Neurocomputing 172 (2016) 180–188

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Simulating heterogeneous crowds from a physiological perspective

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A R T I C L E I N F O

Article history:
Received 31 October 2013
Received in revised form
10 December 2014
Accepted 13 December 2014
Available online 8 May 2015

Keywords:
Crowd simulation
Heterogeneous behaviors
Physiological characteristics
Video tracking

A B S T R A C T

Most of the existing approaches to simulate heterogeneous crowd behaviors focus on the aspect of psychology. From a human's physiological characteristics perspective, this paper presents a method to generate heterogeneous crowd behaviors. We choose four basic physiological characteristics, including *gender*, *age*, *health* and *body shape*, and map them to a navigation method, which is reciprocal velocity obstacle approach in the paper. The mapping parameters are determined through a two-step process. Firstly, a video based method is proposed to obtain simulation parameters for single physiological feature by tracking and analyzing trajectories of persons in real video scenes, and then a comprehensive mapping is presented to combine all characteristics together to generate parameters for a certain person. Through a number of simulations and validation experiments, we demonstrate that the proposed method is simple but effective and efficient to exhibit heterogeneous behaviors of crowds.

1. Introduction

Crowd simulation has been extensively studied and applied to many fields including movies, games, and virtual simulations. A virtual crowd, formed by people with different and various appearances and behaviors, is the so-called heterogeneous, which is natural in real world and important for many applications.

This paper focuses on the aspect of crowd behavior heterogeneity, and most of the existing works utilize psychological characteristics and personality models to produce individual differences. For instance, Guy et al. [1] simulated heterogeneous crowd using personality trait theory based on reciprocal velocity obstacle (RVO) library [2], where a series of user study experiments were done to derive a linear mapping from personality descriptors to RVO parameters to control the extent that agents show various behaviors.

To the best of our knowledge, little effort is devoted to utilizing physiological characteristics to generate behavior heterogeneity. Definitely, this does not mean, however, that physiological features are trivial for simulating a crowd. We think that many works focus on psychology aspect because it is easier to implement. There are many mature and recognized models for personality, such as PEN (Psychoticism, Extraversion, and Neuroticism) and OCEAN (Openness , Conscientiousness, Extraversion, Agreeableness, and Neuroticism), and these models categorize personality into several discrete and orthogonal types. Nevertheless, the physiological features are quite a lot and are mostly continuous, such as age, health, physical power, weight and height, so they are hard to model and lack mature theories about their effects on behaviors. However, simulating behaviors from physiological perspective are more natural and instinctive, for instance, the velocity and radius of occupied space of a person are more relevant to physiological aspects than others including psychology.

Hence, we try to simulate heterogeneous crowd from a pure physiological perspective. Inspired by the work of [1], we also choose RVO library as our simulation algorithm, however, it can be easily replaced by other approaches. Four basic physiological characteristics, including *gender*, *age*, *health* and *body shape*, are taken into account. We determine a mapping from a single physiological feature to RVO parameters through video tracking based method, and a comprehensive mapping, which combines these four characteristics together, is proposed to generate various simulation parameters for agents exhibiting heterogeneous behaviors.

The main contribution of this paper is an anthropometric perspective to simulate heterogeneous behaviors of a crowd. This is the first attempt to conduct crowd simulation completely from physiology aspect. Extended from [3] but instead of using user studies and statistical method, this paper presents a video based analysis approach, which is more direct and objective, to analyze persons in the videos and capture their trajectories in order to determine the simulation parameters. Additionally, relative values of these parameters are used to reduce computing errors on the experimental analysis stage. Experiments show that the proposed approach is simple, light-weight yet effective to generate visually convincing crowd simulation results with excellent heterogeneity.

The rest of the paper is organized as follows. Related works in crowd simulation and behavior difference modeling are described

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http://dx.doi.org/10.1016/j.neucom.2014.12.103
0925-2312/

in Section 2. In Section 3, a brief introduction to RVO parameters is given. And we highlight the proposed mapping methods in Section 4. Section 5 demonstrates both simulation results and validation experiments.

2. Related works

2.1. Heterogeneous crowd

There are several mature algorithms and models for crowd simulation, such as classical Boids [4] and social force method [5], and recent reciprocal velocity obstacles (RVO) algorithm [2], fluid based models [6] and data driven approaches [7]. We choose RVO as the navigation library. The heterogeneity aspect of a crowd is the focus of this paper.

Existing works produce heterogeneous crowds roughly from three aspects: individual model, controlled clustering and autonomous behavior. Crowd simulation credibility will benefit a lot from variety of textured appearances [8,9], as well as body shapes and poses [10]. At the same time, controlled clustering can explore some special distributions [11] and formations [12], and is extensively studied in the multi-robot control field. The following will focus on behavior difference of human crowd.

2.2. Behavior diversification

Jentsch et al. [13] conducted a comprehensive literature review to summarize the social and psychological individual-difference works. As a result, they found that academia concerned relatively little about individual differences from anthropometric and psychological aspects. However, some existing literatures make use of internal characteristics of a person to model behaviors. Personality has been adopted for generating various behaviors. Guy et al. [1] used PEN based personality trait theory to drive agents exhibiting complex variations in behaviors. Similarly, Durupinar et al. [14,15] utilized OCEAN personality model to simulate crowd behaviors by mapping from personality traits to existing behavior types driven by Hi-DAC. Curtis et al. [16] tried to simulate heterogenous individuals with *age* and *gender*, but only simply attached them to the agents' preferred speed and maximum speed.

Another way to achieve heterogeneity goal is cloning behavior from existing video samples. Copy and paste technique is used to produce heterogeneous crowd motion from different sources and patterns [7,17,18]. These methods are effective to generate good results, however, are restricted to the quality and quantity of video samples.

As to physiological characteristics, Kaup et al. [19] proposed age-based crowd behavior simulation by modeling age differences as the strength of forces through social force method. Pelechano et al. [20] presented Hi-DAC model, which assigned agents with different psychological and physiological traits for generating individual-different behaviors.

This paper presents a physiology perspective to produce the diversification of a crowd. Existing psychology based method inspires this work, and video analysis based method will be brought into our paper for determining simulation parameters.

3. RVO library and parameters

RVO library [2] presents a formal approach to perform collision avoidance among reciprocal agents, and each agent acts independently and cannot communicate with others. It provides a set of interface parameters, including *timeHorizon*, *timeHorizonObst*, *neighborDist*, *maxNeighbors*, *prefVelocity* and *radius*.

Parameters *timeHorizon* and *timeHorizonObst* are the minimum amount of time for which the agent's speed, computed by the simulation, is safe with respect to other agents and obstacles, respectively. Here, we call them together as *planning horizon*. The larger the *planning horizon* parameter, the sooner this agent will respond to the presence of other agents or obstacles, that is, the agent is more foresight and of longer vision.

Parameters *neighborDist* and *maxNeighbors* represent the maximal distance and number, respectively, of other agents that the agent takes into account in the path planning. We call these two parameters together as *planning scope*. Basically, the larger the *planning scope* parameter, the more consideration of other agents and the finer of the simulation, of course, with longer calculating time and cost.

Parameter *prefVelocity* is the preferred velocity the agent would take if there are not any other agent or obstacle around. RVO library will achieve a tradeoff between this speed and that will guarantee no collisions.

Parameter *radius* is the radius of occupied space of an agent. This hard constraint can be obtained from physiological body feathers of an agent, as well as psychological aspects [1].

4. Video-analysis based mapping method

4.1. Mapping physiological characteristics

The main object of this paper is to simulate a heterogeneous crowd by leveraging physiological characteristics. Since RVO library is powerful and easy to use, we choose it as a carrying navigation method to render the differences between each individual. Hence, mapping from physiology features to simulation parameters must be considered at first.

Physiological characteristics are inherent to human, and have measurable impacts on people's behavioral reactions. As to *gender*, Conner [21] presented that women had a more sensitivity and an enhanced physical alarm response than men when facing to danger or threat, however, most of men had own a better overall situation than women. Lobjois and Cavallo [22] studied age-related effects on street-crossing decisions, and the results showed that older people tended to choose a greater mean time gap between vehicles to compensate for their increased crossing time, so their crossings are sooner than the younger ones. This indicates that age difference influences their judgments about collision avoidance in walking or running. At the same time, it is obvious that human's age and body shape are directly related to the occupied space, and health is related to their walking speed [23].

Now we need to present a qualitative mapping from person's main four physiological characteristics to the RVO's six parameters. Theoretically, each physiological feature correlates with each RVO parameter. However, for the sake of simplification and operability, we consider only the principal factors and ignore the minor relations. According to the above analysis, males have broad overall situation to consider further distance and more neighbors, but have less agile response on collision avoidance than females, so *gender* is mapped to *neighborDist*, *maxNeighbors*, *timeHorizon* and *timeHorizonObst*. And *age* is the same as *gender* for the reason that maturity is directly related to the behavior of interaction with each other or obstacles. People's *age* and *body shape* determine the occupied space, so we associate them with *radius*. Also, weak or strong people have different walking speed, so health condition is solely related to *prefVelocity*.

The overall mapping is depicted in Fig. 1. Note that *planning scope* and *planning horizon* are used here so the six parameters are simplified to only four. Based on Fig. 1, the following section will define the quantitative mapping.