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Title	**State of the Art on Gesture Data Format in Motion Capture systems**
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1 Introduction

The use of motion capture for motion analysis and synthesis has begun in the late 1970's and is nowadays wide spread. Motion capture is the recording of human body movement (or other movement) for immediate or delayed analysis and playback. The information captured can be as general as the simple position of the body in space or as complex as the deformations of the face and muscle masses. Motion capture for computer character animation involves the mapping of human motion onto the motion of a computer character. The mapping can be direct, such as human arm motion controlling a character's arm motion, or indirect, such as human hand and finger patterns controlling a character's skin colour or emotional state. The most current systems that capture the movement are optical or magnetic systems.
In order to communicate between a motion capture system and an application that uses those data (for character animation or any kind of data processing), or between two applications, many file formats have been created. This document draws an overview of the most current exchange file formats in motion capture.

2 BVA and BVH file format

2.1. General description

BVH means Biovision Hierarchical Data. This format is one of the most currently used today. At the basis, Biovision, a motion capture company, has developed it. The BVA format, also developed by Biovision is the BVH primal form. This format is mainly used for the animation of humanoid structures and gives a standardised definition of them. The format is largely and successfully spread in animation community certainly because of its simple specifications. However, some lack can be notice especially the definition of the skeleton in its rest position (basis pose), which seems to be incomplete and the lack of indication dedicated to the representation of the segments. BVA and BVH files are ASCII files.
In a BVA file, sample coming from each segment of the skeleton are stock in a more or less raw manner, without taking into account the structure of the animated form. For this reason Biovision has then developed the BVH format.
A BVH file is divided into two sections. The head section describes the structure (hierarchy, parent links) and the basis pose of the skeleton. The following section contains the data concerning the movement. The space, in this type of representation, is defined as a direct orthonormed system where the Y-axis is the vertical one. So, the segments of the skeleton are generally aligned following this axis in its rest position.

2.2. Example of a BVA file

```
Segment:   Hips
Frames:    2
Frame Time: 0.033333
XTRAN  YTRAN   ZTRAN  XROT    YROT    ZROT    XSCALE  YSCALE  ZSCALE
INCHES INCHES  INCHES DEGREES DEGREES DEGREES INCHES  INCHES  INCHES
 8.03   35.01   88.36  14.78  -164.35 -3.41    5.21    5.21    5.21
 7.81   35.10   86.47  12.94  -166.97 -3.78    5.21    5.21    5.21
Segment:   Chest
Frames:    2
Frame Time: 0.033333
XTRAN  YTRAN   ZTRAN  XROT    YROT    ZROT    XSCALE  YSCALE  ZSCALE
INCHES INCHES  INCHES DEGREES DEGREES DEGREES INCHES  INCHES  INCHES
```

```
 8.33    40.04   89.69  -27.24   175.94 -2.88    18.65   18.65   18.65
 8.15    40.16   87.63  -31.12   175.58 -4.08    18.65   18.65   18.65
Segment:   Neck
Frames:    2
Frame Time: 0.033333
XTRAN   YTRAN   ZTRAN   XROT    YROT    ZROT    XSCALE  YSCALE  ZSCALE
INCHES  INCHES  INCHES  DEGREES DEGREES DEGREES INCHES  INCHES  INCHES
 9.16    56.60   81.15  -69.21   159.37 -27.46   5.45    5.45    5.45
 9.28    56.09   78.00  -72.40   153.61 -33.72   5.45    5.45    5.45
Segment:   Head
Frames:    2
Frame Time: 0.033333
XTRAN   YTRAN   ZTRAN   XROT    YROT    ZROT    XSCALE  YSCALE  ZSCALE
INCHES  INCHES  INCHES  DEGREES DEGREES DEGREES INCHES  INCHES  INCHES
 10.05   58.32   76.05  -29.04  -178.51 -8.97    3.87    3.87    3.87
 10.20   57.46   72.80  -32.77  -179.46 -9.60    3.87    3.87    3.87
```

2.3. Descriptive section of the hierarchical structure in BVH file

The form to animate is defined in a recursive manner: each segment is defined by its own parameters and by its parentage with an other segment. The head section start with the key word HIERARCHY.
The structure is described in this section. The first element described is the root element indicated by the ROOT keyword. The structure is defined from this first element. The links between the different segments are modelled by a father relation or by a son relation. New hierarchies can be added to the file by adding new ROOT keywords.
Information associated with each nodes of the hierarchy is:

- The offset (OFFSET keyword) gives the position relatively to origin for the root segment and to the parent position for the other segments.
- A number that indicate the number of channels and the name of each channel follows the CHANNEL keyword. A channel carries a one-dimensional signal (position or orientation of the segment relatively to its parent). The root segment generally has six channels (three for the position and three for the rotations) while the other segments generally have 3 channels (the 3 rotations because the joins are fixed in relative translation). Nevertheless it is possible to add channels depending on the user wishes.
- JOINT has the same function than ROOT but is used for the declaration of a son segment. Every son segment of a given father has to be declared in the father structure.
- The “End Site” token closes a hierarchy and means that a segment is a leaf of it. The OFFSET of this ending segment is finally given.

2.4. The data section

The section that contains the movement data starts by the key word MOTION. The next two lines successively give the number of frame and the sampling period. The data of each frame are then disposed one after one on the same line. We change of line for each new frame.
Here is an example of a BVH file

2.5. Example of a BVH file

Start of the head

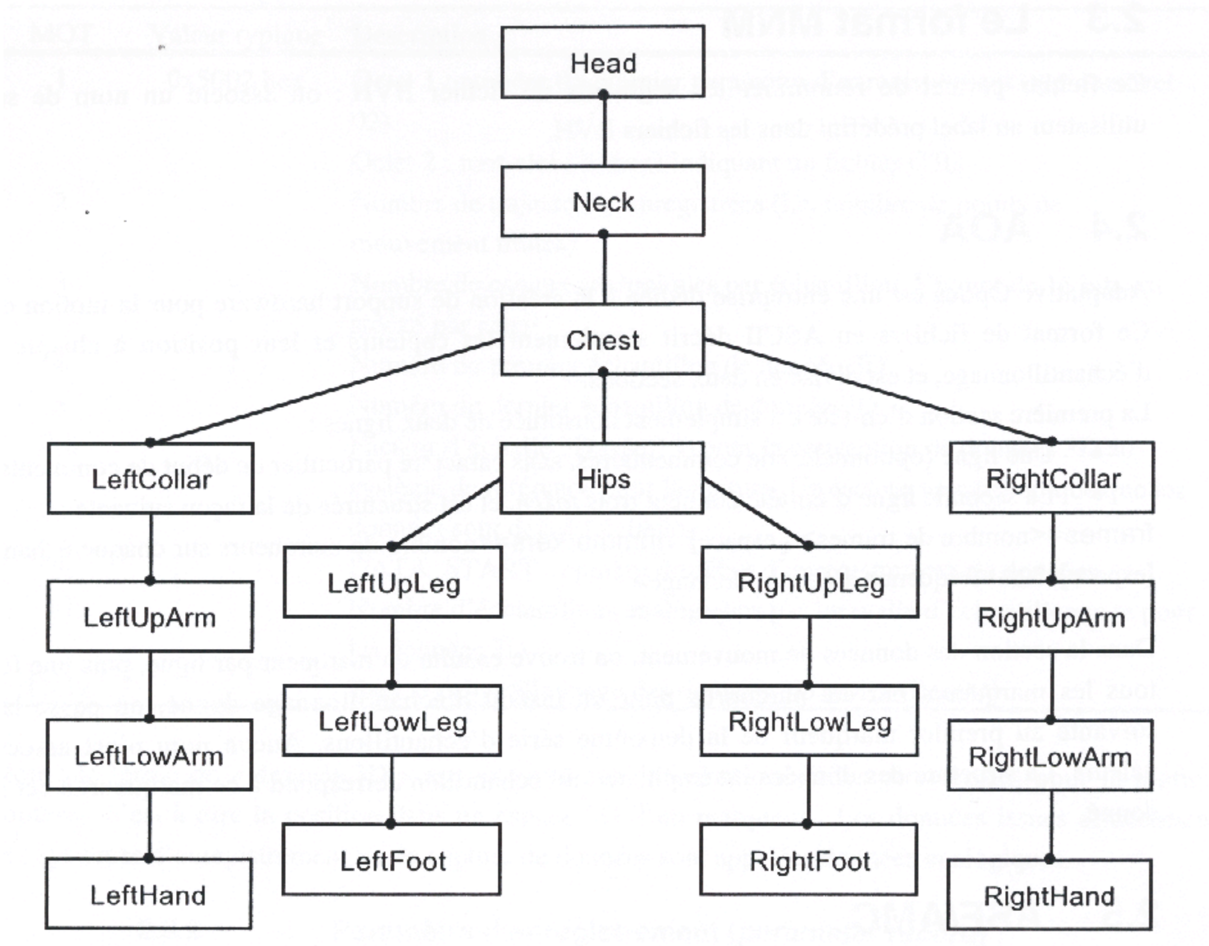
```
HIERARCHY
ROOT Hips
{
        OFFSET 0.00      0.00      0.00
        CHANNELS 6 Xposition Yposition Zposition Zrotation Xrotation Yrotation
        JOINT Chest
        {
                OFFSET 0.00      5.21      0.00
                CHANNELS 3 Zrotation Xrotation Yrotation
                JOINT Neck
                {
                        OFFSET 0.00      18.65      0.00
                        CHANNELS 3 Zrotation Xrotation Yrotation
                        JOINT Head
                        {
                                OFFSET 0.00      5.45      0.00
                                CHANNELS 3 Zrotation Xrotation Yrotation
                                End Site
                                {
                                        OFFSET 0.00      3.87      0.00
                                }
                        }
                }
                JOINT LeftCollar
                {
                        OFFSET 1.12      16.23      1.87
                        CHANNELS 3 Zrotation Xrotation Yrotation
                        JOINT LeftUpArm
                        {
                                OFFSET 5.54      0.00      0.00
                                CHANNELS 3 Zrotation Xrotation Yrotation
                                JOINT LeftLowArm
                                {
                                        OFFSET 0.00      -11.96      0.00
                                        CHANNELS 3 Zrotation Xrotation Yrotation
                                        JOINT LeftHand
                                        {
                                                OFFSET 0.00      -9.93      0.00
                                                CHANNELS 3 Zrotation Xrotation Yrotation
                                                End Site
                                                {
                                                        OFFSET 0.00      -7.00      0.00
                                                }
                                        }
                                }
                        }
                }

                JOINT RightCollar
                {
                                <structure identical to the left collar>
                }
        }
        JOINT LeftUpLeg
        {
                OFFSET 3.91      0.00      0.00
                CHANNELS 3 Zrotation Xrotation Yrotation
                JOINT LeftLowLeg
                {
                        OFFSET 0.00      -18.34      0.00
                        CHANNELS 3 Zrotation Xrotation Yrotation
                        JOINT LeftFoot
                        {
                                OFFSET 0.00      -17.37      0.00
                                CHANNELS 3 Zrotation Xrotation Yrotation
                                End Site
                                {
                                        OFFSET 0.00      -3.46      0.00
                                }
                        }
                }
        }
        JOINT RightUpLeg
        {
                        <structure identical to the LeftUpLeg>
        }
}
MOTION
Frames:    2
Frame Time: 0.033333
8.03  35.01  88.36  -3.41  14.78  -164.35  13.09  40.30  -24.60  7.88  43.80  0.00  -3.61  -41.45  5.82  10.08  0.00
7.81  35.10  86.47  -3.78  12.94  -166.97  12.64  42.57  -22.34  7.67  43.61  0.00  -4.23  -41.41  4.89  19.10  0.00
```

Start of the data section

channels of the root segment

channels of the first son segment

The structure defined in this example (which is the basis structure for the BVH format) can be schematised in be following way:



Many problems are inherent to the BVH format. The most remarkable is that orientation and position of each segment are not absolute. It can lead to a huge cost in term of processing to obtain the position and the orientation for a segment at the leaf of the hierarchy.
Another problem is the lack of calibration for data such as the scale with which the offsets are measured… It becomes very hard to treat several files for which the capture process was not the same (done in the same conditions).

3 ASK/SDL file format

The format is a variant of the BVH file format developed by Biovision. Le ASK file (Alias Skeleton) only contain information concerning the skeleton and, as a result, does not contain any information about the channels or the movement. The offset coordinates are absolute unlike the BVH in which they are relative.
The SDL file associated to the ASK file contain the data of the movement but it can contain many other information concerning the scene than the very samples of the movement.

4 MNM file format

This file format allows renaming the segments of a BVH file: a name defined by the user is associated to the predefined label in the BVH file.

5 AOA file format

5.1. General description

Adaptative Optics is a company dedicated to the creation of hardware support for the motion capture. This ASCII file format simply describes the captors and their position at each sampling period. It is divided into to sections.
The first section (the head section) contain two lines:

- A commentary line without any peculiar starting character.
- A line with three token : frames = <number of frames> [space] nLimmarkers = <number of marker on each sample> [space] hz = <sampling frequency>

Inside the data section, the XYZ positions are given. One line is equal to one marker and once a sample is over a new one starts. No name is associated with the values. Therefore the structure is implicit.

5.2. Example of an AOA file

```
AOA file written by LambSoft Pro Motion
frames = 2 nummarkers = 10 hz = 30
  131.1524   163.0935    71.6937
  124.6823    71.3264    76.5239
  121.2981   102.4109    75.0063
  149.2998   181.1166   132.8877
  134.7889   192.6069   116.5414
  122.5840   190.7085    89.0098
  149.5519   239.0187   104.2023
  131.1980   121.0528   101.0101
  160.2013    95.1255   134.9703
  137.7529    47.9096    96.5317
  131.2017   163.1528    71.7291
  124.6200    71.3926    76.5561
  121.2042   102.5331    75.0017
  149.3542   181.1748   132.9477
  134.8884   192.6407   116.6287
  122.3916   190.7327    88.9545
  149.5145   239.0789   104.2528
  131.3174   121.1239   101.0545
  160.1843    95.1614   135.0377
  137.7782    47.9176    96.5733
```

6 The ASF/AMC file format

6.1. General description

This format was developed by Acclaim, a video game company. Once entered in the public domain it has been used by Oxford Metrics (Vicon Motion Capture Systems).
The Acclaim format is composed of two different files, one for the skeleton and the other one for the movement. The separation between these two types has been done because the same

skeleton is often used for numerous distinct movements. The file containing the skeleton description in the ASF file (Acclaim Skeleton File) and the file containing the movement data is the AMC file (Acclaim Motion Capture data).

6.2. The ASF file

The starting point of the motion capture is the basis position of the skeleton. Each file has only one root segment, therefore only one structure. Each segment carries information useful for its geometric representation as well as information concerning the dynamic of the character. The same information than the other format on this type is present (id, name, length, rotation axes, degree of freedom…) but information about the interval of the possible movement for each rotation (from the basis position) is added.

6.3. Example of an ASF file

```
#
# Comment line
##
 #
:version 1.10
:name BioSkeleton
:units
   mass 1.0
   length 1.0
   angle deg
:documentation
   Example of an Acclaim skeleton
   To be used with "Walk.amc"
:root
   axis XYZ
   order TX TY TZ RZ RY RX
   position 0.0 0.0 0.0
   orientation 0.0 0.0 0.0
:bonedata
begin
   id 1
   name hips
   direction 0.000000 1.000000 0.000000
   length 0.000000
   axis 0.00000 0.00000 0.00000 XYZ
   dof rx ry rz
   limits (-180.0 180.0)
      (-180.0 180.0)
      (-180.0 180.0)
end
begin
   id 2
   name hips1
   direction 0.000000 1.000000 0.000000
   length  4.310000
   axis 0.000 0.000 0.000 XYZ
end

identical declaration for join 3 to join 24

:hierarchy
begin
   root hips
   hips hips1 hips2 hips3
   hips1 chest
   chest chest1 chest2 chest3
   chest1 neck
   neck head
   chest2 leftcollar
   leftcollar leftuparm
   leftuparm leftlowarm
   leftlowarm lefthand
   chest3 rightcollar
   rightcollar rightuparm
```

```
   rightuparm rightlowarm
   rightlowarm righthand
   hips2 leftupleg
   leftupleg leftlowleg
   leftlowleg leftfoot
   hips3 rightupleg
   rightupleg rightlowleg
   rightlowleg rightfoot
end
```

6.4. The AMC file format

This file contains the data concerning the movement of the skeleton. The samples are given one after one. A sample is presented on several lines (one for a segment and all of its degree of freedom).

6.5. Example of an AMC file associated with the ASF file above

```
# Space for comments
##
 #
:FULLY-SPECIFIED
:DEGREES
1
root -1.244205 36.710186 -1.148101 0.958161 4.190043 -18.282991
hips 0.000000 0.000000 0.000000
chest 15.511776 -2.804996 -0.725314
neck 48.559605 0.000000 0.014236
head -38.332661 1.462782 -1.753684
leftcollar 0.000000 15.958783 0.921166
leftuparm -10.319685 -15.040003 63.091194
leftlowarm -27.769176 -15.856658 8.187016
lefthand 2.601753 -0.217064 -5.543770
rightcollar 0.000000 -8.470076 2.895008
rightuparm 6.496142 9.551583 -57.854118
rightlowarm -26.983490 11.338276 -5.716377
righthand -6.387745 -1.258509 5.876069
leftupleg 23.412262 -5.325913 12.099395
leftlowleg -6.933442 -6.276054 -1.363996
leftfoot -1.877641 4.455667 -6.275022
rightupleg 20.698696 3.189690 -8.377244
rightlowleg 3.445840 -6.717122 2.046032
rightfoot -8.162314 0.687809 9.000264
2
root -0.227361 37.620358 1.672587 0.204373 -4.264866 -12.155879
hips 0.000000 0.000000 0.000000
chest 14.747641 2.858763 -1.345236
neck 44.651531 0.000000 -0.099206
head -38.546989 0.678145 -4.633668
leftcollar 0.000000 7.233337 -5.791124
leftuparm 9.928153 -50.015823 25.218475
leftlowarm -40.443512 -0.566324 0.482702
lefthand 6.011584 -0.216811 4.576208
rightcollar 0.000000 -1.936009 5.471129
rightuparm 3.926107 32.418419 -26.396805
rightlowarm -43.958717 3.548671 -3.415734
righthand -4.901258 -0.112565 0.681468
leftupleg 11.932759 0.406248 -1.921313
leftlowleg 13.698170 5.503362 2.643481
leftfoot -16.237123 2.755839 -7.182952
rightupleg 13.767217 0.331739 -1.353482
rightlowleg 22.576195 -7.388037 -3.537788
rightfoot -19.946142 2.525145 8.668705
```

7 The BRD file format

7.1. General Description

The format is uniquely used by the motion capture system Ascension Technology "Flock of Birds" developed by LambSoft. It allowed stocking the data coming from a magnetic system. The first number is the sample number; the first sample in the file is sample 0.The second number is the marker number. The first marker is marker 0. The next token is "P", this indicates that the next three values on the line are position values for the marker.

After the position values the token "Q" appears. This indicates that the next 4 values are quaternions. The last two values on each line are optional. These are the time stamp values for each marker. These numbers are identical to the values returned by the Unix system call gettimeofday() (The system call "_ftime()" under Windows does a similar thing except it returns milliseconds). The first number is in seconds; the second number is in microseconds. It is possible for the time stamp values of one marker to be different from the time stamp values for a second marker in the same sample.

7.2. Example of a BRD file

```
0   0 P     55.9477     32.7718     -5.2410   Q      0.7569      0.3548     -0.4984      0.2299 0
000000
0   1 P     52.5374     26.9382      9.3167   Q     -0.6740     -0.4260     -0.5366      0.2762 0
000000
1 14 P    43.0703    48.2499   -39.1160  Q     0.8875    -0.4361     0.1333     0.0660 0 16666
1 15 P    49.5336    30.1453     4.2165  Q    -0.7198    -0.3039    -0.5944     0.1904 0 16666
2 0  P    57.7803    34.8796    -4.7169  Q     0.7569     0.3548    -0.4984     0.2299 0 33332
2 1  P    53.8193    29.2250     9.4211  Q    -0.6740    -0.4260    -0.5366     0.2762 0 33332
```

8 The HTR and GTR file formats

8.1. General description

The HTR format (Hierarchical Translation Rotation) has been developed as a native format for the skeleton of the Motion Analysis software. It has been created as an alternative to the BVH format to make up for its main drawbacks. A HTR variant exist which is called the GTR format (Global Translation Rotation) and is the same format less the structural information. This format has known few uses.
The HTR format is divided into 4 sections: head, hierarchy and name of the segments, basis position and movement data.
The head section marked by the [HEADER] token contains many data lines including information carried by the BVH format plus:

- The number of segment
- The disposition of the eulerian angles
- The calibration unities
- The rotation unities
- The axes following which the gravity is exerted
- The axis flowing which the segments of the skeleton are aligned
- The global scale factor

One of the interests of this format is that the hierarchy [SegmentNames&hierarchy] is given separately of the characteristic of each segment [BasePosition] what simplifies the reading.

Moreover, the movement data are not indicated by a key word but by the name of the concerned segment.

8.2. Example of a HTR file

```
[Header]                      #      Header keywords are followed by a single value
FileType       htr            # single word string
DataType       HTRS           # Hierarchical translations followed by rotations and Scale
FileVersion    1              # integer
NumSegments    18             # integer
NumFrames      2              # integer
DataFrameRate  30             # integer
EulerRotationOrder     ZYX    # one word string
CalibrationUnits       mm     # one word string
RotationUnits  Degrees        # one word string
GlobalAxisofGravity    Y      # character, X or Y or Z
BoneLengthAxis Y
[SegmentNames&Hierarchy]
#CHILD  PARENT
LOWERTORSO     GLOBAL
UPPERTORSO     LOWERTORSO
NECK           UPPERTORSO
HEAD           NECK
RSHOULDER      UPPERTORSO
RUPPERARM      RSHOULDER
RLOWARM RUPPERARM
RHAND          RLOWARM
LSHOULDER      UPPERTORSO
LUPPERARM      LSHOULDER
LLOWARM LUPPERARM
LHAND          LLOWARM
RTHIGH         LOWERTORSO
RLOWLEG RTHIGH
RFOOT          RLOWLEG
LTHIGH         LOWERTORSO
LLOWLEG LTHIGH
LFOOT          LLOWLEG
[BasePosition]
#SegmentName   Tx, Ty, Tz, Rx, Ry, Rz, BoneLength
LOWERTORSO     0.00      0.00      0.00      0.00      0.00      0.00    200.00
UPPERTORSO     0.00    200.00      0.00     -1.38      0.00      0.35    286.95
NECK           0.00    286.95      0.00      2.90     -0.08      3.20    101.66
HEAD           0.00    101.66      0.00     -1.53     -0.09     -3.55    174.00
RSHOULDER      -10.21    252.02     -0.84      1.85     -1.36     98.76    137.50
RUPPERARM      0.00    137.50      0.00      3.22      0.48     13.42    279.07
RLOWARM 0.00    279.07      0.00     -2.42     -1.40    -15.48    222.64
RHAND          0.00    222.64      0.00     -2.59     -0.32     -6.98     90.00
LSHOULDER      9.79    251.90     -0.84     -5.30      1.36    -98.63    132.79
LUPPERARM      0.00    132.79      0.00     13.46      1.21    -13.67    295.17
LLOWARM 0.00    295.17      0.00     -6.60      2.65     18.04    222.81
LHAND          0.00    222.81      0.00     -1.49      0.10      3.78     90.00
RTHIGH         -96.49    -31.41     26.89     -6.15      0.00    176.17    379.17
RLOWLEG 0.00    379.17      0.00      4.86     -0.14      1.34    394.60
RFOOT          0.00    394.60      0.00     71.40     -0.06      2.48    160.00
LTHIGH         107.90    -45.36      2.84     -4.81      0.00   -178.69    362.85
LLOWLEG 0.00    362.85      0.00      5.06     -0.03      0.30    398.36
LFOOT          0.00    398.36      0.00     69.87     -0.01     -1.61    160.00
[LOWERTORSO]
       1    263.72    816.20  -2874.77     18.03     -7.70    -10.34      1.00
       2    264.42    812.41  -2740.34     19.81    -13.46    -11.93      1.00
[UPPERTORSO]
       1      0.00      0.00      0.00      8.33    -17.38      8.59      1.00
       2      0.00      0.00      0.00      8.71     -6.14      8.64      1.00

Same declaration for marker 3 to 18

[EndOfFile]
```

9 The TRC file format

9.1. General description

The TRC file format is another file format from Motion Analysis. It contains not only the raw data from the full body motion capture system they developed but also the output data coming from their face tracker. The output data of the face tracker are 2D data. So to allow merging 2D and 3D data the Z-coordinate value is set to 0 in the 2D case. The positions are given in absolute coordinate. Each maker has a name and is only referenced by its in the format.

9.2. Example of a TCR file

```
PathFileType   3       (X/Y/Z) Example.trc
DataRate  CameraRate NumFrames  NumMarkers  Units
30 30 2 31 mm
Frame#  Time    bridge  clowlip cuplip  lbrow1  lbrow2  lbrow3  lhead   llaugh  llcheek llowjaw
        llowlip lmouth  lsocket lucheek lupjaw  luplip  nose    rbrow1  rbrow2  rbrow3  rhead
        rlaugh  rlcheek rlowjaw rlowlip rmouth  rsocket rucheek rupjaw  ruplip  tophead
 X1 Y1 Z1  X2 Y2 Z2  X3 Y3 Z3  X4 Y4 Z4  X5 Y5 Z5  X6 Y6 Z6  X7 Y7 Z7  X8 Y8 Z8  X9 Y9 Z9  X10
Y10 Z10  X11 Y11 Z11  X12 Y12 Z12  X13 Y13 Z13  X14 Y14 Z14  X15 Y15 Z15  X16 Y16 Z16  X17 Y17
Z17  X18 Y18 Z18  X19 Y19 Z19  X20 Y20 Z20  X21 Y21 Z21  X22 Y22 Z22  X23 Y23 Z23  X24 Y24 Z24
X25 Y25 Z25  X26 Y26 Z26  X27 Y27 Z27  X28 Y28 Z28  X29 Y29 Z29  X30 Y30 Z30  X31 Y31 Z31

1       0.033333 131.1524 163.0935   71.6937 124.6823   71.3264   76.5239 121.2981 102.4109
75.0063 149.2998 181.1166 132.8877 134.7889 192.6069 116.5414 122.5840 190.7085   89.0098
149.5519 239.0187 104.2023 131.1980 121.0528 101.0101 160.2013   95.1255 134.9703 137.7529
47.9096   96.5317 128.6441   74.4367   94.9948 137.1264   85.1827 106.0074 139.9505 145.9818
111.2604 150.6080 130.9824 134.3215 204.5324   77.3407 144.1150 125.4540   99.9015   93.0702
111.0689 124.5950   72.5558 158.4736 184.0863   17.1546 139.9273 193.7812   32.1008 125.5029
190.9568   57.3250 148.4869 240.4077   55.7514 130.7053 120.1502   48.0696 161.9311   89.6753
21.3688 140.7662   47.0322   54.0298 129.6595   71.2903   57.0318 137.0737   83.6635   44.6577
143.2580 143.2805   37.2008 157.8477 128.4386   17.5263 200.7793   81.9230    9.8090 125.3299
99.0036  56.1530 131.1743 209.7377  71.5724
2       0.066667 131.2017 163.1528   71.7291 124.6200   71.3926   76.5561 121.2042 102.5331
75.0017 149.3542 181.1748 132.9477 134.8884 192.6407 116.6287 122.3916 190.7327   88.9545
149.5145 239.0789 104.2528 131.3174 121.1239 101.0545 160.1843   95.1614 135.0377 137.7782
47.9176   96.5733 128.6558   74.4725   95.0168 136.8899   85.2499 105.9204 139.9980 146.0101
111.2198 150.5929 131.0192 134.3598 204.5233   77.3376 144.1167 125.4860 100.0971   93.2541
111.0917 124.6370   72.5714 158.4663 184.0818   17.2422 139.9324 193.8225   32.1557 125.5762
190.9936   57.3842 148.5566 240.4861   55.8336 130.7453 120.2003   48.1136 161.9240   89.7217
21.3911 140.4146   47.1341   53.9443 129.6737   71.3267   57.0585 137.0995   83.7806   44.6918
143.3501 143.4694   37.4252 157.7448 128.5400   17.5307 200.9130   81.9462    9.9033 125.3576
99.0523  56.1991 131.2355 209.8056  71.6000
```

10 The CSM file format

10.1. General description

The CSM format is an optical tracking format that is used by Character Studio (an animation and skinning plug-in for 3D Studio MAX) for importing marker data. For CSM files to be compatible with Character Studio, they must use names that match the Character Studio setup and they must have an appropriate number of markers in specific locations on the actor. The CSM format itself is capable of holding any kind of marker data, but by being in the CSM (Character Studio Marker) format it is assumed that it also adheres to the name and marker configuration required by Character Studio. The motion data are given in the implicit order of the declaration of the joints.

9.2. Example of a CSM file

```
$comments
This is a Character Studio 2.0 CSM File
```

```
$firstframe 1

$lastframe 3

$spinelinks 3

$rate 60

$order
C7 CLAV LANK LBHD LBWT LELB LFHD LFIN LFWT LKNE LSHO LTOE LUPA LWRA LWRB RANK RBHD RBWT RELB
RFHD RFIN RFWT RKNE RSHO RTHI RTOE RWRA RWRB STRN T10

$points
1       980.6   -2365.8 1541.3  1030.6  -2239.9 1492.1  967.3   -2427.5 181.8   936.2   -2330.1
        1672.9  939.4   -2359.1 1109.3  782.9   -2263.3 1175.7  959.0   -2196.9 1753.8  762.3   -
2135.1  862.6   949.3   -2187.2 1082.1  934.2   -2343.2 583.1   870.4   -2246.7 1525.4  1031.7  -
2339.7  83.1    814.6   -2218.7 1318.8  799.4   -2132.3 993.7   729.2   -2230.2 966.5   1110.1  -
2060.1  197.3   1066.8  -2351.6 1670.5  1114.0  -2391.4 1116.4  1290.5  -2574.6 1396.5  1105.7  -
2231.2  1740.1  1217.5  -2369.8 1149.5  1159.8  -2233.6 1093.8  1138.8  -2119.2 605.9   1136.6  -
2342.8  1564.9  1081.3  -2126.7 775.0   1065.2  -1944.5 112.2   1276.8  -2398.1 1271.2  1294.0  -
2490.1  1183.6  1044.2  -2199.9 1395.9  988.1   -2404.3 1417.4
2       979.8   -2358.9 1540.1  1029.4  -2232.4 1489.5  966.5   -2426.7 181.8   936.2   -2322.0
        1671.1  940.7   -2351.6 1107.3  783.9   -2249.8 1173.7  959.4   -2189.0 1752.6  767.9   -
2113.2  863.4   948.9   -2177.9 1080.7  934.4   -2338.9 583.3   871.7   -2242.9 1523.4  1031.7  -
2339.5  82.9    814.6   -2207.6 1317.8  803.3   -2113.8 994.5   732.4   -2209.8 964.1   1108.3  -
2039.1  197.5   1067.2  -2343.2 1669.3  1115.0  -2382.1 1115.0  1292.6  -2563.1 1400.3  1106.5  -
2223.7  1738.5  1212.0  -2367.2 1155.5  1162.2  -2222.1 1093.8  1140.2  -2119.4 601.9   1135.4  -
2334.3  1563.9  1079.9  -2109.1 774.4   1064.5  -1921.3 116.0   1278.4  -2396.2 1273.8  1284.5  -
2483.4  1186.2  1043.6  -2192.5 1394.0  987.5   -2397.7 1415.2
```

11 The National Institute of Health C3D file format

11.1. General description

Many of the motion capture companies are often linked to the biomechanics research. The systems are then used to assess the performances of an athlete or the needs of a physically handicapped person. The needs of researchers, often supplied by more than one society, lead to the definition of a common format, the C3D format. This format has been built following this philosophy, so it has tried to carry the most complete amount of information useful for the biomechanics research. The features below was considered as necessities:

- The possibility to stock analogical data (i.e. directly coming from the measure instrument) and three-dimensional data (obtained by the information processing).
- The possibility to stock information on the material, which have been used (position marker, force captors), on the recording process (sampling rate, date, type of examination…), on the subject itself (name, age, physical parameters…).
- The possibility to add new data to the ones already recorded.
- The file was a binary file unlike most of motion capture file format, which often are ASCII files.

Therefore, the C3D format is a standard, which can be put aside because of its ability to stock a large amount of data types. This format is used by Adtech, ANZ, BTIS, C-Motion, Charnwood, Innovision Systems, Kaydera Inc., Lambsoft, Motion Analysis Corporation, Motion Lab Systems, National Institutes of Health, Oxford Metrics, Peak Performance Technologies, Qualisys, RUN technologies, Vicon Motion Systems…

The C3D format contains to principal data type: position data (3D coordinates after processing) and what the C3D calls analogical data, which actually are the raw data. The 3D coordinates are stocked into successive samples of XYZ coordinates with information on accuracy and specification of the captors. Each sample of a numerical data coming from a processing is linked to its source. So it becomes very easy to correct some numerical values or to access to the source data.

11.2. The header section

The header of the file is typically a 256 words of 2 bytes structure:

Byte	Typical value	Description
1	0x5002 hex	Byte 1 : number of the first recording parameter (typically 02) Byte 2 : keyword (50 hex) indicating a
2	-	Number of points recorded
3	-	Number of analogical chanels by sample.
4	1	Number of the first sample
5	-	Number of the last sample
7-8	-	Scale factor (a negative factor means no scale)
9	-	DATA_STAKT : number indicating the start of the recording
10	-	Number of analogical sample in a sampling interval for the 3D data
11-12	-	Sampling rate for the 3D data

11.3. Parameter record

The location of the first parameter record is given inside the header. The first 4 bytes of the parameter record contain the following header:

Byte	Typical value	Description
1	0x00 hex	parameter file indicator
2	0x00 hex	parameter file indicator
3	-	Number of parameter record that follow
		83 + processor type
4	85	type 1 - PC DOS
		type 2 = DEC (VAX, PDP-11)
		type 3 = MIPS (SGI, SUN)

The parameters are stock just after the header. They are organized into groups, each parameter belong to only on group. Each parameter and each group are defined by the same header format.
18 events can also be defined in a C3D file. They are instances used to define, for instance, the beginning or the end of a ground contact. The event units can content one to four labels, its execution moment relatively to the first sample, etc.

11.4. Recording of the data

Then follow the parameters themselves. They can appear inside the file whatever the order can be. The order just has to follow the one defined by the headers.

The 3D data and the analogical data are written in the file as sequential fields:

Analogical data for the field number 1
Analogical data for the field number 2
3D data for the field number 2
Analogical data for the field number N
3D data for the field number N

11.5. 3D position data format

- Integer data:

The data are stored in 4 words, the X, Y and Z coordinates in the first 3 words. The fourth word contains information on the captor used for the measure and on the measure error after interpolation.

- Floating point data:

The data are also stored in 4 words, which are dedicated to the same things than in the integer case.

12 A standardisation of the humanoid structures: the MPEG-4 standard

The amount of proposed format, the needs of the users, the future development associated with the object-oriented way of coding in the multimedia community lead to the definition of a new file standard for the following application:

- Digital television
- Interactive graphics applications (synthetic content)
- Interactive multimedia (World Wide Web, distribution of and access to content)

Inside this standard, a common structure for modelling the human skeleton and animating it has been proposed.
The data transmission is made in two steps:

- Humanoid structure initialisation before its animation. The data transmitted here will remain unchanged during the running of the application: structure of the skeleton, information on the surface texture, etc. The skeleton structure is defined as follow:
    - 6 degrees of freedom for the whole animated form
    - 62 degrees of freedom for the own movement of each skeleton.
    - The hand structure is defined apart and has 25 degrees of freedom. This is an optional structure, which can be omitted for low data rate transmission.

  The skeleton is defined with 59 segments or 29 segments without the hands.
- Update of the structure during the animation.

Many optimisations are possible through this format like the reduction of the number of byte used for each degree of freedom, the maximum being 4 bytes. Priority rules for data transmission have been also proposed. In this case the most important parts of the body should be actualized in priority. So, the priority order proposed is (from the most important to the less important):

- The global position and orientation of the skeleton

- The orientation angle having a great visual importance for the animation: shoulders, knee, elbow, leg, and some peculiar joins of the hand.
- The other values

13 Conclusion

Most of the file formats presented are largely used in today motion capture based applications. For instance, the most popular animation tools (3DS Max, Maya, Lightwave…) all support the importation of BVH files. The case is the same for C3D file, which is largely a standard in biomechanics research. Some files are more oriented for one system like the CSM file of Character Studio.

The main limitations for real time uses is that most of the available formats presented her are ASCII formats (except C3D file format). It can be a limitation for applications that need to run in real-time and that need to consume data, which is stocked in a hard drive. If we look at the case of multimedia for instance, sound or movie are coded into binary files what allows the reader software a fast access to the data.

In addition, most of those file formats are dependant of the application:

- The C3D is really biomechanical data centred. The presence of analogical data (raw data in C3D language), the link with the 3D data, information about captors, 3D orientation (what do we do with 2D or 1D data?) , are features that can't really be considered as generic. Nevertheless this is the only binary format, it is widely spread in biomechanical research community, and it is also supplied by the most known motion capture systems. Kaydera's FILMBOX gesture editor also allow import/export of C3D files what link C3D file with the Computer Graphics community in a certain sens. Moreover it is constructed to be flexible (ability to add new data structure) and very well documented (the web site is really well shaped and very accurate).
- BVH, HTR, ASF/AMC, MNM files are very skeleton dependant what make their use very oriented to character animation.
- AOA is quite less oriented but only considered 3D coordinate.
- TCR could allow taking into account data of different dimensionalities but is sadly an ASCII file.
- BRD is oriented by the magnetic technology of Ascencion Technology Corporation.
- CSM is dedicated to the Character Studio software

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