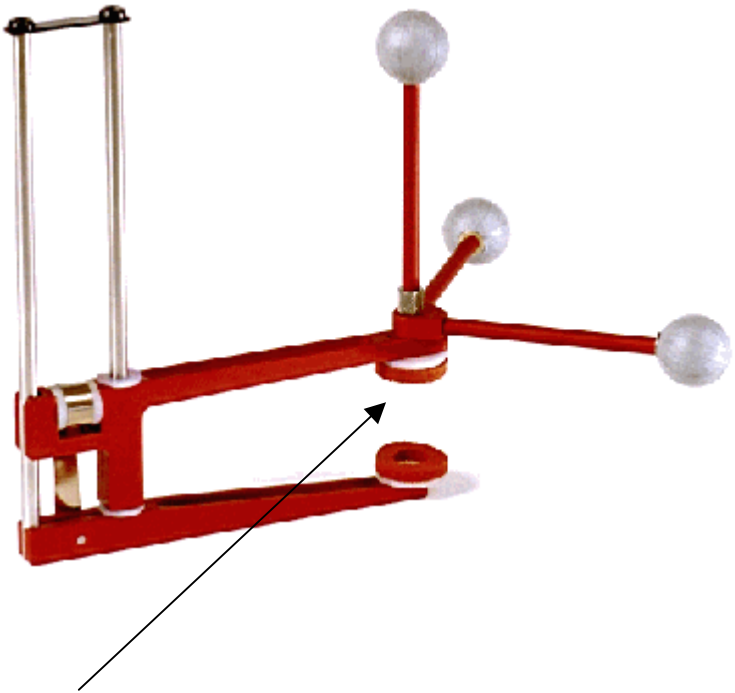
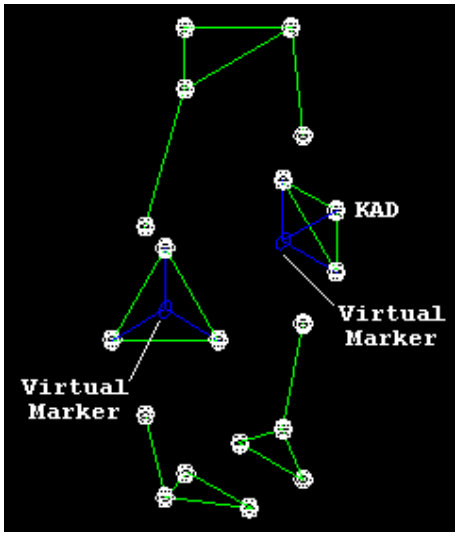
Motion Lab Systems, Inc. - Knee Alignment Device (KAD):

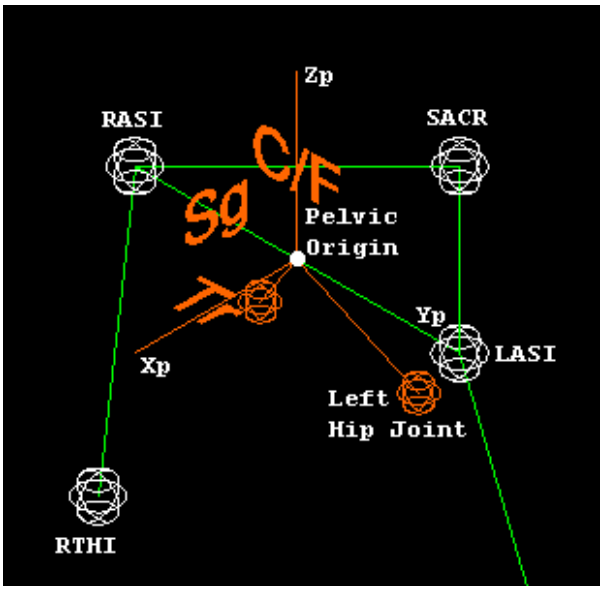


Virtual Marker:
the crossing of the three sticks determines the position of the virtual marker

Basic model - Static trial:



1. Hip joint center:
We used the equations described in the page 141 of the VCM user's manual (Davis, Õunpuu and Tyburski).



Coordinates system of the pelvis:

Pelvic Origin: Po = (LASI + RASI)/2

Yp = (LASI - RASI) / |(LASI - RASI)|

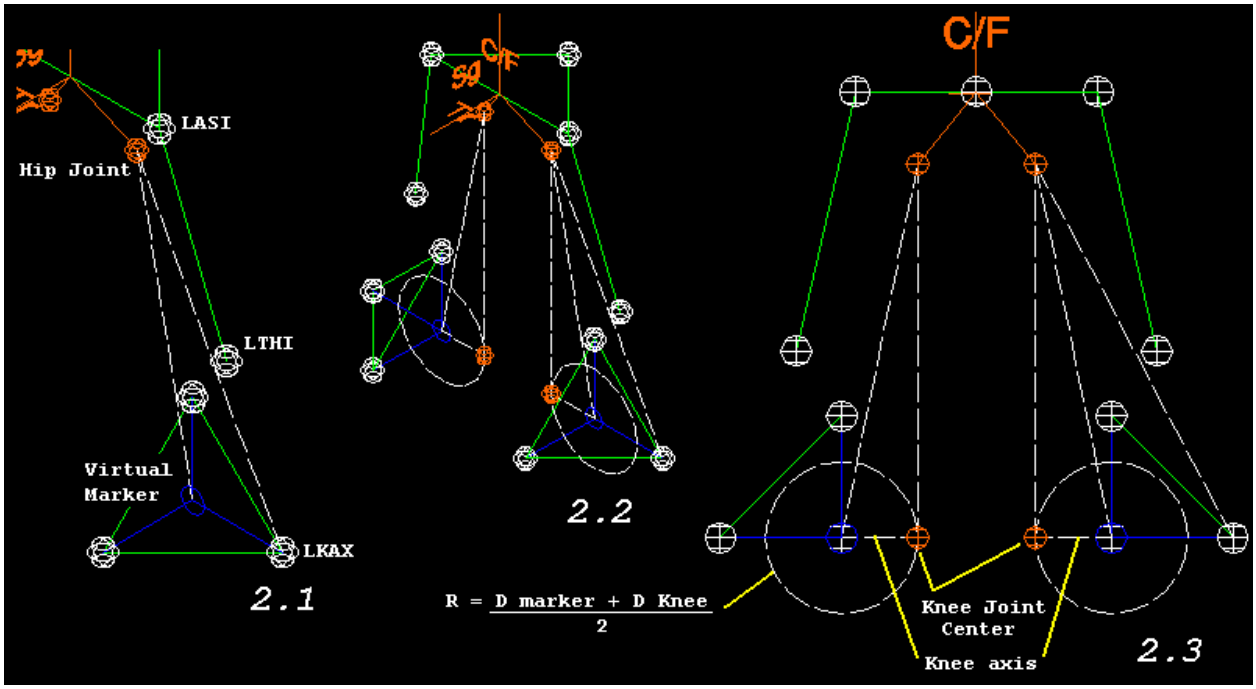
auxiliary vector X':
X' = Po - SACR

Zp = (X' x Yp) / |(X' x Yp)|

Xp = Yp x Zp

2. Knee Joint Center - Calculation sequence (Left):

2.1
Determination of the frontal plane of the thigh:
This plane is determined for the following points: Left Hip Joint Center, Virtual Marker and LKAX.
2.2 and 2.3
To guarantee that the knee axis is perpendicular to the hip-knee joint center axis, it was made a circumference with the
Radius = [(Marker Diameter (25mm) + Knee 'diameter' (width)) / 2] and traced a tangent line to circumference.



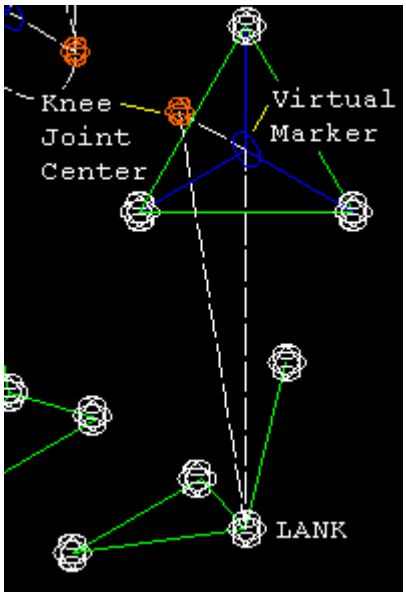
3. Ankle Joint Center with application of tibial torsion:
The following definitions were used for the determination of the calculation process:
VCM user's manual (page 13):
"... If Tibial Torsion is entered in the session form, the plane containing the ankle flexion axis and the knee center is rotated by the amount of reported Tibial Torsion, with respect to the plane containing the knee flexion axis and the ankle center."
"Note: Shank rotation and Tibial Torsion are both measured about the axis jointing the ankle and knee centers..."
VCM user's manual (page 23):
"12. The knee-ankle joint center axis is perpendicular to that ankle flexion axis at the ankle joint center, and these tho axes define the frontal plane of the shank."

To maintain these conditions, it was necessary to write a function to relate all the variables.

Calculation sequence:

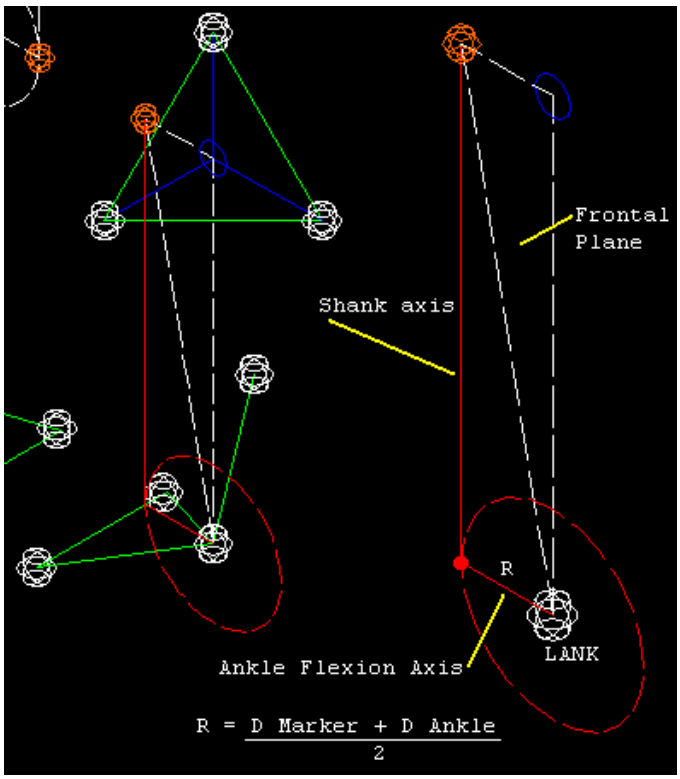
3.1. It was determined the area in the space that preserves all the definitions for the ankle joint center and ankle flexion axis.
This region is a circumference that is constructed according to the sequence of drawings below:
(I apologize, certainly my limitations with the language hinder the accurate explanation of this sequence).

a. frontal plane of reference:



This plan is formed by the knee flexion axis and for the ankle marker.

b. A similar construction to the previous item (2. Knee Joint Center) was made to generate two perpendicular axes (Shank Axis and Ankle Flexion Axis - red lines) and to determine the ankle joint center:



These auxiliary constructions are made in the frontal plane of reference.

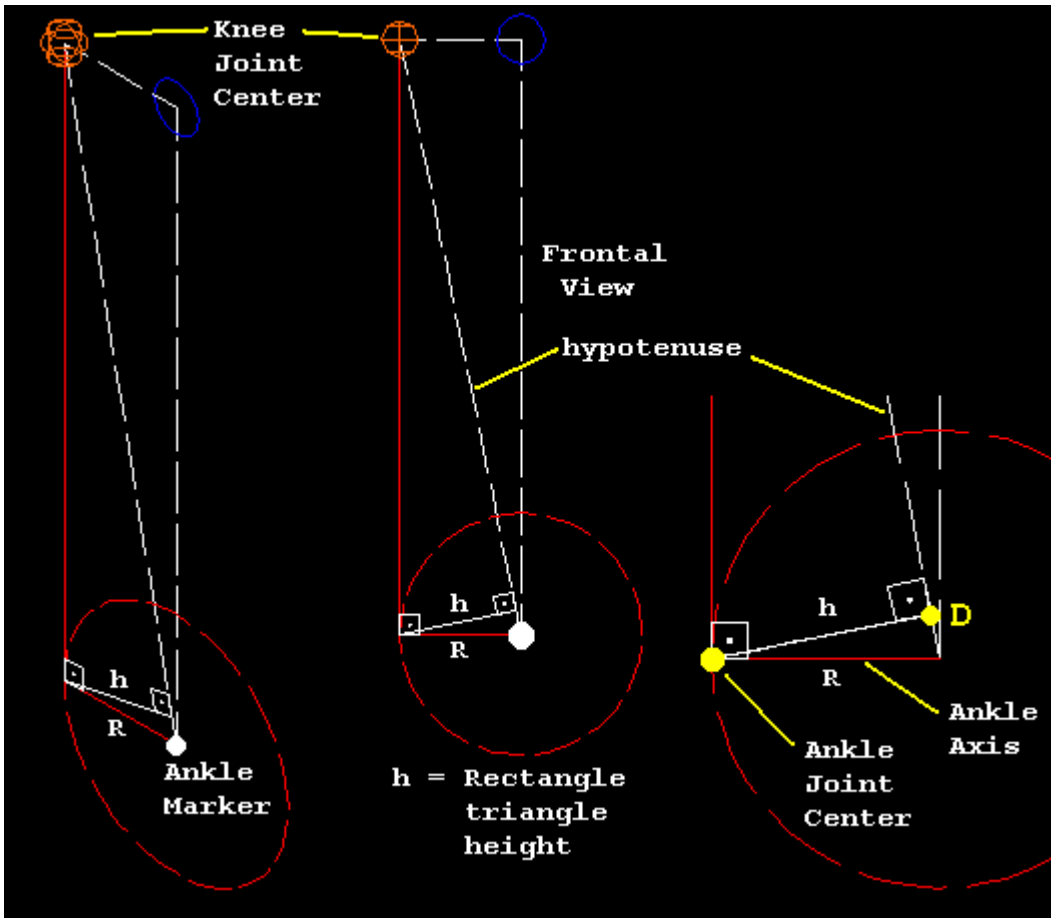
circumference radius:
Radius = [Marker Diameter (25mm) + Ankle 'diameter' (width)] / 2

Note: for this specific situation the tibial torsion is zero.

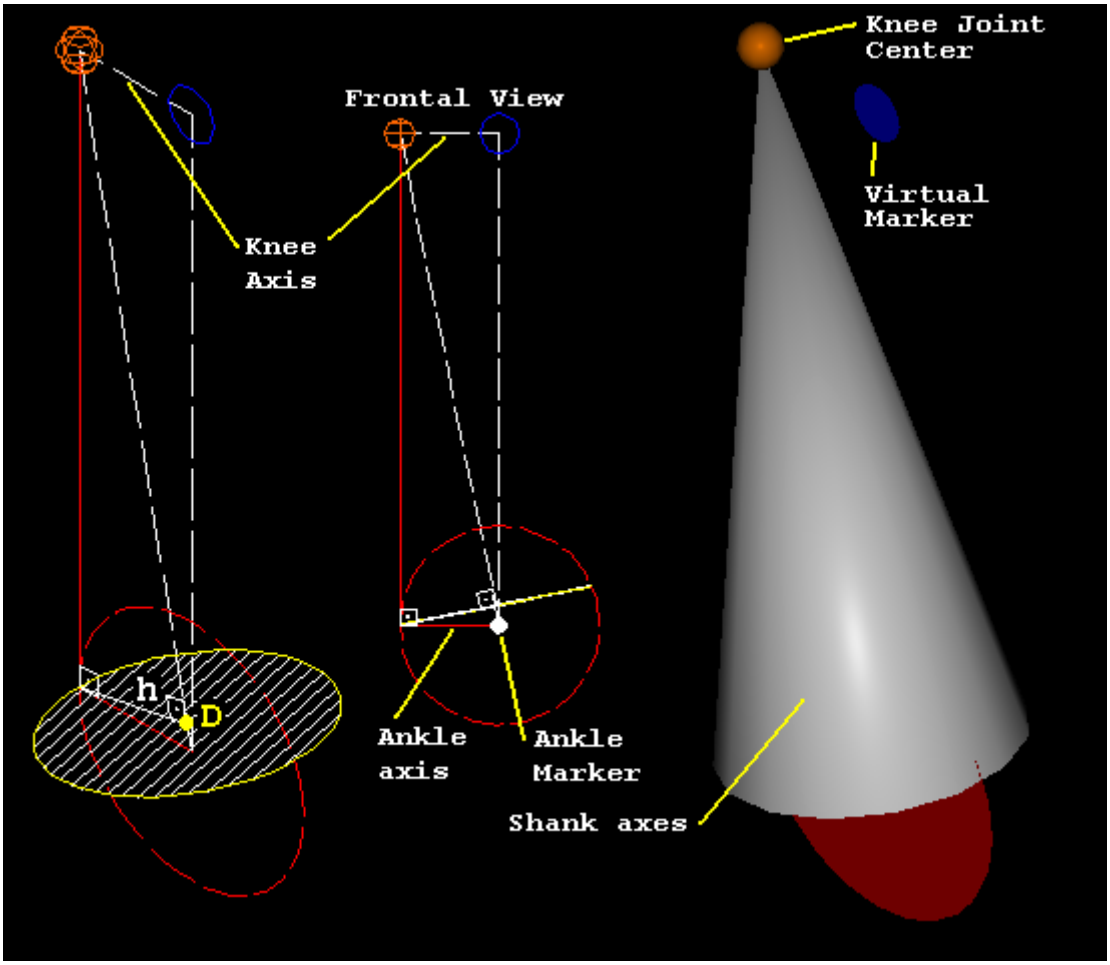
c. Region in the space that includes any angle of tibial torsion:

Construction sequence:

c.1. determination of the rectangle triangle height (h) and of the intersection point (D) between the height and the hypotenuse of the triangle:



c.2. The area in the space that corresponds to all possible mathematical solutions (0° < tibial torsion < 360°) is a circumference (yellow circunference) with radius = h, center on the D point and parallel to a perpendicular plan to the rectangle triangle hypotenuse.



All shank axes (for each tibial torsion value) are contained in the gray cone.

It was written a function (in Mathcad) to relate the tibial torsion with the circumference coordinates (ankle joint center).