Modeling and Simulation of Synchronized Multi-modal Sensory data on Muscle Activity

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[Abstract] We visualized an anatomically precise muscle-skeleton geometric model consisting of 80 surface muscles. Using synchronized multi-modal sensory data, i.e., motion capture data and electromyography (EMG) data collected from activities of a ball-throwing movement, we compiled several 3D CG animations for scientific visualization, in which the time-series geometric modeling changes of body movement show physical movements at the time of the ball-throwing and specific muscle color changes represent the EMG changes along the time series. From the viewpoint of cognitive science, we evaluated and selected a proper animation suitable for a dynamic visual perceptive capability to understand multi-modal information.

[Keywords] muscle-skeleton model, motion capture, electromyography, 3 dimensional computer graphics animation, scientific visualization

1 Introduction

In these days, there are many occasions for us being able to see moving skeletons either on popular science TV programs or SFX movies. To the public, these are perceived as a wonder. However, specialists such as medical professionals and sport science researchers would not consider these moving skeletons seriously. We, therefore, tried to create an anatomically precise muscle-skeleton geometric model to exhibit human movements and various muscle activities simultaneously.

Editing 3D CG animations based on the motion capture system has been well explored. However, when any animations containing multi-modal information such as movements and muscle activities are concerned, it becomes difficult for a person to perceive all significant events in a time-series development so that scientific visualizations may be more sophisticated from the standpoint of cognitive science.

2 Creating a mucle-skeleton model

Our approaches are as follows:

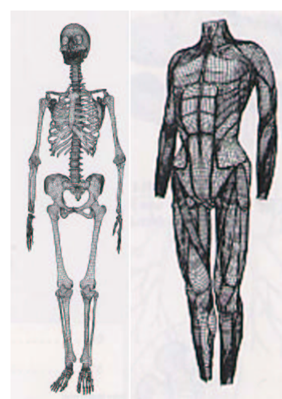

Figure 1: Viewpoint's VP2129 and VP20078

1. A human ' s skeleton consists of more than 250 bones as well as muscles attaching thereto, so that it is unproductive efforts to produce it from its initial state even with using computer graphic tools. Thus, we picked up some commercially available tool-products relating to bones and muscles, such as Viewpoint (TM) catalogue number VP2129 (skeleton female; 142,944 polygons) and VP20078 (surface muscles 65,792 polygons). These two products had nothing in common between them so that it was required to modify them or rescale their original ploygons to produce our desired shapes and therefore we

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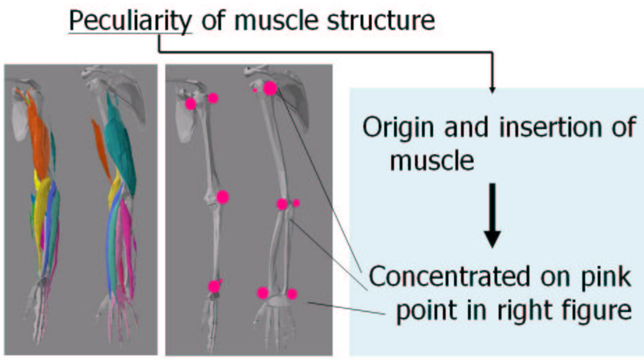

Figure 2: the origin and the insertion points

had to create some necessary parts from scratch.

2. Muscles should be positioned properly to corresponding bones respectively. We applied the anatomical understanding of "peculiarity of muscle structure": a muscle attaches to a specific location of a corresponding bone at the origin point and the insertion point.

3. The shape of a muscle should be formed exactly as much as possible in a cluster of 3-dimensional polygons. At the present time, detailed information as for the thickness of specific muscles are not available so that we leave the thickness matter for a future study.

4. Sport science specialists may provide necessary anatomical information [1][2][3]. So people engaging in 3D CG creators are able to utilize these know-how and manipulate the geometry models interactively (we used Lightwave 3D CG software.). Conceiving these various factors, we reached the present muscle-skeleton model consisting of 80 surface muscles.

The muscles from upper limb to lower limb via trunk are as follows :

- the upper limb
  extensor capri radialis breris, flexor capri ulnaris, biceps brachii, triceps brachii, brachialis, pronator teres, corac brachialis, palmaris longus, flexor capri radialis, brachio radials, extensor capri ulnaris,extersor digitiminimi, extersor digitorum
- the trunk
  external oblique abdominal, levator scapular, laissimus dorsi, teres minor, Teres major, internal oblique abdominal, transverses abdominal, infrasinatus, omohy, recbdom, stemast, trazins, deltoid, Pecajor major, serrantus anterior
- the lower limb
  bifrusl bocepsfemoris, semmemb semimem branosus,semtend, glutmay,gludmed,iliacus,psoasm,rectfem,vmed,vlat,vint, hirome, gast, tibianta, perlong, pertent, tenclat, peconeus, addgus, addlong, extdong, grailis, sertor

Figure 3: the anatomically precise model

3 Multi-modal sensory measurement

3.1 Motion capture

A ball-throwing movement by a collegiate baseball pitcher was captured at 200 Hz using six high-speed video cameras (HAS-200R, DITECT). Twenty-six reflective markers were attached to the pitcher and digitized them later. Their time-position data in three dimensions (x, y, and z coordinates in the unit of millimeter) were obtained by the Direct Linear Transformation (DLT) method. Using these data, Euler angles (-180 degrees to +180 degrees) of each body segment in terms of its parent coordinate system were calculated [4].

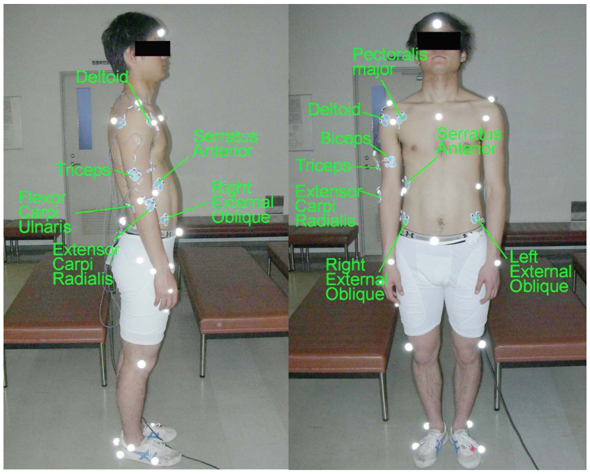

Figure 4: reflective markers for motion capture and EMG measurement pads

1	Time	ECR	FCU	BB	TB	Deltoid	PM	SA	rightEO	leftEO
2	-833.333	1	1	0	0	0	0	0	0	1
3	-816.667	1	1	0	0	0	0	0	0	1
4	-800	1	1	0	0	0	0	0	0	1
5	-783.333	1	1	0	0	0	0	0	0	1
6	-766.667	1	1	0	0	0	0	0	0	1
7	-750	1	1	0	0	0	0	0	0	1
8	-733.333	1	1	0	0	0	0	0	0	2
9	-716.667	1	1	0	0	0	0	0	0	2
10	-700	1	1	0	0	0	0	0	0	2
11	-683.333	1	1	0	0	1	0	0	0	2
12	-666.667	1	1	0	0	1	0	0	0	2
13	-650	1	1	0	0	1	0	0	1	2
14	-633.333	1	1	0	0	1	0	0	1	3
15	-616.667	1	1	0	0	1	0	0	0	2
16	-600	1	1	0	0	1	0	0	0	2
17	-583.333	1	0	0	0	1	0	0	0	2
18	-566.667	1	0	0	0	1	0	0	0	2
19	-550	1	0	0	0	1	0	0	1	2
20	-533.333	1	0	1	0	1	0	0	1	3
21	-516.667	1	0	1	0	1	0	0	1	4
22	-500	1	0	1	0	1	0	0	2	4
23	-483.333	1	0	1	0	1	0	0	2	4
24	-466.667	1	0	1	0	1	0	0	2	3
25	-450	1	0	1	0	1	0	0	1	3
26	-433.333	1	0	1	0	1	0	0	1	3
27	-416.667	1	0	1	0	1	0	0	1	2
28	-400	1	0	1	0	1	0	0	1	2
29	-383.333	1	0	1	0	1	0	0	1	2
30	-366.667	1	0	1	0	0	0	0	0	2
31	-350	1	0	1	0	0	0	0	0	3
32	-333.333	2	0	1	0	0	0	0	0	3

Figure 5: "EXCEL" image of 5 levels expression (partially)

Table 1: muscle activity levels

level	ratio	color gradation
0	0.0 - 0.5	thinnest
1	0.5 - 1.5	thinner
2	1.5 - 2.5	middle
3	2.5 - 3.5	thicker
4	3.5 - 4.0	thickest

3.2 Electromyography

The muscle activities of 9 muscles were recorded in mV at 1000 Hz by the electromyograph (EMG-035, Harada Hyper Precision) and bipolar Ag-AgCl surface electrodes (F-150S, NIHON KODEN). The value in mV was divided by the value of surface electrodes, when muscles contract at maximum: that is a ratio. Each muscle activity is graded by 5 levels. The each level is displayed in a shade of color in the animation.

The abbreviation in Figure 5 stand for as follows;
ECR : extensor capri radialis breris
FCU : flexor capri ulnaris
BB : biceps brachii
TB : triceps brachii
deltoid : deltoid PM : pectoralis major
SA : serrantus anterior
rightEO : extensor pollicis brevisn
left EO : extensor pollicis longus

3.3 Synchronized data acquition

Synchronization of the video and the EMG signal became possible by means of an electronic pulse which makes a mark at the margin of the picture and the EMG signal simultaneously.

	Time	Rarm1		
0	-400.00	19.22	347.45	67.18
1	-366.67	13.66	346.25	58.28
2	-333.33	9.53	344.33	52.04
3	-300.00	4.88	342.91	47.57
4	-266.67	359.96	341.63	43.86
5	-233.33	358.06	339.79	39.07
6	-200.00	357.99	341.95	31.06
7	-166.67	359.45	345.98	13.82
8	-133.33	1.82	347.53	344.86
9	-100.00	360.00	351.02	307.89
10	-66.67	351.98	359.38	280.24
11	-33.33	351.60	10.03	283.48
12	0.00	355.98	10.38	318.08
13	33.33	355.82	14.73	78.99
14	66.67	17.96	38.93	74.50

Figure 6: "EXCEL" image of 14 keyframes of motion captured data (partially)

4 Simulation by 3D CG

4.1 Conventional 3D CG animation

At present, CG creators use one of the four major CG tools. They are "SoftImage", "Maya", "3D Max", and "Lightwave". Whatever tools are used, the task is carried out interactively not by doing a batch mode work. But they only deal with geometry model's coordination changes (i.e. geometry data) without changing model colors (i.e. attribute data) throughout the demonstration of an animation process.

For the purpose of this paper, it was necessary for us to manipulate the attribute data to exhibit individual muscle activities throughout the displaying time. Among four major CG tools, we selected "Lightwave", because it provided an adequate interface ("an envelop file") for users, with which we could provide some pre-processed data file to "Lightwave" , and then the inner program of "Lightwave" were able to be created in the animation file..

4.2 Manipulating the Attribute Data

The original multi-modal sensory data i.e., a ball-throwing motion lasts about 1 second in time. We allocate the entire data into 14 time slices so that we can create 14 keyframe data for CG animation. In general, this procedure from the reviced and preprocessed motion capture data in the "aquarius format" can be accepted by the major 3D CG animation software such as "Lightwave". In the same manner, we wish to handle the EMG data. The five level data for nine muscles along the time-series are reculculated able to convert into the "envelop file" of "Lighwave" which is responsible to handle the attribute data.

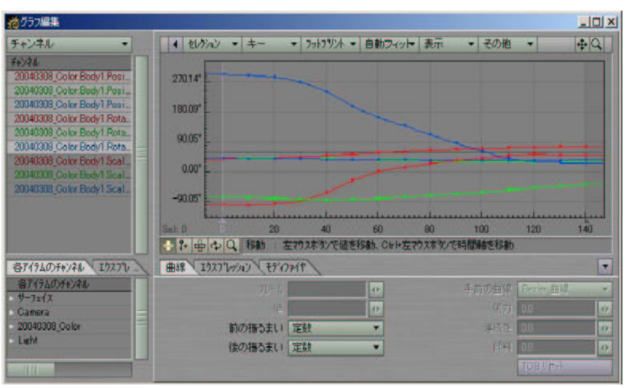

Figure 7: Original envelop file graph in Lightwave

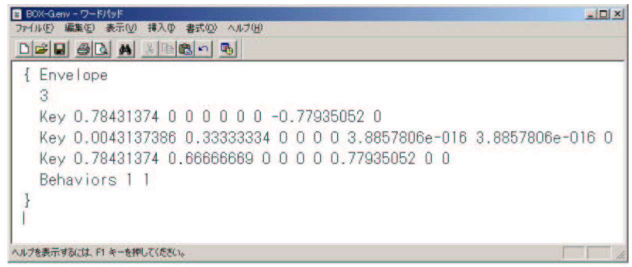

Figure 8: "EXCEL" image of preprocessed text file format envelop file

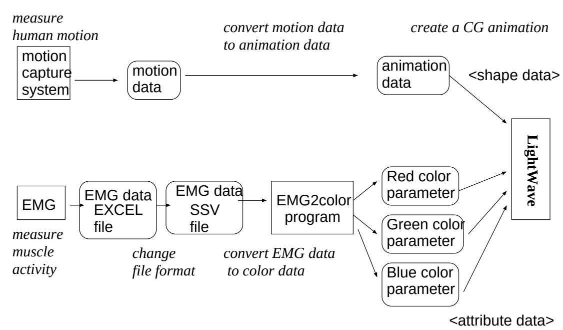

Figure 9: Data flow

Out of 50 subjects, the majority prefer "Trial 3". The objective of simulation in this study is whether scientific visualization of multi-modal sensory data can reveal the delicate movement difference between an professional and an amateur sportsmen. If we observe the movement only, it is difficult to distinguish a sophisticated amateur's move from a professional'. However, if, along with movement, we can see EMG data, it tells clearly the difference. In the case of a professional's, muscles such as pectoralis major muscle locating around his trunk start to be

5 Evaluation from Congitive viewpoint

Based on the same measured data, we create four different 3D CG animations.

We present these animations to our students asking which animation is easier to understand the major events of movement and muscle activities.

Table 2: Animations for the comparison

Animation	time span	assigned colors	students vote numbers
Trial 1	1 second	6	0
Trial 2	10 seconds	6	6
Trial 3	10 seconds	1 (only red)	36
Trial 4	50 seconds	1 (only red)	8

active first, then muscles along the upper arm (e.g. brachialis) then the lower arm follow in smooth sequence. In the case of an amateur, we do not observe the activity of muscles on his trunk well. Only muscles along the arm get activated so that the initiating power of ball throwing is weaker than that of a professional. Up to now, only well experienced researchers on sport science have been able to read the difference out of a table of observed numbers. If laymen and beginners of sport science could understand the difference easily, it could have contributed to the training method. In this sense, the Trial 1 shows the animation speed as fast as the actual ball throwing (ca.1sec) Different colors are assigned to Different muscles and according to the level of activity. Due to only 1 second display time, it is very difficult to perceive EMG change. The trial 2 is displed slower but different color assigned to different muscles makes it difficult for us to understand. The trial 3 has only one color to all muscles but the location of each muscle is clear so that we can perceive when which muscle is active. The Trial 4 is displyed very slowly so that we can appreciate the change of muscle activity well. On the other hand, the slowness of the movement gives us a difficulty to understand the movement itself.

6 Conclusion and Future Study

Our finding is that there is an optimum display speed of animation when we try to perceive multipl phenomenon at the same time. It indicates that our dynamic visual perceptive capability has some limitation. Up to now, most of 3D CG animation creators spent most of their effort how to create new CG technology and have not payed much a ttention to this scope. In this paper, we point out the importance of the cognitive viewpoint in 3D CG research.

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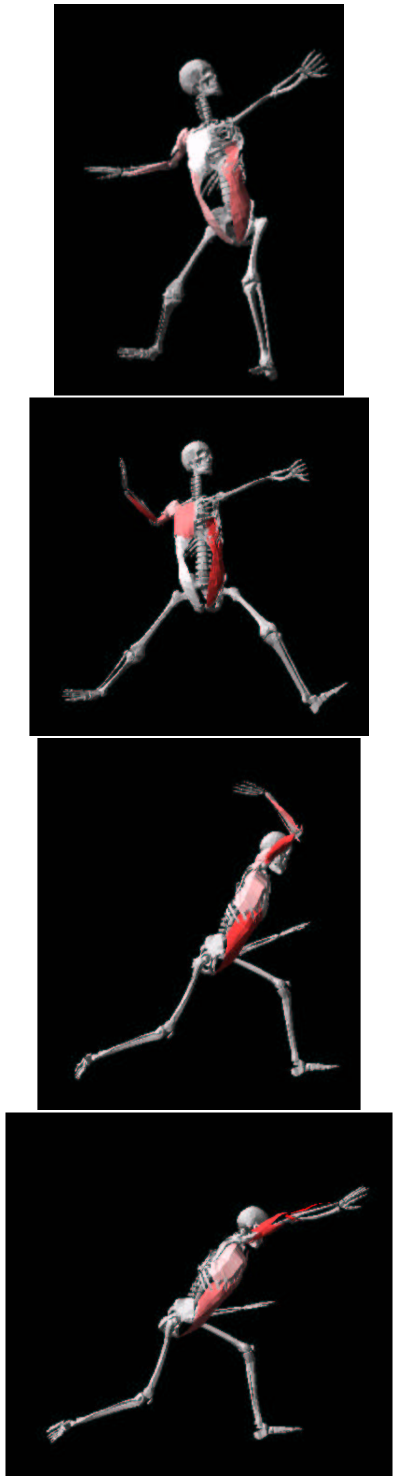

Figure 10: 4 Slides from trial 3 animation