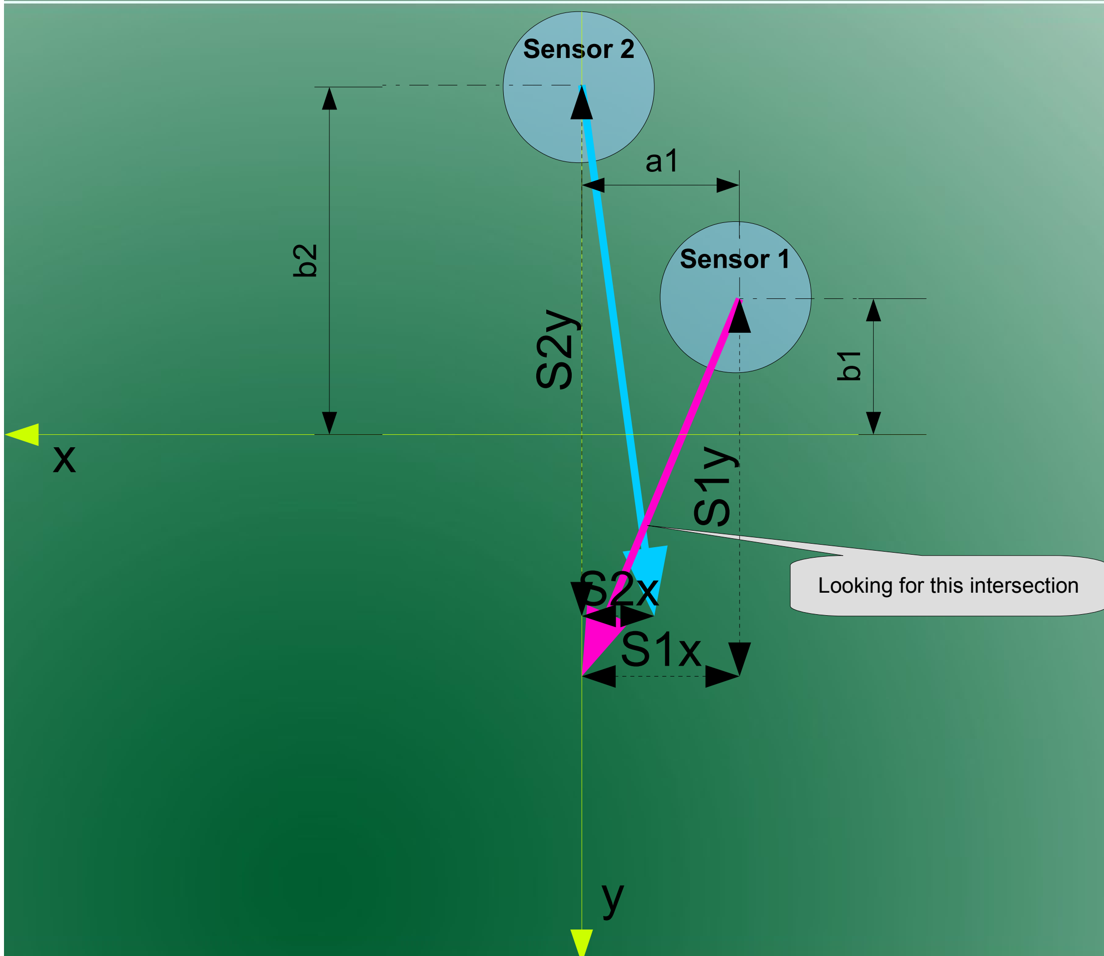


The values of ***a*** and ***b***
are constant and wellknown.

The values of ***S3x*** and ***S3y*** are
measured by "Sensor 3"

The values of ***S1x*** and ***S1y*** are
measured by "Sensor 1"

Intersection of Sensor 1 and 2

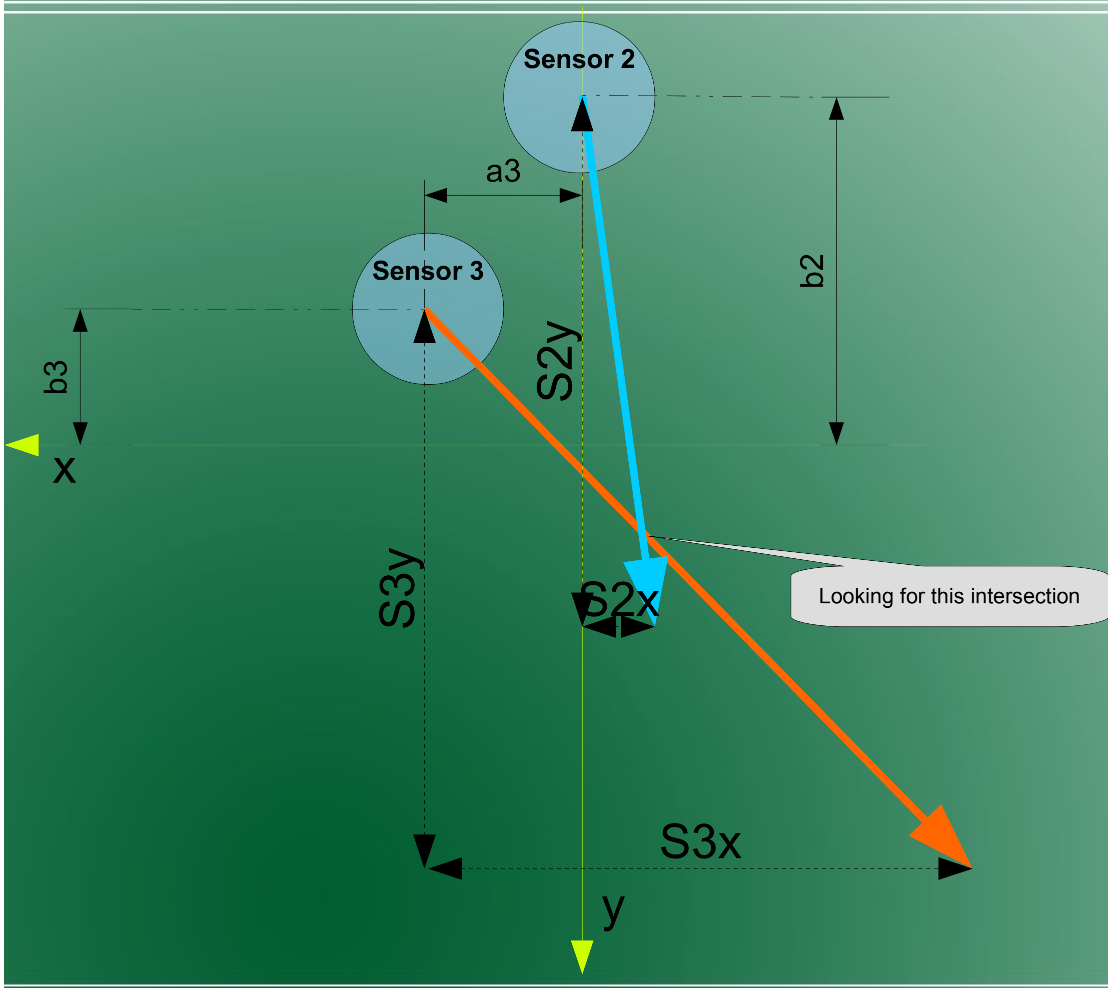


The values of ***a, b*** and ***c*** are constant and wellknown.

The values of ***S2x*** and ***S2y*** are measured by "Sensor 2"

The values of ***S1x*** and ***S1y*** are measured by "Sensor 1"

Intersection of Sensor 2 and 3

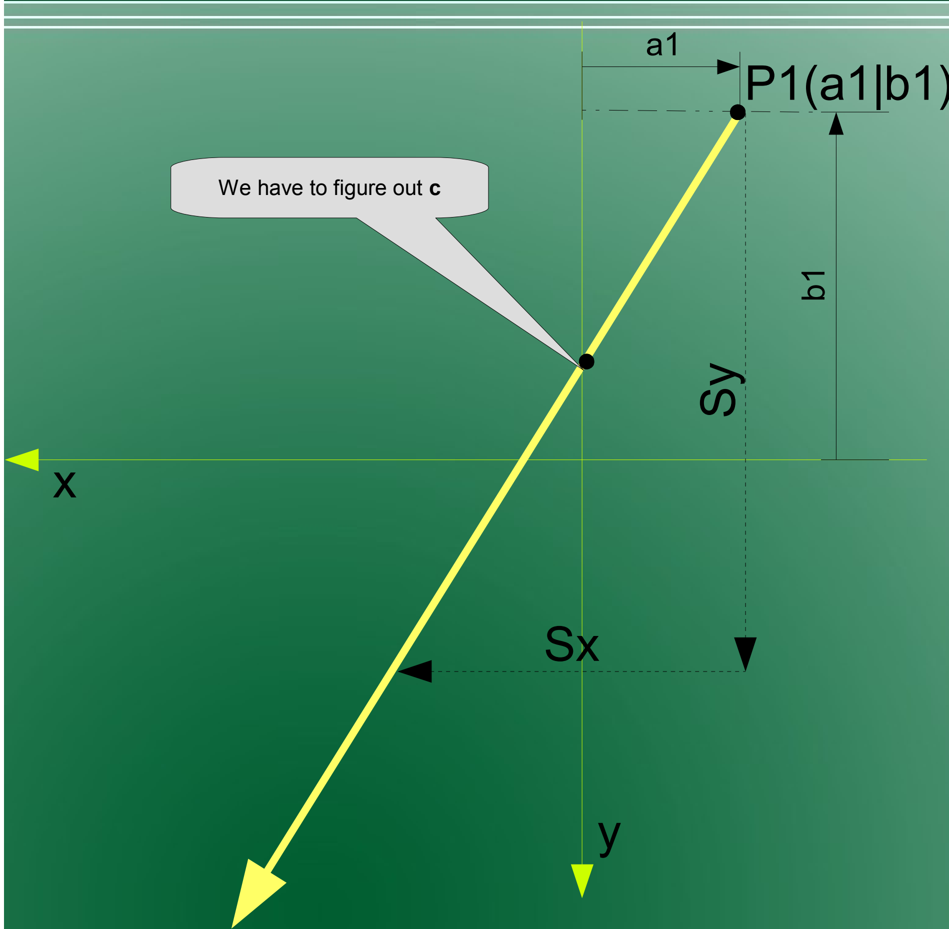


The values of ***a, b*** and ***c***
are constant and wellknown.

The values of ***S2x*** and ***S2y*** are
measured by "Sensor 2"

The values of ***S3x*** and ***S3y*** are
measured by "Sensor 3"

linear equation, looking for "c"



Sy and Sx come from Sensor

$$y = m \cdot x + c \quad \Big| \quad m = \frac{Sy}{Sx}$$

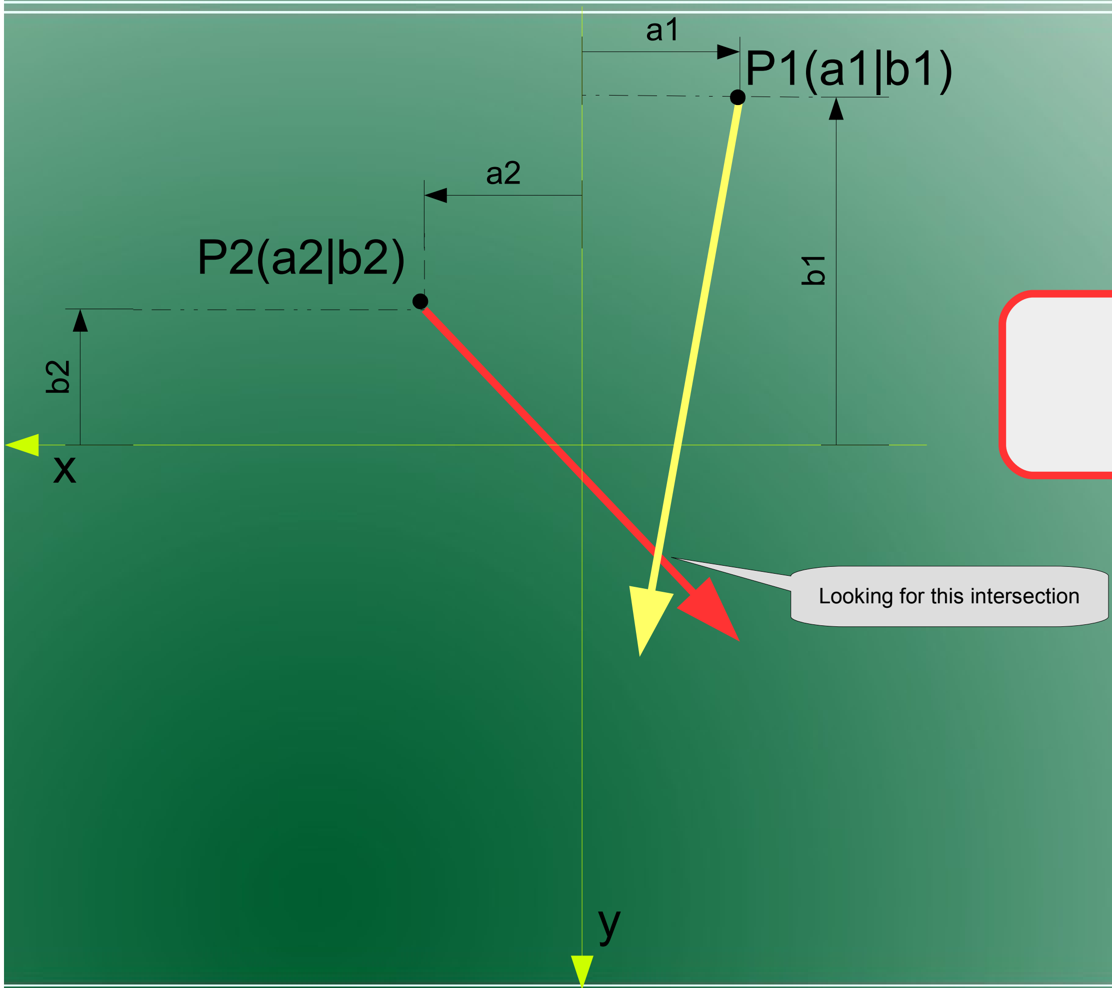
$$y = \frac{Sy}{Sx} \cdot x + c \quad \Big| \quad -\left(\frac{Sy}{Sx} \cdot x\right)$$

$$c = y - \frac{Sy}{Sx} \cdot x \quad \Big| \quad y = b,\ x = a$$

$$c = b - \frac{Sy}{Sx} \cdot a$$

$$y = \frac{Sy}{Sx} \cdot x + b - \frac{Sy}{Sx} \cdot a$$

Intersection of two lines in general 1/4



$$y1 = y2$$

Intersection of two lines in general 2/4

$$y1 = y2$$

$$\frac{S_{1y}}{S_{1x}} \cdot x + b_1 - \frac{S_{1y}}{S_{1x}} \cdot a_1 = \frac{S_{2y}}{S_{2x}} \cdot x + b_2 - \frac{S_{2y}}{S_{2x}} \cdot a_2 \;\Big|\; -\left(b_1 - \frac{S_{1y}}{S_{1x}} \cdot a_1\right)$$

$$\frac{S_{1y}}{S_{1x}} \cdot x = \frac{S_{2y}}{S_{2x}} \cdot x + b_2 - \frac{S_{2y}}{S_{2x}} \cdot a_2 - \left(b_1 - \frac{S_{1y}}{S_{1x}} \cdot a_1\right) \;\Big|\; -\left(\frac{S_{2y}}{S_{2x}} \cdot x\right)$$

$$\frac{S_{1y}}{S_{1x}} \cdot x - \frac{S_{2y}}{S_{2x}} \cdot x = b_2 - \frac{S_{2y}}{S_{2x}} \cdot a_2 - \left(b_1 - \frac{S_{1y}}{S_{1x}} \cdot a_1\right)$$

Intersection of two lines in general 3/4

$$x \cdot \left(\frac{S_{1y}}{S_{1x}} - \frac{S_{2y}}{S_{2x}}\right) = b_2 - \frac{S_{2y}}{S_{2x}} \cdot a_2 - \left(b_1 - \frac{S_{1y}}{S_{1x}} \cdot a_1\right) \quad \Big| : \left(\frac{S_{1y}}{S_{1x}} - \frac{S_{2y}}{S_{2x}}\right)$$

$$x = \frac{b_2 - \dfrac{S_{2y} \cdot a_2}{S_{2x}} - \left(b_1 - \dfrac{S_{1y} \cdot a_1}{S_{1x}}\right)}{\left(\dfrac{S_{1y}}{S_{1x}} - \dfrac{S_{2y}}{S_{2x}}\right)}$$

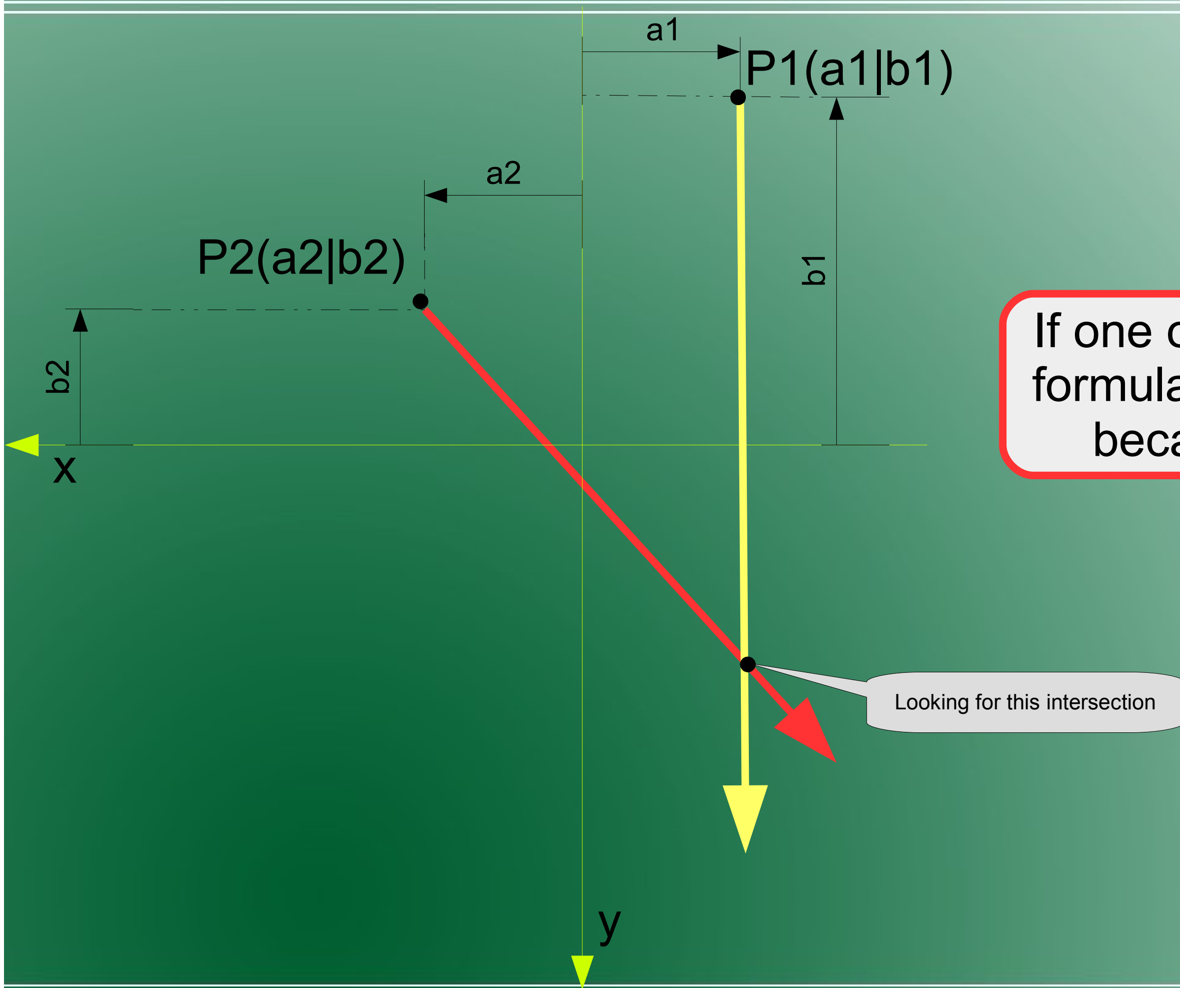
Intersection of two lines in general 4/4

$$y=\underbrace{\frac{S_{1y}}{S_{1x}}}_{m}\cdot\underbrace{\frac{b_2-\frac{S_{2y}\cdot a_2}{S_{2x}}-(b_1-\frac{S_{1y}\cdot a_1}{S_{1x}})}{(\frac{S_{1y}}{S_{1x}}-\frac{S_{2y}}{S_{2x}})}}_{x}\underbrace{+b_1-\frac{S_{1y}}{S_{1x}}\cdot a_1}_{c}$$

We use m from P1

We use c from P1

Division by zero 1/3

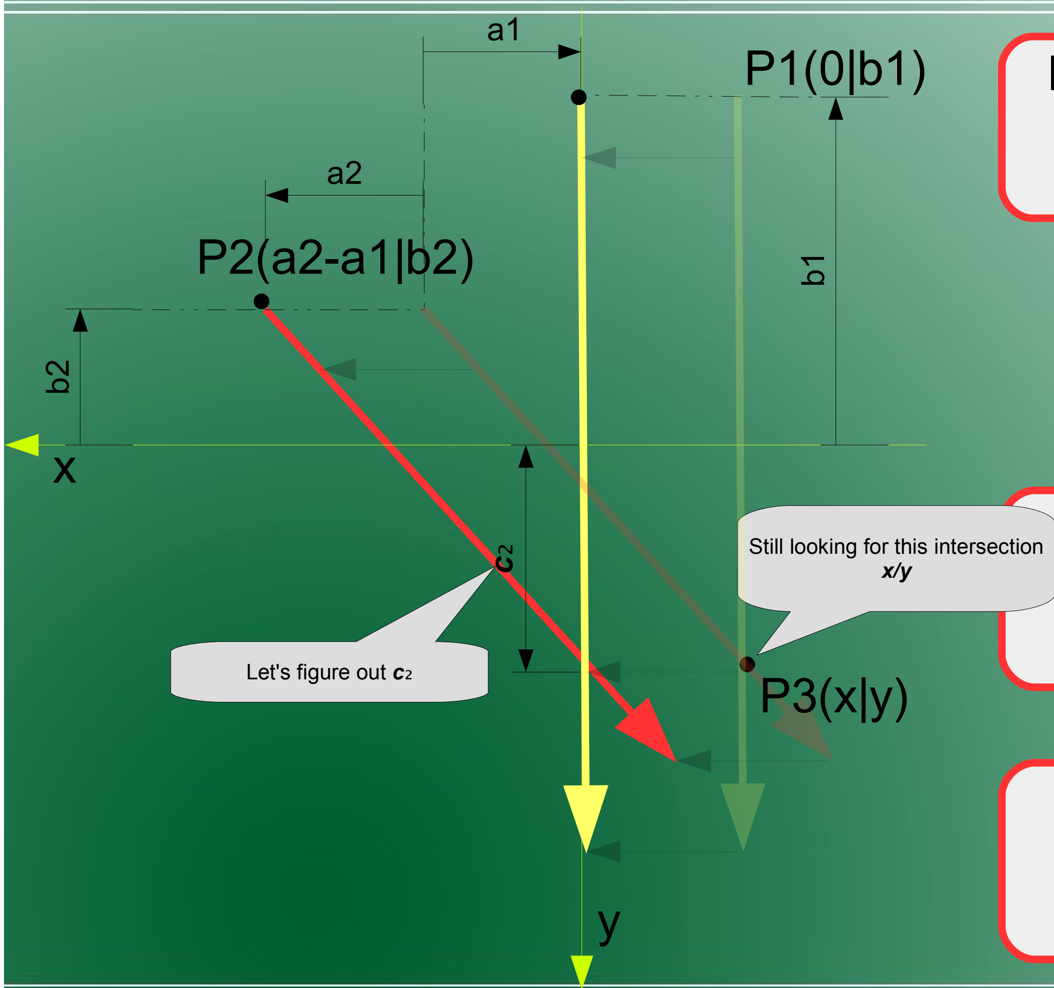


If one of the lines are vertical (***Sx***=0), the formula on the previous pages won't work, because ***m*** of this line will be invalid.

$$m = \frac{Sy}{Sx} \,!$$

If Sx = 0, ***m*** will be invalid

Division by zero 2/3



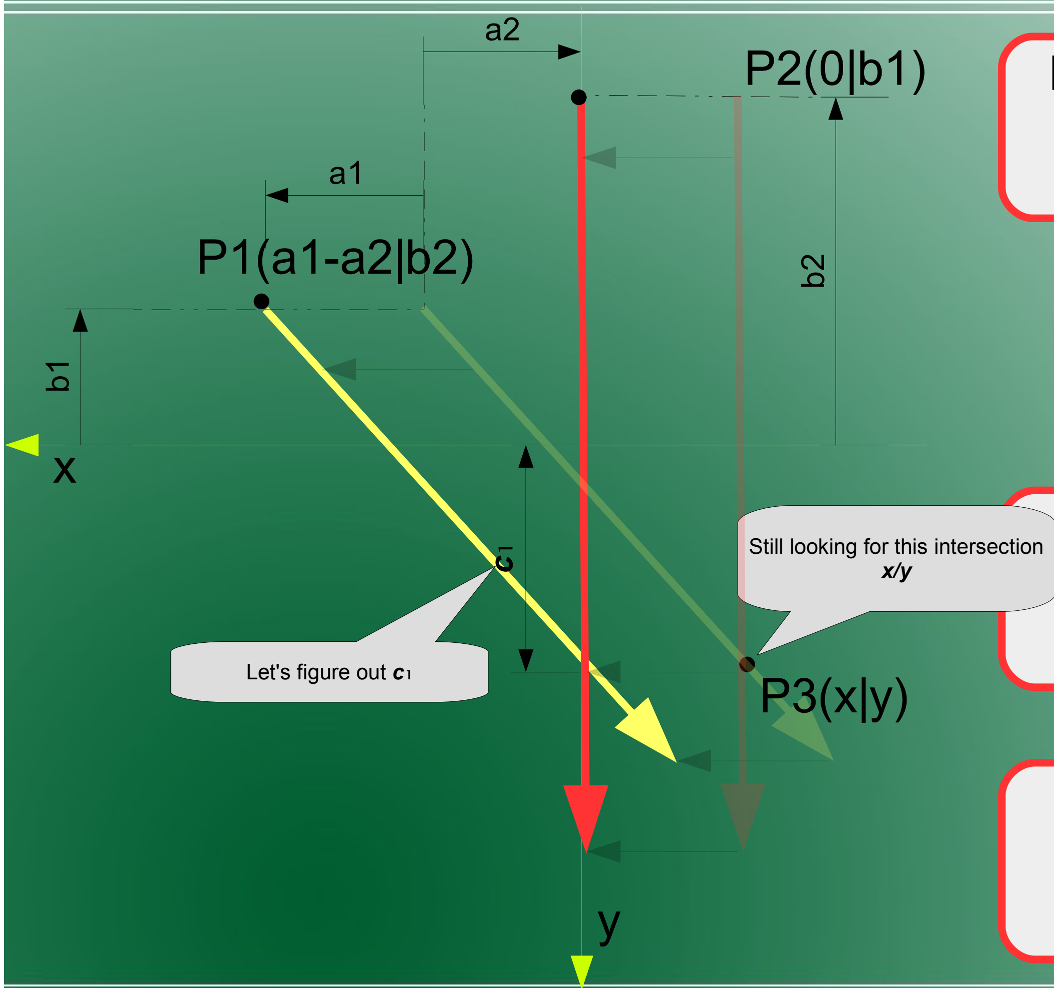
In case of vertical line, we have to move both lines in a kind, that the vertical line lays on the Y-axis.

$$c_2 = b_2 - \frac{S_{2y}}{S_{2x}} \cdot (a_2 - a_1)$$

$$x = a_1$$

$$y = c_2$$

Division by zero 3/3



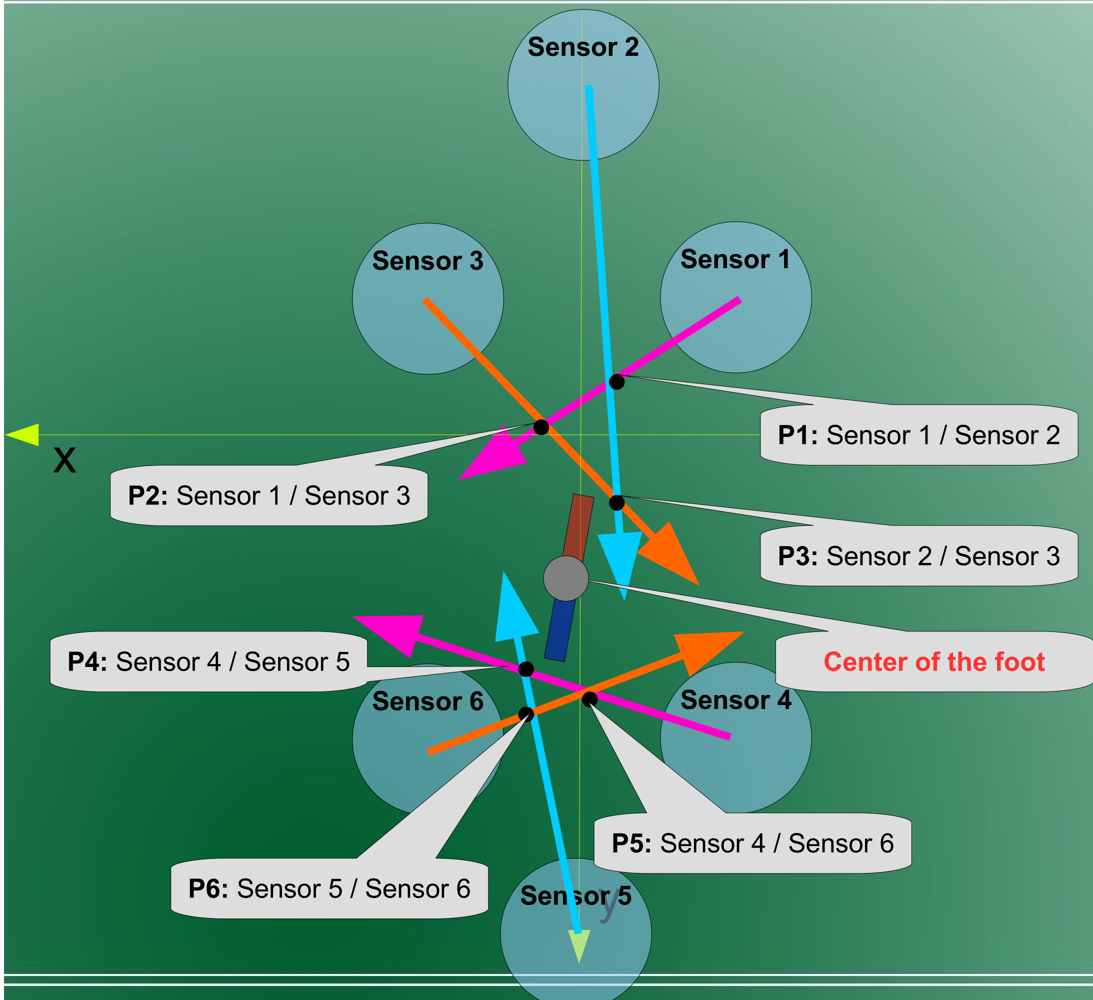
Here, you see the second line is vertical
(the red one).
The formular is nearly the same:

$$c_1 = b_1 - \frac{S_{1y}}{S_{1x}} \cdot (a_1 - a_2)$$

$$x = a_2$$

$$y = c_1$$

Center of the foot



There are P1, P2, P3 pointing to the front of the foot.

P4, P5 and P6 are pointing to the end of the foot.

The center of the foot should be the average of P1, P2, P3, P4, P5 and P6. But in practice this is not the case. See next page.

Magnetic field lines/too close to sensor

When the magnet is too close to the magnetic field sensor, this sensor will produce useless data, because of the magnet field lines, coming "out" of the magnet.

The tangent of the field lines then changes very quickly and point to the "wrong" direction.

<u>But the good thing:</u> if the magnet is too close to one of the magnet field sensors, the distance to the other two magnetic field sensors is increased. So, we have to trust the other two magnetic field sensor datas and to ignore the third one which create useless data.