

# Self-organizing Museum Visitor Communities: A Participatory Action Research based Approach

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**Abstract**—This paper introduces a self-organizing museum visitor communities' formation exploiting their personal characteristics and social interactions, aiming at enhancing their visiting experience based on a participatory action research (PAR) process. Initially, visitors' (a) interest and social ties, (b) expertise and willingness for participation in communities and (c) physical ties, are captured towards formulating their communities, and selecting the facilitator of each community. The latter will lead the PAR process, the outcome of which will be adopted by the members of each community. A museum touring framework is proposed towards maximizing visitors' perceived Quality of Experience (QoE), while three different community formation alternatives are studied and evaluated.

**Keywords**—Museum visitor communities; Participatory Action Research (PAR); Quality of Experience (QoE); social interactions; museum touring.

## I. INTRODUCTION

Museums are becoming dynamic environments in the service of the society aiming at reconnecting with the public and demonstrating their value and relevance in contemporary life. Several recent statistics [1], [2] have made evident that museum exhibition draws the crowd, offering multiple experiences to the visitors. However new techniques are required towards actively engaging the museum visitors in a participatory manner towards improving their visiting experience. Several research works have dealt with the problem of formulating museum visitors' satisfaction [3], [4]. The seminal paper by Eliseo and Martine [5] identified four visiting styles, i.e., ant, butterfly, fish and grasshopper, while in [6], [7] a quantitative approach was followed towards evaluating visitors' Quality of Experience (QoE). In [8], the effect of smart routing and intelligent recommendations on improving museum visitors' QoE was studied, while in [9] a holistic approach in the formulation and optimization of museum visitors' QoE functions was introduced.

In this paper, we propose a self-organizing museum visitor communities' formation exploiting visitors' personal characteristics and social interactions among them, towards enhancing their visiting experience through a participatory action research (PAR) approach. Initially, we introduce a novel communities' formation methodology, which considers visitors' styles, as they have been proposed in [5], as well as visitors' personal information, e.g., age, interest of visiting

specific exhibitions in the museum, personal interests, background knowledge, etc., in order to organize visitors in homogeneous research groups with common characteristics and interests. Then, based on visitors' characteristics and social ties among them within the created groups, we select the facilitator of each community, who will be responsible to initiate and orchestrate the Participatory Action Research (PAR) process [10], [11]. Through such a process visitors can create, share and connect with each other around the exhibits, thus being actively engaged to the exhibitions / museums. Moreover, in this paper a touring methodology of the visitors within the museum based on their perceived satisfaction is introduced and their communities' formation under different criteria is studied and evaluated.

The remaining part of the paper is organized as follows. Section II elaborates the details and assumptions of a participatory museum model. In Section III, the social, physical and expertise ties among the visitors are defined, while in Section IV, the overall communities' formation process is explained. In Section V, the Participatory Action Research process is introduced, while in Section VI, a touring methodology of visitors within the museum is proposed. Three different communities' formation criteria are introduced. Indicative initial numerical results are provided in Section VII.

## II. ASSUMPTIONS AND BACKGROUND INFORMATION

The participatory museum is a concept, where visitors are able to form communities, exchange opinions and co-create knowledge. Let us denote by  $V = \{1, \dots, v, \dots, |V|\}$  the set of visitors within the exhibition area, who can be characterized by a visiting style, i.e., ant, butterfly, fish and grasshopper, as proposed in [5]. Visitors' personal information, interest in visiting a specific exhibition within the museum, expertise on the thematic area of the exhibition, as well as willingness to participate in research communities with other visitors, is registered and considered.

Let  $E = \{1, \dots, e, \dots, |E|\}$  denote the set of exhibits within the museum under consideration,  $d_{ee'}[m]$  the distance between two exhibits,  $e, e' \in E$  and  $\rho$  [visitors/ $m^2$ ] the local crowd density in  $d_{ee'}[m]$  distance around the exhibit. We adopt visitor's Quality of Experience (QoE) function  $QoE_x(\cdot)$ ,

where  $x=A(\text{ant})$ ,  $B(\text{butterfly})$ ,  $F(\text{fish})$  and  $G(\text{grasshopper})$  as they have been introduced in [9] and we define visitor's total QoE function with respect to  $d_{ee'}$  and  $\rho$  as follows:

$$QoE_x(d_{ee'}, \rho) = w_{d_{ee'}} QoE_x(d_{ee'}) + w_\rho QoE_x(\rho) \quad (1)$$

where  $w_{d_{ee'}}$ ,  $w_\rho$  denote the weights of each parameter within the overall visitors' QoE function [9].

### III. VISITORS TIES IN A PARTICIPATORY MUSEUM

#### A. Interest and Social Ties

In the proposed framework, the interest and social ties measure the strength of the relation between the museum visitors that are related to each other. Towards expressing the interest and social ties among the visitors, we will exploit the following provided information: (a) visiting style, (b) age and (c) interest in visiting a specific exhibition in the museum. Based on museum visitors' interest to communicate with each other, we present the interest and social ties among the  $|V|$  visitors by a symmetric  $I = \{i_{v,v'}\}_{|V| \times |V|}$ , where each element  $i_{v,v'}$  (or equivalently  $i_{v',v}$ ) expresses the interest of the  $v^{\text{th}}$  visitor to communicate and exchange information with the  $v'^{\text{th}}$  museum visitor. We assume that the museum visitors  $v$  and  $v'$  have the same interest to communicate with each other, thus the interest matrix  $I$  is symmetric. The interest degree  $i_{v,v'}$  ranges from zero to one, i.e.,  $i_{v,v'} \in [0,1]$ , where the values close to zero reflect less interest of communication among the two visitors, while the values close to one show willingness of close collaboration among the visitors.

The interest degree  $i_{v,v'}$  is a function of visitor's (a) visiting style ( $VS$ ), (b) age ( $Age$ ) and (c) interest in visiting the same exhibition ( $E$ ) and is formulated as follows:

$$i_{v,v'} = \frac{\sum_{y=\{VS, Age, E\}} w_y c_{y,v,v'}}{\sum_{y=\{VS, Age, E\}} w_y}, \quad v, v' \in V \quad (2)$$

where  $w_y, y = \{VS, Age, E\}$  denotes the weight of each factor  $y, y = \{VS, Age, E\}$  and  $c_{y,v,v'}$  is the degree of each factor  $y$  defined as follows:

$$(\zeta\iota\sigma\iota\tau\iota\nu\gamma\ \Sigma\tau\psi\lambda\epsilon) \quad c_{VS,v,v'} = \begin{cases} 1, VS_v = VS_{v'} \\ 0, VS_v \neq VS_{v'} \end{cases} \quad (3)$$

$$(A\gamma\epsilon) \quad c_{Age,v,v'} = \frac{Age_v - Age_{v'}}{100} + 1 \quad (4)$$

where  $Age_v$  is the age of the  $v^{\text{th}}$  visitor, assuming that  $Age = (0,100]$  and

$$(E\xi\eta\iota\beta\iota\tau\iota\omicron\nu\ I\nu\tau\epsilon\rho\epsilon\sigma\tau) c_{E,v,v'} = \begin{cases} 1, E_v = E_{v'} \\ 0, E_v \neq E_{v'} \end{cases} \quad (5)$$

We propose a threshold based communication establishment among the visitors, i.e., the communication and collaboration among two visitors is established if their interest and social tie is above a threshold  $i_{\text{thr}}$ ,  $i_{\text{thr}} \in [0,1]$ .

#### B. Expertise and Willingness for Participation

Following the participatory paradigm, the expertise of the visitors regarding a specific exhibition, as well as their willingness to participate in communities is critical in the communities' formation process and in the selection of the facilitator of each community. Acting as a facilitator assumes high expertise and willingness to share knowledge with the rest of the visitors. Combining these two-types of information, we introduce the expertise and willingness (EW) factor characterizing each museum visitor  $v, v \in V$  as follows:

$$EW_v = a \cdot w_{e_v} + (1-a) \cdot w_{w_v} \quad (6)$$

where  $a$  is the percentage expressing the importance of each factor, i.e., expertise and willingness and  $w_{e_v}, w_{w_v} \in [0,1]$  are their respective weights. The EW factor will be considered in the facilitator selection process (Section IV.A).

#### C. Physical Ties

Towards establishing a meaningful, feasible and practical communication among the museum visitors, their physical proximity within the museum should be considered. We adopt a symmetric matrix  $Q = \{q_{v,v'}\}_{|V| \times |V|}$  towards indicating the physical proximity between the  $v^{\text{th}}$ ,  $v'^{\text{th}}$  visitors. We set the range of  $q_{v,v'}$ , as  $q_{v,v'} \in [0,1]$  and we assume that the physical proximity between two museum visitors is directly proportional to the value of  $q_{v,v'}$ . A threshold value  $q_{\text{thr}}$  is also considered in our proposed framework, where if  $q_{v,v'} < q_{\text{thr}}$  the communication and collaboration among  $v, v'$  visitors can be potentially established.

### IV. SELF-ORGANIZING MUSEUM VISITOR COMMUNITIES

#### A. Facilitator Selection

Let us consider a subset  $V' \subseteq V$  of museum visitors, which will be a candidate community over the set of all museum visitors  $V$ . A facilitator should be selected among the museum visitors that have already established a community, towards orchestrating the PAR process. A representative Importance Factor ( $IF_v$ ) is defined for each visitor  $v, v \in V', V' \subseteq V$

showing his/her importance to be selected as facilitator, considering the overall interest, social, expertise, willingness and physical ties, related to this museum visitor  $v$ .

Let us define the  $IF_v$  for each museum visitor  $v, v \in V', V' \subseteq V$  as follows:

$$IF_v = EW_v \sum_{v' \in V'} i_{v,v'} q_{v,v'}, \quad \forall v, v' \in V', v \neq v' \quad (7)$$

where  $EW_v$  considers the expertise and willingness for participation in communities of the  $v^{\text{th}}$  museum visitor and  $\sum_{v' \in V'} i_{v,v'} q_{v,v'}$  synthetically represents the interest of the rest of the museum visitors within the community to communicate with the  $v^{\text{th}}$  museum visitor, while considering their physical proximity. Then as facilitator  $f_c$ , where  $c \in C$  and  $C$  denotes the set of communities in the museum, of the  $c^{\text{th}}$  community is selected the  $v^{\text{th}}$  visitor that presents the maximum importance factor  $IF_v$ , i.e.,  $f_c = \arg \max_{v \in V'} IF_v$ .

### B. Communities Formation

A multi-factor communities' formation process is proposed considering the interest, social and physical ties among the museum visitors, as well as their expertise and willingness for participation in order to select the facilitator. An iterative methodology is proposed towards determining the communities among the museum visitors. The main steps of the proposed communities' formation methodology are:

1. Initially, we consider the whole set of museum visitors, i.e.,  $V$ , as an initial community, thus  $V' = V$ .
2. For the considered coalition  $V'$ , the facilitator can be determined via utilizing equation (7) and we have  $f_c = \arg \max_{v \in V'} IF_v$ .
3. Considering the rest of the museum visitors in the community  $V'$ , if the following conditions hold true

$$\begin{aligned} i_{v,f_c} &\geq i_{\text{thr}} \\ q_{v,f_c} &\leq q_{\text{thr}}, \quad \forall v \in V' - \{f_c\} \end{aligned}$$

then the  $v^{\text{th}}$  museum visitor belongs to the same community as  $f_c$ . The museum visitors that do not satisfy the above conditions formulate another coalition  $V'' \subseteq V'$ .

4. Set  $V' = V''$  and if  $|V'| > 1$  return to step 2, otherwise stop.

Based on the above communities' formation methodology, we are able to dynamically determine (a) the number of communities, (b) the specific museum visitors that belong to each community, and (c) the facilitator of each community.

The communities' formation algorithm can be executed per a reasonable time-window, where visitors' characteristics will have a substantial difference.

## V. PARTICIPATORY ACTION RESEARCH (PAR) VISION

PAR is a research method that brings together the community members so that they can work together to identify problems faced by the community, to empower the community members to research and create solutions to those problems and to improve in the community. PAR has been applied in various fields, such as education, public health, workplace organization, feminism, culture and arts, etc. [11]. PAR has already been applied to the field of culture and arts towards actively engaging the young people with the museums [10]. In this paper, we adopt the PAR vision towards enabling the museum visitors to exchange opinions, share knowledge and improve their visiting experience in an interactive and social manner. Initially, a group/community of museum visitors having common characteristics and interests is established and a facilitator is selected among them towards organizing the community and orchestrating the PAR process, as described in Section IV. Then, the PAR routine: *observe, think, act*, is followed towards providing a roadmap where PAR can be realized [10], [11]. It should be noted that, the museum visitors move within the museum towards visiting the exhibits of their own interest. Thus, the community formation can dynamically change and the visitors are able to participate in multiple communities and gain diverse knowledge during their visit. The latter, as well as the successful formation of the communities, contribute to enhanced visitor's visiting experience. Through this process, the facilitator of each group will select a subset of exhibits to be visited by all members of the specific community.

## VI. MUSEUM VISITORS QUALITY OF EXPERIENCE TOURING & COMMUNITIES FORMATION ALTERNATIVES

### A. Museum Touring

In this section, we propose and formulate a Museum Visitor QoE Routing (MVQoER) problem, which aims at determining the optimal route of a visitor within a museum, while considering his/her QoE-related characteristics, as expressed in equation (1). We consider that the exhibits residing in an exhibition area can be modeled as a graph  $G = (V, E)$ , where  $V = E \cup \{ent, ex\}$  is the set of vertices and  $E$  denotes the set of QoE-aware links among two exhibits. It is noted that the nodes *ent* and *ex* of the graph represent the physical entrance and exit of the exhibition, respectively. Each link among two exhibits  $e$  and  $e', e, e' \in E$  has a QoE-related weight, as expressed in equation (1). Let us assume that the visitors of each community decide to visit  $N$  exhibits,  $N \leq |E|$ .

Given that the facilitator has selected the specific  $N$  exhibits that the community is interested in visiting, each visitor's main goal is to maximize the overall perceived Quality of Experience while visiting the selected exhibits. Thus, the corresponding optimization problem can be formulated as follows:

$$\min_{\mathcal{R} \in \mathcal{R}_{s,d}} \left\{ \sum_{r=s}^d \frac{1}{QoE_{ee'}} \right\} \quad (8)$$

s.t.  $r \in \mathcal{R}, \mathcal{R} \in \mathcal{R}_{s,d}$

where the route  $\mathcal{R}$  includes all the exhibits  $N$  that the user has selected to visit. The optimization problem (8) is a problem of finding the shortest path from a “source” exhibit to a “destination” exhibit using  $\frac{1}{QoE_{ee'}}$  as link weights such that the path visits each of the  $N$  exhibits exactly once. It is noted that each member of the community may follow a different path towards visiting the  $N$  exhibits.

### B. Visitors Satisfaction from Communities Formation

In this subsection, we quantify museum visitor's perceived satisfaction from the communities' formation and his/her participation in the PAR process. Each visitor perceived satisfaction increases if he/she participates in communities with homogeneous characteristics, in terms of interest, social and physical ties, as well as if the facilitator is expert and willing to orchestrate the PAR process. In the following, we introduce three different approaches/factors in order to quantify visitor's satisfaction.

i. *Pure Interest and Social-Aware Interaction (PISAI)*. In PISAI approach, the communities are formulated based only on visitors' interest and social ties following the communities' formation algorithm, as presented in Section IV.B. The PISAI factor that quantifies visitor's perceived satisfaction is formulated as follows:

$$PISAI_v = IF_{f_c} \sum_{v,v' \in V'} i_{v,v'}, \quad \forall v, v' \in V', v \neq v' \quad (9)$$

ii. *Pure Physical-Aware Interaction (PPAI)*. In this case, the communities' formation depends only on museum visitors' physical ties, thus it is possible that the museum visitors will create communities without having great interest to communicate with each other. The corresponding PPAI factor is formulated as follows:

$$PPAI_v = IF_{f_c} \sum_{v,v' \in V'} q_{v,v'}, \quad \forall v, v' \in V', v \neq v' \quad (10)$$

iii. *Joint Interest, Social and Physical-Aware Interaction (JISPAI)*. In this approach, the communities are formulated via jointly considering museum visitors' interest, social and physical ties. The JISPAI factor is formulated as follows:

$$JISPAI_v = IF_{f_c} \sum_{v,v' \in V'} i_{v,v'} \sum_{v,v' \in V'} q_{v,v'}, \quad \forall v, v' \in V', v \neq v' \quad (11)$$

## VII. NUMERICAL RESULTS

In this section, we provide some indicative numerical results illustrating the operational features of the proposed framework. The weight  $w_y$  of each factor  $y = \{VS, Age, E\}$  is

considered as  $w_y = 0.33$  and the percentage expressing the importance of expertise and willingness of each visitor is  $a = 0.5$ . A detailed Monte Carlo analysis is performed for increasing number of visitors, i.e., 10 to 100, where for each number of visitors the experiment has been repeated 10000 times. The values of interest and social ties  $i_{v,v'}$ , expertise and willingness for participation  $w_e, w_w$  and physical ties have been randomly assigned.

Fig. 1 illustrates visitors' total PISAI, PPAI and JISPAI factor as a function of the number of visitors. It is observed that in the case that the visitors create communities based only on their physical proximity, i.e., PPAI curve, they do not have high interest to communicate with each other and with the facilitator, thus their overall interest expressed through the PPAI factor is low. Corresponding observations hold true for the PISAI curve as well. The aforementioned drawbacks are faced via considering both physical and interest/social ties among visitors towards creating the communities, i.e., JISPAI curve.

Fig. 2 presents visitors' total perceived satisfaction as a function of the number of visitors via quantifying the combined outcome of visitors' QoE during the museum touring under the three alternatives of communities' formation. The results reveal that in the case that both interest and social ties and physical ties are considered in order to form visitors' communities, the visitors have high interest to communicate with each other, exchange information and participate to the PAR process, thus their overall perceived satisfaction is increased. On the other hand, if only the physical ties or only the interest and social ties are considered for the communities' formation, then visitors' total satisfaction is low due to either the low interest to communicate with each other or the low physical proximity among them.

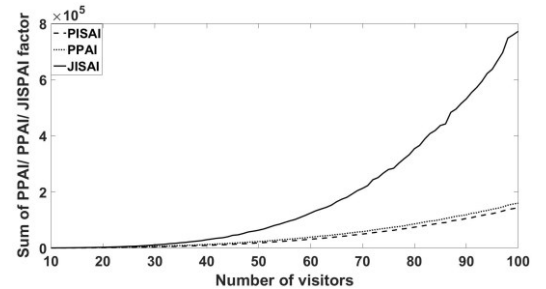


Fig. 1. Total community creation satisfaction factor vs. # of visitors.

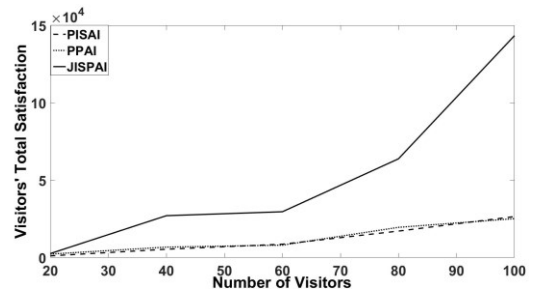


Fig. 2. Total perceived touring satisfaction vs. # of visitors.

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