Computer Vision-Based Visitor Study as A Decision Support System for Museum

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***Abstract*—As an institution that operates within the public domain, a museum should be knowledgeable about several factors that can improve its services. One of these factors that can support the decision making for museum is visitors experiences during their visits. To gauge these collective experiences, visitor studies are conducted regularly by museums. Several visitor study approaches have been introduced, ranging from a simple field observation to sophisticated sensory devices. We proposed a new approach to monitor the behavior of museum visitors through the implementation of a computer vision software called Eyeface. The software was used to capture visitor data, including demographic information and engagement level data. These data can be used by museum to make a decision in rearranging its exhibition that can improve visitors engagement level. Additionally, the demographic data can be a basis information for museum to create particular events or promotions targeting some specific group of visitors. This approach was tested in three different museums; one was located in Edinburgh, UK while two were in Jakarta, Indonesia.**

***Keywords*—museum, visitor study, computer vision, engagement, decision support**

I. Introduction

Museum as an institution that operate in a public domain should aware of their visitor experiences. They have to assure that every decision related to object or service they made is meet visitors expectation and satisfaction. In order to keep an eye on this matter, visitor studies are commonly undergone by museums. Museum institutions have started to implement this since long times ago even before 1940 [1].

Each visitor study has its own different intention, and to get the expected results from this study, museums need to design an appropriate method for their visitor study [2]. Bitgood, says in his book that before 1940 scholars tried to get useful insights from museum visitors in some different aspects [1]. Attention time, museums fatigue, and object competition are some of [illegible] have been introduced. Some scholars did lab experiments that simulate museum environment to have more controlled result [1]. Some others conducted field observations in order to obtain more real data [3]–[5]. Paper questioners and interviews have also been commonly used in visitor studies [6]. The massive growth of technology has influenced the way of researchers and museums to execute visitor studies [7]. From simple technology application such as Hodometer concept [8] that allows researcher to track visitors by using sensors attached on the carpet to a sophisticated computer vision technology using 3D cameras to get visitors behavior data from architecture perspective [9].

The outcome of this visitor study will be used by museums as their considerations to formulate the right decision to improve their service. Museums will have enough reasons to redesign their exhibits plan, if they get significant feedback from visitor study.

Recently, computer vision application has commonly used by some advertising companies to evaluate their advertisement installations [10], [11]. This method allows researchers to get a big size of simultaneous real time data in an automated system. Using this method researcher can get several kinds of data at the same time. Demographic information and attention time are two main data that commonly generated from this system. These kinds of data are often to be found in museum environment. Some museums are keep doing manual observations and surveys to get these data. Museums need to consider to implement computer vision technology to help them generate visitors' data automatically and eficiently.

II. Methodology

A. Development Approach

Each researcher or developer has a different design approach to his/her project. The method used in this project is the combination of two development approaches. These approaches are The Double Diamond Model [12] and The Stanford Design Thinking Process [13]. Both of them has different stages to see a solution development as a process. The Design Council, [illegible]s [12]. A design process [illegible], then define the idea, followed with the development stage and end on the delivery stage. This model shows the convergent and divergent thinking along the process. The process start with discovery stage to get as many as possible solutions. Then it is continued by focusing on defining one most appropriate solution to answer the problem. The same process can be applied for the development and delivery stage.

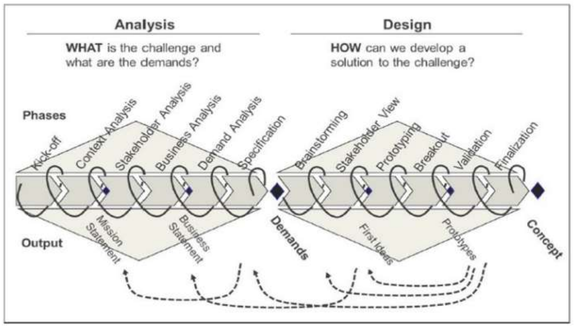

Fig. 1. The Combination of Two Different Design Process Models [14]

By contrast, Stanford Design Thinking Process has more details stages along the journey. This approach sees a development process as an iterative one, instead of linear. There are 6 phases in a development process based on this approach. It starts from understanding the problem, observing all resources to support and justify the problem, and synthesizing all of that information into one big picture. Ideation phase is based on the tailored information from the previous step. The next step is to make the idea more visible by building the prototype. This process will end with the prototype testing to get validation of the idea. We can go back to previous step if we feel that the current condition and status is not making any sense.

By combining these two approaches, the development process can be smoothly executed. The concept from The Double Diamond Model can be adopted in constructing the general concept of design and development. Then the Stanford Design Thinking Process can be implemented in more detailed steps that requires iteration. Ninkc in his article, Creative Problem Solving as a Learning Process, clearly demonstrated how these two design process models can be combined [14].

B. *Technology Stack*

Main consideration in choosing the right technology in this research were the simplicity and ease of use. There are a lot of computer vision software available to use. Eyeface from Eyedea Recognition is one of the pioneers [15]. It is actually a software development kit (sdk) to build computer vision application, especially face detection application. It can be used in some programming languages such as java, php, and python. This company provides the demo version of face detection software using their own sdk. The output of this software analysis, which includes demographic analysis, was also another strong point of this software.

This software can be automatically analyse a live streaming video from a webcam. The output of this software is very comprehensive. It can output the data and graph about dwell time (i.e how long a person standing in front of the object), attention time (i.e how long a person standing in front of the object and facing the object), and audience (How many visitors interact with the object). The audience data can be classified into age and gender groups. All features from this software are just perfectly matched with this study requirements.

III. Results

Prior to use the solution in real environment for visitor study, a simple test was conducted to measure the accuracy of this solution. 14 participants were invited to join a controlled experiment in a studio. Each participant was asked to stand in front of the camera while the software analyzed their appearance. This test was conducted to check the accuracy in term of age and gender detection. From age perspective, the data captured by the software shows only around 85% inaccuracy.

However, this issue was not really a big deal because at the end, the output graph from this software will categorize the age in groups such as 1-10, 11-20, 21-30, 31-40, and so on. From table 1 we can see that 92% of the data shows a good accuracy as a categorized age. The gender detection shows a really good accuracy to detect gender from each participant as can be seen in Table 1. Only one of the participants was mistakenly detected by the software. The mistake was not wrongly detected as the opposite gender, but rather detected as an unknown gender.

TABLE I. Solution's Accuracy Testing

	Actual Age	Age Captured by software	Accuracy as categorized age	Actual gender	Gender Captured by software	Accuracy
Participant 1	26	23	Accurate (21-30)	Female	Female	Accurate
Participant 2	25	24	Accurate (21-30)	Female	Female	Accurate
Participant 3	25	23	Accurate (21-30)	Male	Male	Accurate
Participant 4	25	21	Accurate (21-30)	Female	Female	Accurate
Participant 5	24	24	Accurate (21-30)	Male	Male	Accurate
Participant 6	24	23	Accurate (21-30)	Female	Female	Accurate
Participant 7	23	22	Accurate (21-30)	Female	Female	Accurate
Participant 8	25	22	Accurate (21-30)	Female	Unknown	Not Accurate
Participant 9	23	23	Accurate (21-30)	Female	Female	Accurate
Participant 10	22	18	Not Accurate	Female	Female	Accurate
Participant 11	23	21	Accurate (21-30)	Female	Female	Accurate
Participant 12	27	24	Accurate (21-30)	Male	Male	Accurate
Participant 13	22	23	Accurate (21-30)	Male	Male	Accurate
Participant 14	26	24	Accurate (21-30)	male	male	Accurate

A. National Monument of Indonesia (Monas), Indonesia

The first visitor study was took place in National Monument of Indonesia (Monas) in Jakarta. Monas has a unique characteristic as a public attraction. The main attraction in this place is actually the monument itself as the icon, not only for the city, but also for the country. Inside the monument, there is a huge area, which is intended to be a museum. All of its collections are dioramas about history of Indonesia since the prehistoric era. The study was conducted on 27, 29 December 2015 and 3 January 2016.The first result is a comparison table of visitor numbers between the one that captured by the system with the actual number from manual calculation by museum's staff.

The percentage of of these comparison were all under 10%, as can be seen in Table 2. On the first day, the face detection software only captured 1% of total actual visitor number. It was because the study was conducted only for 2 hours.

In term of interaction between visitor and object, dwell time and attention time were compared between male and female visitors. From Figure 2, we can see that the average male visitors' dwell time and attention time were higher than female visitors'. Only on the second day, attention time from female visitors was slightly higher.

TABLE II. VISITOR NUMBER COMPARISON IN NATIONAL MONUMENT OF INDONESIA

Date	Captured	Actual	Percentage
27/12/2015	144	11465	1.00%
29/12/2015	1040	11616	9.00%
3/01/2016	641	11989	5.00%

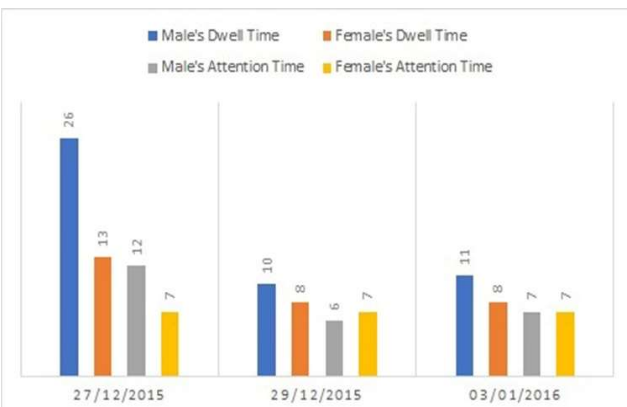

Fig. 2. Dwell and Attention Time Comparison in National Monument

B. National Museum of Indonesia Indonesia

National Museum of Indonesia is a museum that has the biggest collection of historyof Indonesia. There are seven different categories of collections in National Museum of Indonesia, consist of prehistoric, archeology, ceramics, numismatic heraldic, historic, ethnography, and geography [16]. The way they display the collections is far more modern than Monas. Almost all of their collections are static objects, except one interactive screen displays a summary of museum's collections in several attractive animations and games.

In order to get a better study result in this museum, this interactive panel was compared to a static panel about Indonesian ethnography. These two objects are located at the same area so the comparison could be fair, as illustrated in Figure 3.

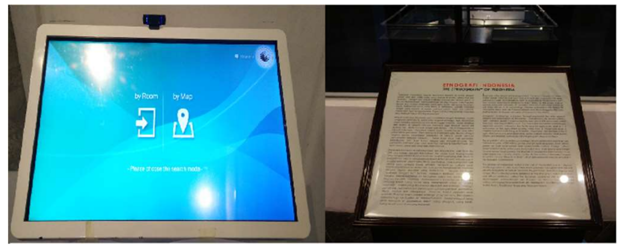

Fig. 3. Objects in National Museum of Indonesia

The study in this museum was conducted for three days, on 5, 8, and 9 January 2016. Visitor number in National Museum of Indonesia was not as many as visitors in Monas. It was only less than 1% comparing with Monas visitors. Yet, the quality of visitors, in term of the intention of visit, is much better. It is reflected from the Table 3. It shows that the average percentage of visitors who interacted with either static or interactive object was more than 50% from total visitors on average.

TABLE III. VISITOR NUMBER COMPARISON IN NATIONAL MUSEUM OF INDONESIA

Static	Captured	Actual	Percentage
5-Jan-16	129	168	77%
8-Jan-16	206	768	27%
9-Jan-16	1014	1019	99.50%
Interactive	Captured	Actual	Percentage
5-Jan-16	103	168	61%
8-Jan-16	353	768	46%
9-Jan-16	745	1019	73%

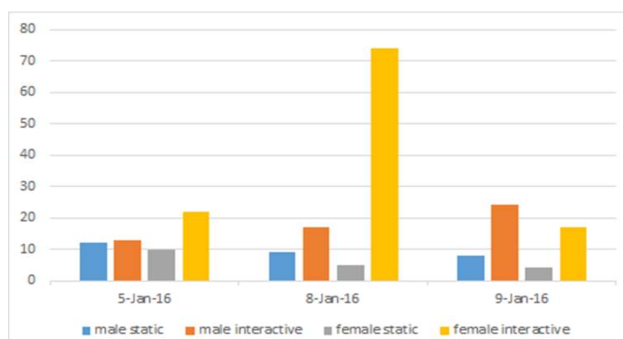

Fig. 4. Dwell Time Comparison in National Museum of Indonesia

The main important thing of the study in this museum was to know which object could engage visitors better. From the graph in Figure 4 and 5, we can see that the interative object was clearly more engaging for visitors rather than the static one as the dwell time and attention time for the interactive object showing a greater number. It also shows that female visitors were more engaged with the interactive object but not the same for static object.

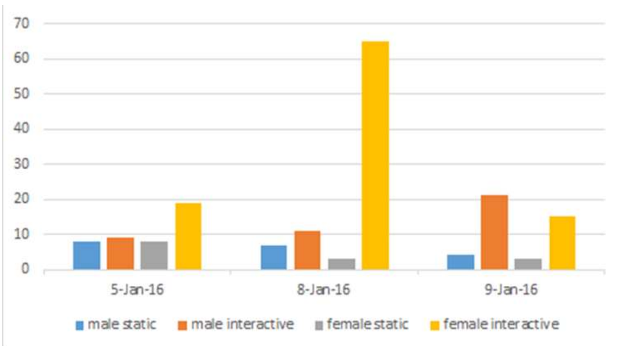

Fig. 5. Attention Time Comparison in National Museum of Indonesia

C. Museum of Edinburgh, Scotland

The last series of visitor study was took place in the Museum of Edinburgh. Two fascinating interactive installations were included in this study. The first one is a huge touch screen display about Edinburgh-born World War I British Commander Earl Haig. This installation consists of several objects related to the Earl Haig story and a projector that projects an interactive animation into a wide touch screen glass.

The second one is the museum‘s secret courtyard that projected into an interactive screen equipped with Leapmotion to control the content [17]. Each of these objects was compared with a static object within the same theme and same location. It turned out that the light condition is very crucial in order to make face detection software run well. In Earl Haig gallery, especially the interactive screen, the light condition is not very good. Besides, the cabinet, which made of glass, gave a reflection from the projector to the camera so it affected the accuracy of face detection software. Thus, the result of study in this gallery was not good enough.

Realizing that the light condition in Earl Haig gallery was not supportive for this proposed solution, the museum curator proposed another set of objects. Finally, the second interactive installation at the museum, the courtyard interactive screen, was picked for this study. This object was compared with the static object, Armorial panel, which is the most common object in the courtyard area. These two objects can be seen in Figure 6.

The study in this museum was arranged for five days from 19 until 23 January 2016. However, on the second and third day there was a technical issue on face detection software for static object, so it did not capture suffecient data.

Audience dwell time analysis graph in Figure 7 shows that there is a significant gap between number of visitors who interact with interactive object and visitors who interact with the static one. A big distinction was also shown from the attention time graph for both objects as shown in Figure 8.

Fig. 6. Objects in Museum of Edinburgh

TABLE IV. VISITOR NUMBER COMPARISON IN MUSEUM OF EDINBURGH

Static	Captured	Actual	Percentage
19-Jan-16	11	90	12%
20-Jan-16	4	224	2%
21-Jan-16	NA	97	NA
22-Jan-16	41	105	39%
23-Jan-16	82	311	26%
Interactive	Captured	Actual	Percentage
19-Jan-16	50	90	56%
20-Jan-16	78	224	35%
21-Jan-16	91	97	94%
22-Jan-16	74	105	70%
23-Jan-16	114	311	37%

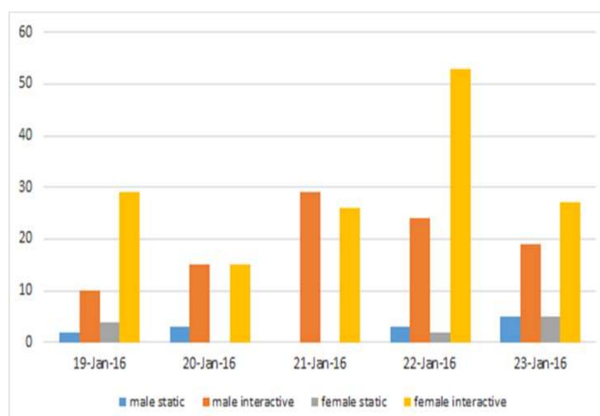

Fig. 7. Dwell Time Comparison in Museum of Edinburgh

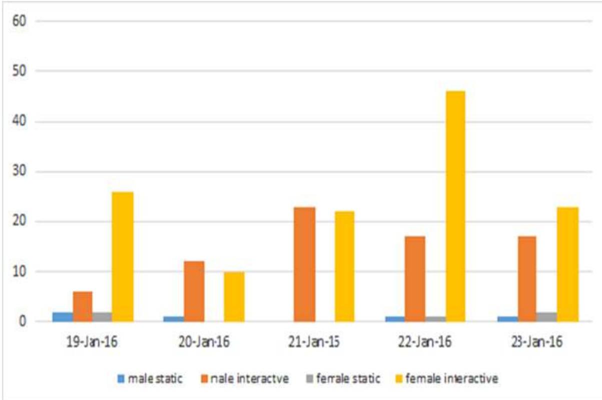

Fig. 8. Attention Time Comparison in Museum of Edinburgh

In order to assure that the difference of engagement level, reflected by attention time, for both types of object in each museum was significant, a non-parametric t-test was conducted. Visitor study in National Monument was excluded in this analysis because there was not an interactive object available to be compared. Table 5 shows that both in Notional Museum of Indonesia and Museum of Edinburgh, the difference of engagement level were quite significant (p value <0.05).

TABLE V. Mann-Whitney Test for Each Museum

Museum	P-value
National Museum of Indonesia	<2.2e-16
Museum of Edinburgh	1.794e-09

IV. Discussion

The three series of visitor study presented in this paper provide different lessons depends on the characteristics of each museum.

In National Monument of Indonesia, there was an important fact that can be taken by museum organizer related to the quality of visitor number. We can see in Table 2 that visitor number captured by software were far below the actual visitor number throughout three days of visitor study. This data actually was not surprising because according to the manual observation, the huge number of visitors was happening because the period of the study was in holiday session, so a lot of people from other cities were coming to the museum. The worse point about this fact was that most of visitors did not actually intent to come and enjoy the objects at the museum. They were just find a place for them to take a rest after they looked around the monument.

That was a common problem for this museum during holiday session according to the head of National Monument of Indonesia, Mrs. Rini Hariyani. Museum management has already tried their best to prevent visitors from taking a rest at museum area by asking them one by one to move to another place. Yet, this conventional way seemed not give a good result because people kept doing it. To answer this issue, for next holiday session, they are planning to hold a temporary exhibition on the hall of the museum so there will not be spaces left for visitors to sit or lie on the floor to take a rest.

From the finding in Monument National Indonesia, we can see how the result from this proposed solution can be considered by museum management to take action to improve the quality of their service. Finally, by taking this decision, museum organizer hope their visitors can take valuable experience by visiting their museum.

Completely different situation was found in National Museum of Indonesia and Museum of Edinburgh. The main intention of executing the series of visitor study in this museum was particularly to answer one specific research question, whether interactive installations can attract and engage visitors better than the static one. This question will be a base for museum organizers to take decisions on how they will exhibit their artifacts.

This study setting was clearly not appropriate to be done in National Monument of Indonesia because of the inavailability of interactive object. However, the result data still gave useful insight about the percentage of visitors that interact with the object at this museum. A relatively low number of this percentage could be an indication that the lack of interactive installation could affect the visitors' attention. The huge number of daily visitors at this museum can be a great opportunity for museums if they can maximize the quality of their collections by installing interactive object to support existing exhibitions.

On the other hand, visitor studies in National Museum of Indonesia and Museum of Edinburgh gave better perception related to this research question. Visitor study series in both museums were enough to answer that interactive installation could engage visitors better.

However, there were some points need to be highlighted as a lesson learned from the visitor study in these museums. The first one was the environment setting and condition that can affect the accuracy of face detection software. The excessive amount of light around the object will be a biggest challenge for face detection software proposed in this paper.

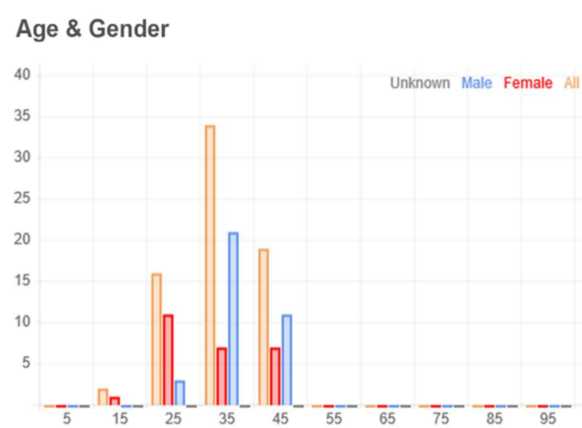

Fig. 9. Demographic analysis for Interactive Object in Museum of Edinburgh

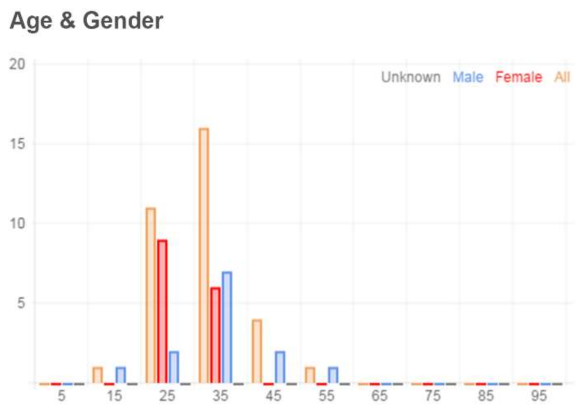

Fig. 10. Demographic analysis for Static Object in Museum of Edinburgh

The second point was how the result of demographic and engagement analysis can be used by museum organizers to support their decision. From gender perspective, museum organizers can use this result to design their exhibition to be non-gender sensitive so it can attract either male or female visitors. The same rule can be applied to design exhibition that can attract visitors from all groups of age. For example, we can see in Figure 7 and 8 how different type of object can give different effect to attract visitors. As mentioned before, it is clearly that interactive object will attract and engage visitors better. Yet, turned out that this kind of object attract more male visitors than female visitors. Additionally, this kind of object only attractive to visitors in the range of age between 20-50 years old. While, for the static object, it gave roughly the similar effect for either male or female visitors. It also attracted wider range of age group of visitors (10 - 60 years old). Eventually, these data can be considered by museum organizers to design better exhibition for every group of visitors.

V. Conclusion

This paper has clearly presented a proposed solution for museum to do a visitor study. The use of face detection software as a solution that generate visitor demographic and engagement level data can be used as a tool to help museum organizers to formulate particular decisions related to their exhibition. The automated feature in this software can help museums to get as many as possible data with less control. It will help museums to evaluate their exhibitions in a simple yet robust method. One of the museum curators at The Museum of Edinburgh said that this method could help them to get valuable data related to their visitors.

Acknowledgment

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