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This section builds on the information presented in *The Essentials of Motion Capture* to describe non-standard techniques needed by some advanced users.

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There are many examples where the study of multiple subjects is important, for example, interaction in sports scenarios or the movement of groups for film, animation and computer games. Objects such as furniture, walking aids, sports equipment and theatrical props can be considered subjects in their own right and the system can be used to study their interaction with a living subject. All of these types of object will be referred to as props.

Before attempting to capture multiple subjects you should be familiar with the techniques described in the section The Essentials of Motion Capture, including the details of Subject Calibration. Preparation is similar to that for single subjects; they have markers attached and each subject must be calibrated.

Attaching markers

When capturing a single subject the subject is calibrated so that the autolabeller can distinguish markers on different body segments. To this end some markers are placed in positions not directly associated with skeletal movement but to add asymmetry to the marker arrangement.

When capturing two or more subjects the autolabeller must also be able to distinguish between them. One way of achieving this when the marker sets used are the same for each subject is to use different asymmetry markers. In general:

• Swap the back markers so one subject has LBAC and the other has RBAC

• Reverse positioning of asymmetry markers between subjects

This is particularly important if the subjects are both the same height and build.

Subject calibration

Before capturing data you must calibrate each subject. There are two ways of doing this:

• Calibrate each subject in a separate trial

• Calibrate all subjects in the same trial

Calibrating the subjects individually

Each subject may be calibrated in an individual trial, making sure that the others are out of the field of view of all cameras:

• Capture a static trial for the first subject

• Manually label the trajectories ensuring '(no subject)' is selected in the Labelling Control Bar

• Select Trial | Create Autolabel Calibration

Now test the autolabeller:

• As a precaution save the trial and then select Edit | Unlabel All the Trajectories

- Select Trial | Options

- In the Options dialog select the newly created subject and 'Include subject names in labels'

- Click OK

- Select Autolabel from the Trial menu
You can now calibrate other subjects in exactly the same way.

When you include subject names in labels this allows for the differentiation of the subjects. After confirming that the autolabeller does indeed work with this simplest of trials try it with something more demanding. Capture your subjects performing a few standard moves – warming up exercises such as subjects standing together and walking in a circle.

Calibrating the subjects in the same trial

To save time you can also calibrate the subjects in the same trial:
- Capture a static trial including all subjects separated by some distance and in the motorcycle pose

- Reconstruct the trial

- Attach a marker set and select '(no subject)' in the labelling Control Bar

- Manually label one of the subjects

- Create Autolabel Calibration (Trial Menu)
At this stage you can test the autolabeller as you did previously.

Now manually label the second subject:
- Select Edit | Unlabel All Trajectories

- Select '(no subject)' in the Labelling Control Bar

- Label the trajectories

- Create Autolabel Calibration
Once again you can test the autolabelling for the individual subject. Repeat this for any additional subjects.

You can also test the autolabelling for all:
- Select Edit | Unlabel All Trajectories

- Select Trial | Options

- Select all subjects in the options dialog and select 'Include subject names in labels'

- Click OK to close the options dialog

- Select Trial | Autolabel

All subjects should now be labelled. Check the labelling using the mouse helper.

Capturing multiple subjects

Now that the subject calibration is complete you can proceed as you would with a single subject to capture the moves, reconstruct and process the data. When capturing trials:

- Select Trial | Capture… to open the Trial Data Capture dialog

- In addition to other parameters select all of the subjects to be included in the trial

- Click Capture

You will see that the mechanics of data capture itself is no more complex than capturing a single subject, for example using Trial Types and the Pipeline to speed things up.

Data processing may be more time consuming because, with more than one body moving around, there are more opportunities for markers to be hidden. This leads to more occlusions and more broken trajectories.

Hints and tips for capturing multiple subjects

Helping the autolabeller
Maintaining different asymmetry markers between the subjects is very important. If the autolabeller is mislabelling two similarly built subjects try changing the relative differences between the two, using different wrist markers sets or adding an extra optional marker. In instances where data has already been captured, hand labelling key parts of one of the subjects will help the autolabeller as it uses the manually labelled points as a reference.

Test the Autolabeller
If practical, check that the autolabeller is working for all subjects before capturing scripted moves. Start with a few simple moves such as walking through the volume, walking in circles and so on.

Markers
If you are capturing moves where there is some bodily contact between the subjects, for example fight scenes or sports moves, consider using soft markers as they are less likely to be knocked off. If markers move or are lost then you will have to recalibrate the subjects.

Editing
With more than one subject there are likely to be more occlusions and therefore more broken trajectories. The editing process is therefore likely to be more involved than for single subjects.

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Saving subjects separately

By default the system saves all subjects to the same C3D file. The pipeline includes an option to save subjects to separate C3D files. If you choose this option ensure that the data is completely labelled for all subjects. Unlabelled trajectories will not be saved with this option.

Capturing props

Props are considered additional subjects and treated in a similar way. The main differences are that you have to decide how and where to place markers and that they may be treated as a separate subject or as part of the main moving subject or actor.

Defining the prop: markers

When considering using props you have to decide how and where to attach markers. The idea is to be able to define the shape in as simple a manner as possible. A single marker will allow you to capture a prop's position only. Two markers will allow you to capture its position and orientation. Three markers will allow you to capture position, orientation and rotation. Any additional markers allow for complete data to be captured when occlusions occur.

Objects such as swords or a golf club can be defined mostly by the intersections of a number of straight segments. Here four markers define a golf club:

Example markers for a golf club
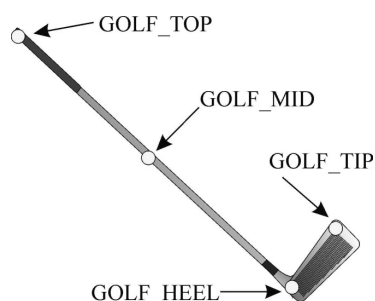
A tennis racket could be defined with three or four markers depending on the definition required. The main ones are on the handle and two on either side of the head. A fourth may be added at the top of the head as shown below.

Note that with props you also need to consider asymmetry to aid the Autolabel feature:

Example Markers for a tennis racket: note the asymmetry of the markers
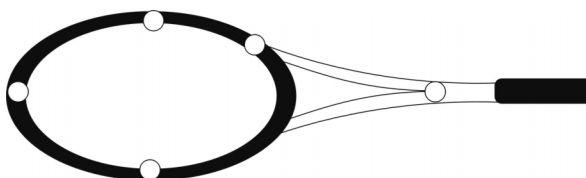
Defining the prop: marker files

In order to label the prop and to use the autolabeller the prop must have a marker file. This may be a completely separate marker file or it can be a combined subject and prop marker file. To create your own marker file see the

guidelines in the Reference section. Vicon includes examples of both marker files for individual props and human marker files including labels for props. If necessary you could edit the segments section of the marker file in order to define the green sticks that will appear when you label the prop.

Defining the prop: separately or combined with the subject

Even if you choose to use a combined marker file for your actor and prop you can still treat them as separate subjects. To do this, follow the method given for calibrating and labelling multiple subjects together. In either case the prop may have its own marker file or a combined file with the subject:

• Label the subject ignoring the prop markers and create a subject in Workstation accordingly

• Unlabel and test

• Label the prop ignoring the subject and create a subject for the prop in Workstation

• Unlabel and test autolabeller

Alternatively you can calibrate the prop on its own. To do this you could lay it on the floor or have an assistant hold it still in the volume in a position where they do not obscure any camera views.

Hints and Tips for capturing props

Define the prop with as few markers as possible
Using more markers leads to a greater chance of occlusions occurring and therefore more broken trajectories. With objects such as footballs, since the markers are all on the outside the ball will appear larger than it really is and there is a much greater chance of markers blooming and merging with markers on the feet of the subject.

Make sure markers will not be obscured
When attaching markers, ensure that the hand holding the prop will not obscure them.

Use appropriate marker label names'
Although the Vicon sample marker sets include extra label names make sure that they are what you need. For clarity rename them to represent the prop you are using.

Check that the marker file will Autolabel the prop correctly
When creating your own marker file you must create a suitable segments section to allow the system to Autolabel your prop.

Check that your capture rate is appropriate for your moves
The tips of handheld props such as swords or golf clubs move very rapidly and you may need to alter the capture rate to make sure the movement is captured properly. Another solution may be to attach markers some distance from the tip so that the angular velocity of the marker is lower.

Also, you may need to adjust the Maximum Acceleration parameter (Trial | Reconstruction Parameters) for rapidly moving markers at the end of a prop.

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Before attempting to capture in small volumes you should be familiar with the techniques described in the chapters *Preparation* and *The Essentials of Motion Capture.*

There are several key differences when capturing subjects in small volumes:

• Use of smaller markers

• The marker set specific to the type of capture, e.g., face or hand

• Choice of lenses for close up work

• Arrangement of cameras to view the small volume

• Calibration objects: FlatCal and 100mm wand

• Use appropriate reconstruction parameters for the size of the volume

Otherwise the workflow is generally the same:

• Set up and calibrate the Capture Volume

• Attach markers to the subject

• Calibrate the subject

• Capture motion

• Process data

Preparing the volume for capturing facial movement

Camera setup   Good results may be obtained with five to eight cameras. The following example setup shows six cameras. In general we recommend the use of infra-red cameras for facial captures, as they are easier on the subjects in such confined spaces.

In all cases the individual camera field of view should be checked using the Live Monitor window in Workstation. As in other capture sessions, each marker should be visible to two or more cameras. Also check the subject's face fills the usable space in the live monitor window.

In the following example individual cameras are between 1.2m and 1.5m from the subject's head. Using 25mm lenses a distance of 1.2m is suitable but using 12.5mm lenses the cameras will need to be placed much closer. For best results you will want to back focus your cameras for this distance.

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Example of MCam lens field of view
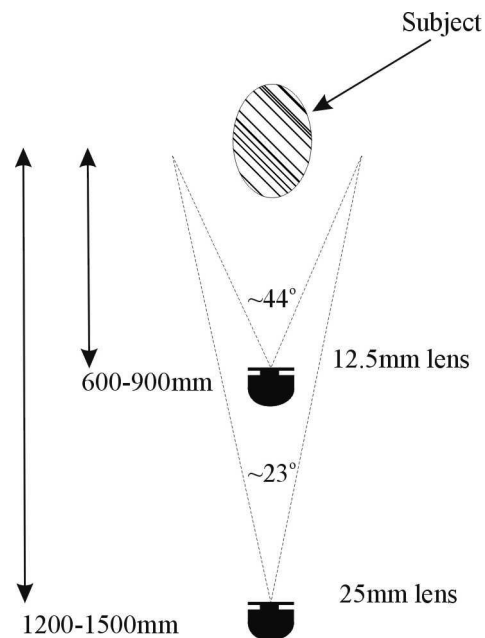
The figures below show the arrangement of six cameras as an arc in front of the subject's face.

Camera setup for facial capture, view from above. The cameras with 25mm lenses are all approximately 1.2m from the subject
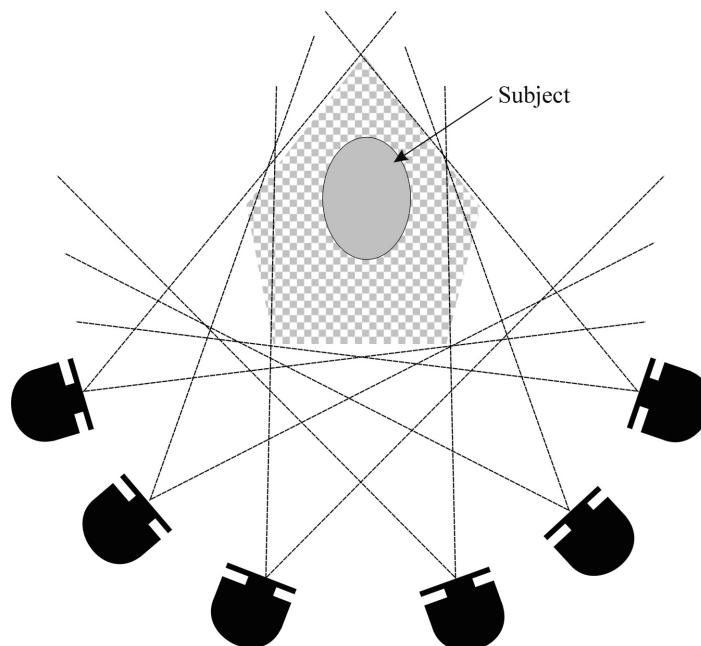
Best results may be obtained if the camera heights are staggered so that some are viewing the face from slightly above and some from slightly below the horizontal midline of the face.

Camera setup for facial capture, view from the front
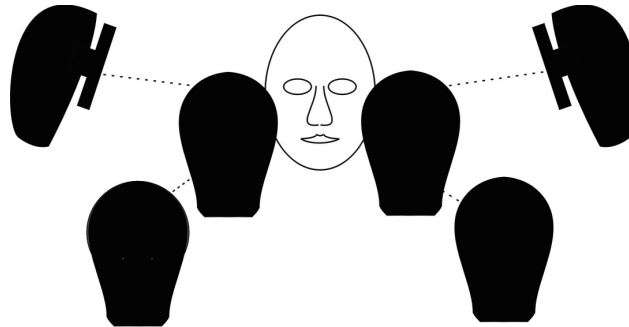
Volume calibration

Calibration follows the usual pattern of static and dynamic calibration but uses smaller calibration objects. We recommend the use of the small FlatCal static calibration object. This is a black plate, approximately 300mm square, that can be mounted to a standard tripod base. Reflective circles are attached in the usual L shape. The dynamic portion of calibration uses a small wand with markers attached 100mm apart. When using these calibration objects you must change the calibration Reference Object in the Calibrate cameras dialog:

- Select System | Calibrate Cameras... to open the dialog

- Verify that the Reference Object name is set to FlatCal 100mm Wand

- Click Calibrate

Static calibration

The FlatCal should be placed directly behind where the subject's face will be during capture. For facial animation the movement of the head and body are relatively unimportant, so the volume is usually just that space immediately surrounding the face. It may be convenient to seat the subject to eliminate excessive body and head movement. In this case you may want to mount the FlatCal to the back of the subject's chair at head height and then just cover it when not in use.

Dynamic calibration

The wand waving method is essentially the same as for larger areas but the wand is waved in the region that will be occupied by the face. Take care when you are waving the wand to stay in the small volume and not move too quickly. Using the live monitor window will help you determine the range in which you should wave the wand for this small volume.
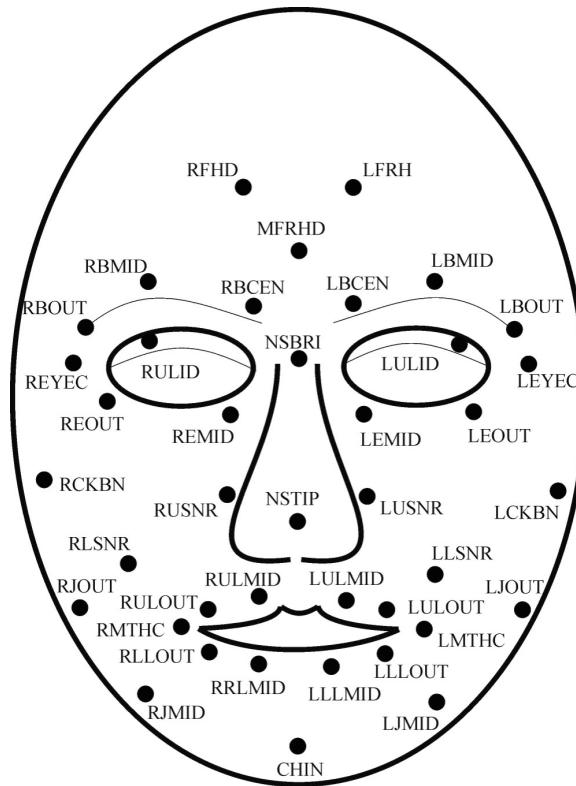
Markers

Facial capture typically uses 3mm hemisphere markers. These may be attached to the face using double-sided tape or mastic based theatrical glue. Care must be taken when attaching these markers – particularly on the eyelids and near the eyes and mouth. How many markers you choose to use will depend on your application. For example, Famous3D allows you to use an unlimited number of markers that you can attach to weighted clusters of vertices that drive the

animated face. Other applications, such as FiLMBOX, use only a limited number. As with full body capture, extra markers can sometimes be used to provide stability to the motion capture data. Vicon has used anywhere from a simple 13 marker set to a more complex 155 marker set. You can see an example facial marker set below.

Example Facial Marker Set

Marker	Definition	Marker	Definition
LFRHD	Left forehead	RFRHD	Right forehead
MFRHD	Mid forehead		
NSBRI	Bridge of the nose	NSETP	Tip of the nose
LEYEC	Left eye corner	REYEC	Right eye corner
LBCEN	Left centre eyebrow	RBCEN	Right centre eyebrow
LBMID	Left mid eyebrow	RBMID	Right mid eyebrow
LBOUT	Left outside eyebrow	RBOUT	Right outside eyebrow
LULID	Left top eye lid	RULID	Right top eye lid
LEMID	Left lower eye middle	REMID	Right lower eye middle
LEOUT	Left lower eye outside	REOUT	Right lower eye outside
LCKBN	Left cheek bone	RCKBN	Right cheek bone
LCHEK	Left cheek	RCHEK	Right cheek
LUSNR	Left upper sneer	RUSNR	Right upper sneer
LLSNR	Left lower sneer	RLSNR	Right lower sneer
LULMID	Left upper lip middle	RULMID	Right upper lip middle
LULOUT	Left upper lip outside	RULOUT	Right upper lip outside
LMTHC	Left mouth corner	RMTHC	Right mouth corner
LLLMID	Left lower lip middle	RLLMID	Right lower lip middle
LLLOUT	Left lower lip outside	RLLOUT	Right lower lip outside
LJMID	Left jaw middle	RJMID	Right jaw middle
LJOUT	Left jaw outside	RJOUT	Right jaw outside
CHIN	Chin marker		

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Placement of markers
for facial capture

RFHD   LFRH
MFRHD
RBMID   LBMID
RBCEN   LBCEN
RBOUT   LBOUT
NSBRI
RULID   LULID
REYEC   LEYEC
REOUT   LEOUT
REMID   LEMID
RCKBN
NSTIP
RUSNR   LUSNR   LCKBN
RLSNR   LLSNR
RJOUT   LJOUT
RULMID LULMID
RULOUT LULOUT
RMTHC   LMTHC
RLLOUT
RRLMID LLLMID LLLOUT
RJMID   LJMID
CHIN

In contrast to full body movement, facial movement seems relatively subtle and the grouping of markers for auto-labelling are focused around facial muscle groups instead of skeletal segments.

It may be helpful to note, the root for this facial capture uses two of the three forehead markers (MFRHD, LFRHD), the left and right eye corner markers (REYEC, LEYEC) and the bridge of the nose marker (NSBRI). The third forehead marker has not been grouped here specifically to create asymmetry in the root marker Autolabel segment. This asymmetry aids the system in recognizing and labelling the root. Please refer to Marker Files in the Reference section for details on creating marker files and Autolabel segments.

Performing the capture

Again this is the same as for full body capture but scaled down for size. You should set suitable reconstruction parameters for the small volume (these will differ from your full body capture sessions). The workflow is:

• Set reconstruction parameters

• Static capture and subject calibration

• Capture, reconstruct, auto-label, clean up and process

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Reconstruction parameters

Set the Reconstruction Parameters:

- Select Trial | Reconstruction Parameters

You may need to adjust reconstruction parameters for your particular set up but the following are a good starting point.

Suggested reconstruction parameters for facial capture

Max Acceleration	~5mm/s/s
Max Noise	~1
Intersection Limit	~2 mm
Residual Factor	~3
Predictor Radius	~5mm

You may also find it useful to create some Trial Types just for static and dynamic facial captures using these reconstruction parameters and your facial marker set. Creating Trial Types is described in The Essentials of Motion Capture.

Calibrate the subject

- Perform a static capture and reconstruct
- Attach a suitable marker set for your subject
- Manually label the trial
- Create the Auto-label Calibration
- Test the auto-label

Perform the capture

Perform your data capture in the normal way, reconstruct, auto-label and clean up the data.

Capturing hand motion

In capturing the motion of the hands the differences are again in camera setup and in the marker set used. Much of the technique, calibration and suitable reconstruction parameters are similar to facial capture.

Camera setup

Unlike facial capture the cameras may be setup all around the small region where the hands will be placed. The FlatCal can be used for the static capture portion of calibration. Don't forget to specify this option in the "Calibrate Cameras" dialog box.

Small volume capture
for hand motion
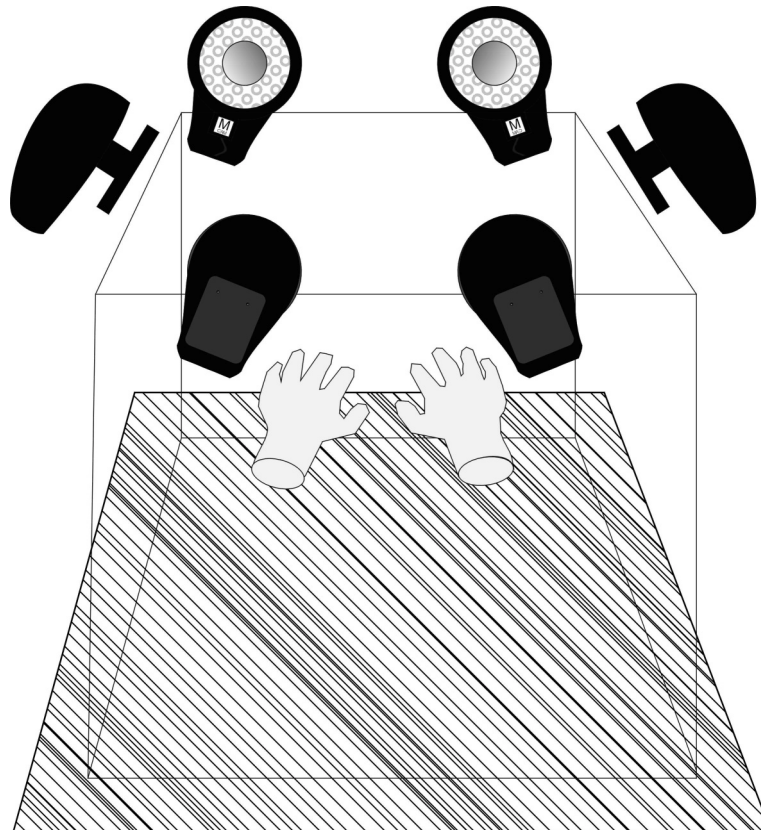
Marker set Complete Marker Set includes all definitions and links for the reconstructed hand. The table below just shows the labels and definitions of the markers used for the hand.
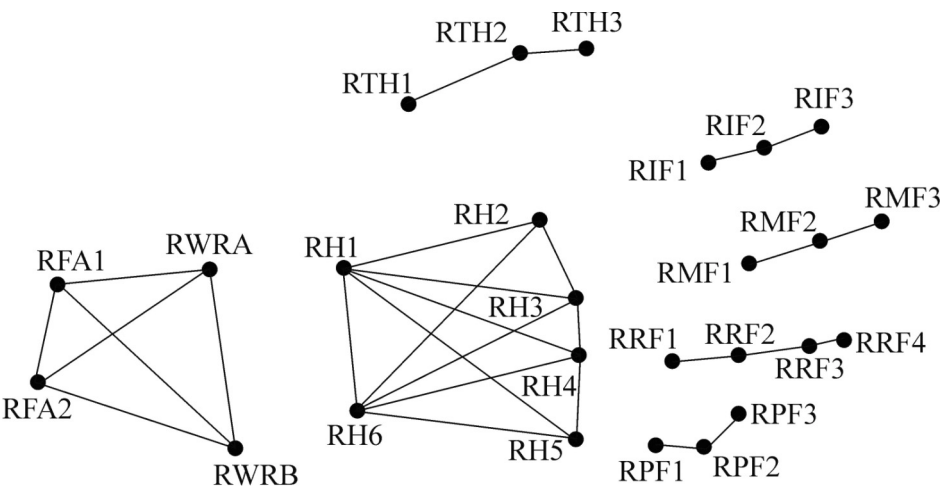
Example Hand
Marker Set

Marker	Definition	Marker	Definition
LFA1	Left fore arm 1	RFA1	Right fore arm 1
LWRA	Left wrist (thumb side)	RWRA	Right wrist (thumb side)
LWRB	Left wrist (little finger side)	RWRB	Right wrist (little finger side)
LFA2	Left fore arm 2	RFA2	Right fore arm 2
LH1	Left hand 1	RH1	Right hand 1
LH2	Left hand 2	RH2	Right hand 2
LH3	Left hand 3	RH3	Right hand 3
LH4	Left hand 4	RH4	Right hand 4
LH5	Left hand 5	RH5	Right hand 5
LH6	Left hand 6	RH6	Right hand 6

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Marker	Definition	Marker	Definition
LTH1	Left thumb 1	RTH1	Right thumb 1
LTH2	Left thumb 2	RTH2	Right thumb 2
LTH3	Left thumb 3	RTH3	Right thumb 3
LIF1	Left index finger 1	RIF1	Right index finger 1
LIF2	Left index finger 2	RIF2	Right index finger 2
LIF3	Left index finger 3	RIF3	Right index finger 3
LMF1	Left middle finger 1	RMF1	Right middle finger 1
LMF2	Left middle finger 2	RMF2	Right middle finger 2
LMF3	Left middle finger 3	RMF3	Right middle finger 3
LRF1	Left ring finger 1	RRF1	Right ring finger 1
LRF2	Left ring finger 2	RRF2	Right ring finger 2
LRF3	Left ring finger 3	RRF3	Right ring finger 3
LRF4	Left ring finger 4	RRF4	Right ring finger 4
LPF1	Left pinkie finger 1	RPF1	Right pinkie finger 1
LPF2	Left pinkie finger 2	RPF2	Right pinkie finger 2
LPF3	Left pinkie finger 3	RPF3	Right pinkie finger 3

Hand marker placement for the right hand
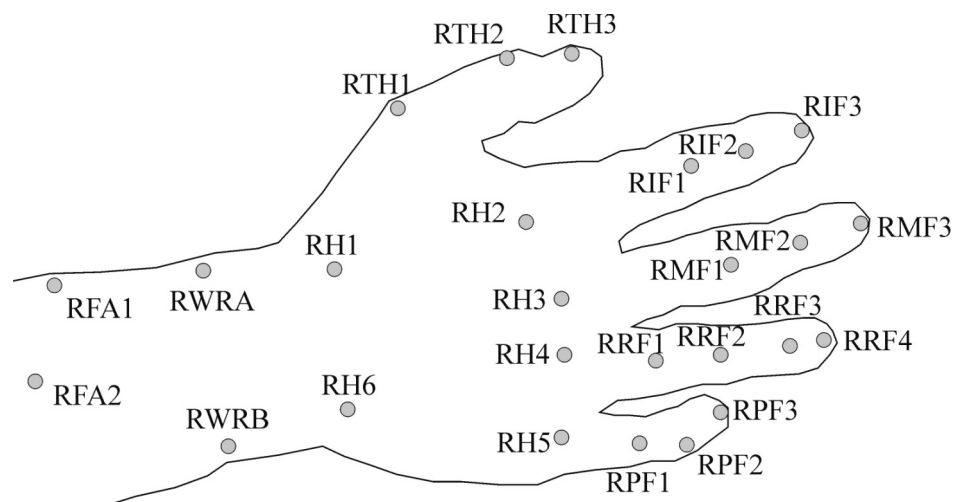
Hand markers (right hand) when reconstructed

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