Reflection Rate Index of Markers for Motion Capture Application

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Abstract Motion capture application continues to grow in many sectors of the industry, including medical science, sports science, animation, robotics, and many more. In order to capture any specific movement to be analyzed, markers are utilized to identify joint movement. Passive reflective markers are usually utilized in motion capture systems equipped with infrared cameras. Active reflective markers are usually utilized in motion capture systems with digital video recorders. These markers usually transmit or diffuse specular light distribution to be captured by the camera system. In this study, the reflection rate index (RRI) of 4 different types of markers was measured (M1, M2, M3, and M4). Based on the RRI value, the type and level of reflection and light distribution from each marker can be identified. Results indicated that M1 and M2 had RRI values above 1, which means that these markers produced diffuse reflection, whereas M3 and M4 had RRI values below 1, which means that these markers produced specular reflection. Based on this study, we can categorize each markers light distribution or reflection rate based on the calculated RRI. This is helpful to researcher for deciding what type of marker that needs to be utilized in each respective research area.

Keywords Motion capture · Motion analysis · Markers · Biomechanics · Bioengineering

1 Introduction

Motion capture systems have been around since the nineteen century [1] and have become increasingly important in today's research associated with motion analysis. Many industries conduct motion analysis in their working area, which include

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R. Adnan et al. (eds.), *Proceedings of the International Colloquium on Sports Science, Exercise, Engineering and Technology 2014 (ICoSSEET 2014)*,
DOI: 10.1007/978-981-287-107-7_3,

sports science, health and clinical science, automotive industries as well as entertainment and gaming industries. Current state-of-the-art motion capture systems require markers to identify movement performed by objects in motion that are being tracked. These markers come in many sizes according to the requirements of the industries. The markers that are used in motion capture systems could be either active marker, where the markers have lighting capabilities with either conventional lamps or light-emitting diodes (LED) or it could also be passive markers, where the markers are built from light-reflecting materials and the motion capture systems require lighting during the motion capture. However, no lighting effect is required for an active marker system.

Typical active markers in motion capture systems will usually utilize a standard video-recording camera, while passive markers in motion capture systems typically utilize infrared cameras for video recording. However, passive marker systems can also use a standard video-recording camera, but require lighting to create a source of reflection for the markers. Both active and passive marker systems are suitable for either 2-dimensional or 3-dimensional motion analysis as long as the motion analysis system can interpret the coordinates of the tracked objects that have been identified by the markers used in the motion capture system.

There is a perception that active markers generate better movement tracking when compared to passive markers. Although almost all current motion capture systems could easily provide the movement information, a previous study [2] indicated that much more improvement is needed in order to produce a real-time motion capture and motion monitoring system. In certain situations, marker recognition can be difficult due to the marker positioning. It was also found [2] that passive markers sometimes could not recognize two markers sitting very close with each other. It is believed that reflection created by the markers affected this recognition capability. Different types of reflective markers interact differently with different light sources. Different specifications of light distribution for active markers also create different states of recognition.

Passive marker motion capture systems are preferred compared to active markers due to the fact that it is easy to use. Although there is evidence that active marker motion capture systems are becoming more user friendly [3], nonetheless, it is still not hassle free. More time is utilized at the setup stage when using active marker motion capture systems. Marker-less motion capture systems are also becoming more popular [4, 5], but there is no real indication as yet that there is a marker-less motion capture system that is as accurate and reliable as marker motion capture systems.

In terms of the passive marker, a reflective surface influences the reflection capability, where previous studies [6, 7] had indicated that there was evidence that a smooth surface creates a longer light reflection distance, whereas a less smooth surface, such as orange peel-like surface, creates a sharper reflection of the light. Based on these findings, markers with different purposes are being designed according to application requirements. More information regarding marker classifications and specifications for different scenarios, situations, and conditions are

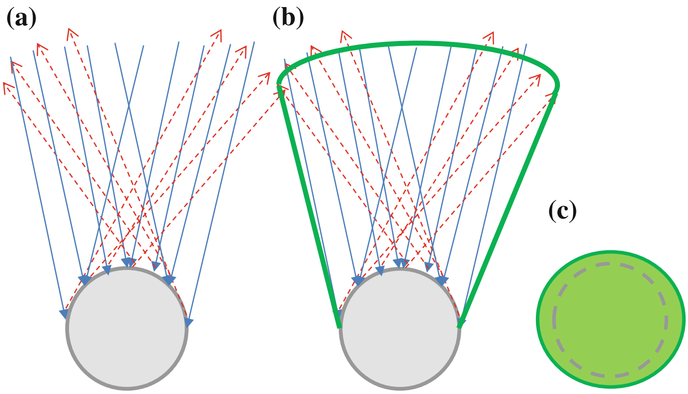


Fig. 1 **a** Incoming and reflection light, **b** range of light distribution beam, and **c** glowing lighting effects

needed in order to help researchers utilize the most suitable markers for their studies and applications.

The purpose of this study was to establish a simple method to indicate the rate of light reflection created by markers that are typically utilized in motion capture systems.

2 Method

2.1 Understanding of Light Emission, Reflection and Distribution

Light travels in a straight line. A light-emitting object produces its on lighting and distributes them. LED is one example of a light-emitting object. Materials without its own light-emitting capabilities, but capable of reflecting incoming light are known as reflective materials. The beam of the light distribution from either a light-emitting object or a light-reflected object will either be a diffused or specular distribution beam. A diffused distribution represents glowing lighting effects surrounding the object, while specular distribution lighting do not have glowing lighting effects surrounding the object's surface. Figure 1 illustrates the concept of light reflection and light distribution viewed from the top view ('a' and 'b') and front view ('c').

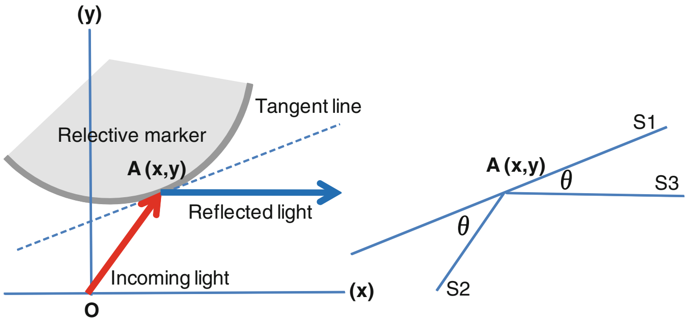


Fig. 2 Light reflection model

2.2 Light Reflection Model

Light reflection is influenced by the lighting source and also the surface conditions of the reflective object. Figure 2 illustrates a light reflection model on a passive marker.

The model shown in Fig. 2 considers that when the reflective marker surface is evenly smooth and equal, the angle created between the incoming light and tangent line on point A (reflection point) and the reflected light and tangent line on point A to be equal. Based on these assumptions, we would obtain the following relationship:

$$\tan\theta = \frac{S1 - S2}{1 + S1S2} \tag{1}$$

Here, $S1$, $S2$, and $S3$ are the slopes of each of the respective sources.

Under real situations, the angle will not be the same due to the marker surface conditions and incoming light properties. This is why we would obtain reflection light with either diffused of specular reflection. In order for the reflection light distribution to be diffused reflection, the angle of the reflection light will have to be a smaller angle when compared to the angle of the incoming light. Inversely, in order for the reflection light distribution to be a specular reflection, the angle of the reflection light will have to be a larger angle when compared to the angle of the incoming light.

Calculating these angles on a spherical shaped object is complicated, but we are interested to understand about the reflection rate of a marker. Therefore, this study proposes an alternative method to categorize light reflection or distribution rate of a marker.

Table 1 Marker description

Type	Symbol	Description	Size (diameter) (mm)
Active marker	M1	Bulb type	11
Active marker	M2	LED type	10
Passive marker	M3	Reflective markers conventional	12
Passive marker	M4	Reflective markers prototype	16

2.3 Marker Description

In this study, four different types of markers were investigated (Table 1). All of these markers are commonly used in motion capture and motion analysis application systems, except for M4 that is a prototype and is not yet available commercially.

Each of the markers light reflection and distribution images were captured using a still image camera (Casio ZX-100) in a dark room. The camera was positioned approximately 5 cm in front of the markers, while it was in the light-reflecting and distributing condition. All dimensional calculations were obtained using the Kinovea Software (v 0.8.15). Each of the marker images was taken 10 times, and the average value was calculated.

The following equation was utilized in order to categorize the rate of light reflection and distribution of the markers. This was named as the rate of reflection index (RRI):

$$\text{RRI} = \frac{\text{Total glowing light cross-section area}}{\text{Total cross-section area of marker}} \tag{2}$$

RRI is the ratio of the cross-sectional area of reflected or distributed light with respect to the markers total cross-sectional area. Figure 3 illustrates the flow chart for this study.

3 Results and Discussion

Results of the RRI are presented in Table 2. Based on the results, it was evident that passive markers have lower RRI when compared with the active markers. Figure 4 illustrates the representative still images of each of the markers.

Based on the results of the still images, it was clear that active markers generate diffuse light distribution, whereas passive markers generate specular light reflection.

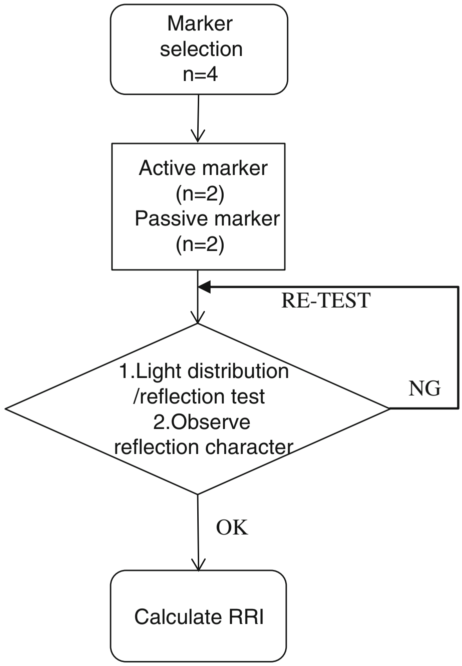


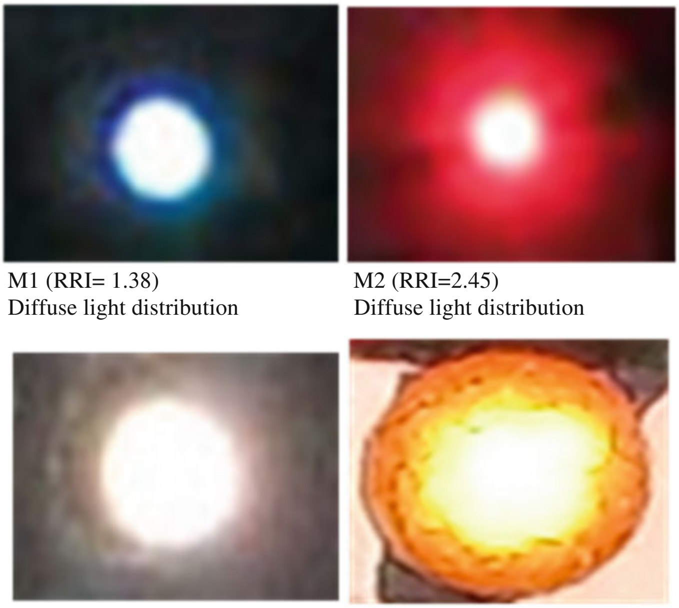
Fig. 3 Flow chart of study

Table 2 RRI of markers

Marker	Light distribution/reflection	RRI
M1	Diffuse	1.38
M2	Diffuse	2.45
M3	Specular	0.95
M4	Specular	0.78

It is also acknowledged that this study found that markers with RRI of below 1 generate specular light distribution or reflection, whereas RRI of above 1 generates diffuse light distribution or reflection.

The value of RRI would enable us to identify the reflection and light distribution rate based on the marker size. It is also useful for researchers to select the type of marker to be used in their respective research area. This is important because certain motion capture studies would require the markers to be more glowing, or more diffusive rather than specular light reflection or distribution. There would also be motion capture studies that prefer specular lighting reflection. However, this is associated with many parameters, including research location, type of video recorder, lighting effects, and also the type of the motion itself.



M1 (RRI= 1.38)
Diffuse light distribution

M2 (RRI=2.45)
Diffuse light distribution

M3 (RRI=0.95)
Specular light reflection

M4 (RRI=0.78)
Specular light reflection

Fig. 4 Light distribution and reflection of markers

4 Conclusion

A simple method, of determining the RRI, for categorizing types of light reflection and distribution of markers that are typically utilized in motion capture systems is proposed. By identifying the RRI of the markers, the types of light distribution or reflections are known. Based on this information, a better understanding of the markers is established. Thus, these results will enable researchers and practitioners of motion capture and motion analysis systems to select the markers more correctly for their work.

Acknowledgments Thanks are due to the Faculty of Sports Science and Recreation, Universiti Teknologi MARA, Malaysia, for the financial support of this study.

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