A Fuzzy Ontology for the Classification of Crowds at Concerts

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Abstract. The paper presents a fuzzy ontology for the classification of crowds according to existing theories from social sciences and bottom–up computational approaches. The behavior and dynamics of crowds can be studied as resulting from the behavior of huge numbers of individuals taking part to it and, even if theories on crowd behavior are still open issues for several disciplines, we refer to Elias Canetti's theory on masses, one of the most known and explanatory of crowds behaviors and dynamics. This work is part of an ongoing research project whose goal is the development of decision support systems to design and manage public spaces and events. In particular, we focus here to a collaboration with the famous Italian singer Lorenzo Cherubini and his band, whose aim is to develop formal and computational tools for the classification of different crowd phenomenology that can appear during rock concerts. One of the main contribution of this work is towards knowledge sharing and exchange, since several experiences but also software platforms are nowadays available that could better support the study, e.g. through simulation, of crowd behavior and dynamics.

1 Introduction

The research context of this paper refers to bottom–up approaches to *crowd dynamics* that is, the study of how and where crowds form and move [10]. Several phenomena like *crowd aggregation, dispersion* and *self–organized movement* have been observed and studied by multiple disciplines (e.g. physics, sociology, ethology, social and behavioral psychology). The growing interest to crowd behavior is motivated by relevant applicative contributions for, e.g. building design, urban planning, security and safety management, among others. This work is part of an interdisciplinary research (SCA4CROWDS, Situated Cellular Agents for Crowds) within this context that aims at contributing towards the development of an ontology on crowds allowing the integration of contributions coming from several disciplines and empirical experiences (e.g. model comparison, validation, calibration). Potential exploitations of crowd studies are towards the support of design and management solutions for public and crowded spaces to improve security, safety and comfort of people. SCA4CROWDS, in particular, aims at developing formal and computational tools to support the design, execution and

analysis of crowds' behavior as effect of individual interactions (e.g. physical, social, emotional) according to Situated Cellular Agent (SCA) [1]. SCA is a modeling and simulation framework to model and study crowd dynamics phenomena with an approach based on Multi–Agent Systems (MAS) and Cellular Automata [2] principles.

In this paper, we present the ontological framework for crowds' study we are developing, in which a classification and ontological description of crowds have been proposed referring to Elias Canetti work [4]. The latter is one of the most known theoretical contributions resulting from 40–years of empirical observations and studies from psychological and anthropological viewpoints. Elias Canetti can be considered as belonging to the tradition of social studies that refer to *the crowd as an entity dominated by uniform moods and feelings*. We preferred this work among others (see for instance [3, 6, 11, 7]) due to its clear semantics and explicit reference to concepts of *loss of individuality*, *crowd uniformity*, *spatio-temporal dynamics* and *discharge*, that could be fruitfully represented by modeling approaches like SCA and bottom-up approaches in general. Section 4 presents the translation of the proposed conceptual model into a computational one, and its implementation with Protégé in order to support classification of new instances of crowds according to Canetti's theory. To this aim, fuzzy logic [12] has been adopted to disambiguate crowd instances: membership functions developed to deal with fuzzy concepts have been experimentally developed thanks to the collaboration of the Italian singer Lorenzo Cherubini and his staff. The paper ends with some considerations about the state of the project and future works towards the development of a decision support system based on the integration of ontologies and bottom-up approaches to crowd simulation software to study crowds behavior at rock music concerts.

2 A Crowd Definition Based on Canetti's Theory

Elias Canetti's definition of "*crowd*" can be summed up as follows:

> ... a unic entity dominated by uniform moods and feelings; it is characterized by the spontaneous will of growing and aggregating other pedestrians, and has a target, that is identified as a location of the environment or an object that all the individuals aggregated into the crowd desire. The *aggregation* phenomenon describes the growing effect that starts from an aggregative psychological impulse called the "*discharge*" . The "*discharge*" occurs spontaneously in people and overcomes the natural social repulsive behavior of the "*fear to be touched*". On the other side, crowd disgregation is the result of an other psychological impulse called "*panic*", rising as the result of "*individulistic impulses*".

According to social sciences a crowd is not a unic body but can be composed by sub–structures (i.e. groups), that have their role in the general behaviors and dynamics of the crowd itself at the macro-level [8].

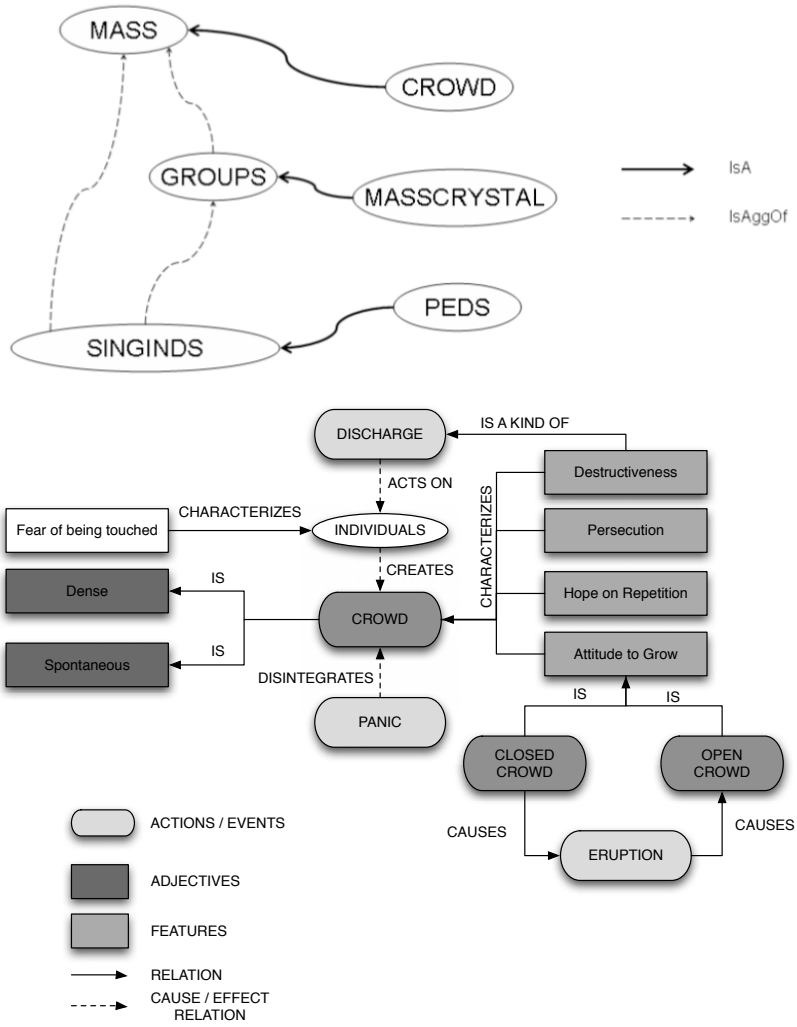

Fig. 1. A graphical representation of crowd classification according to Canetti.

Basic features of the crowd and mechanisms governing the crowd formation and dispersion, as described by Elias Canetti, are represented in Figure 1. The first concept that Canetti introduces in his work is "*fear of being touched*", that affects all individuals.

> "There is nothing that man fears more than the touch of the unknown." [...] "All the distances which men create round themselves are dictated by this fear."
>
> "It is only in a crowd that man can become free of this fear of being touched. That is the only situation in which the fear changes into its opposite." ["Crowds and Power" pg. 15]

This concepts corresponds to the *social distance* represented by several computational models for pedestrian dynamics, and it refers to the fact that individuals usually avoid to stay too close to each other unless they feel themselves part to the crowd. According to Canetti one of the main features of a crowd is thus the lack of "*fear of being touched*". This concept is normally not explicitly considered in computational models for pedestrian dynamics that can be found in literature, where the *social distance* parameters influence individual behaviors in a static relationship (usually as a reduction of attractive forces directing movements).

Crowd formation is characterized by an event called "*discharge*". It creates a crowd and it is described as a sort of psychological impulse that affects individuals that are in the same place, and can be aroused by a common desire normally related to an event or a situation like the beginning of a large massive event (e.g. sportive, religious or politic events) or a dangerous situation (e.g. a blaze). Sometimes can also arise spontaneously between people that feel to have something in common.

> "The most important occurrence within the crowd is the *discharge*. Before this the crowd does not actually exist; it is the discharge which creates it. This is the moment when all who belong to the crowd get rid of their differences and feel equal." ["Crowds and Power" pg. 17]

This feeling that the *discharge* gives and that makes a group of pedestrians a crowd, does not last forever.

> "The moment of discharge, so desired and so happy, contains its own danger. It is based on an illusion; the people who suddenly feel equal have not really become equal; nor will they *feel* equal for ever." ["Crowds and Power" pg. 18]

Elias Canetti introduces the concept of *panic* as the main mechanism responsible of crowd dispersion. Panic rises as a consequence of the presence of individualistic impulses in crowd members: people realize that are not equal to the other and the return of *fear of being touched* makes the dense mass of people to violently disgregate.

> "Panic is a disintegration of the crowd." [...] "The more fiercely each man "fights for its life", the clearer it becomes that he is fighting against all the others who get him in." [...] "Whilst the individual no longer feels himself as "crowd", he is still completely surrounded by it. Panic is a disintegration of the crowd within the crowd. The individual breaks away and wants to escape from it because the crowd, as whole, is endangered." ["Crowds and Power" pp. 26-27]

Other fundamental characteristics of a crowd, defined by Elias Canetti, are:

1. *The crowd always wants to grow.* Canetti specifies that the growing of a crowd is different according to different crowd typologies and to different situations, and he describes this phenomenon specifically for each kind of crowd he described in his work.
2. *The crowd needs a direction*, a target that can be a location (as for example a safe place), a person (for example a whipping boy), or any other mobile or static object.

> "Crowd it is in movement and it moves towards a goal. The direction, which is common to all its members, strengthens the feeling of equality. A goal outside the individual members and common to all of them drives underground all the private differing goals which are fatal to the crowd as such." ["Crowds and Power" pg. 29]

The lack of a goal for the members of a crowd is one of the main causes of the insurgence of individualistic impulses. Therefore a crowd that reaches its goal must quickly find another target, or it probably will start to disgregate.

> "A crowd exists so long as it has an unattained goal." ["Crowds and Power pg. 29"]

3 Crowd Classification

Open and Closed Crowds are the most generic classification including many crowding scenarios. Elias Canetti speaks about "*Open and Closed Crowds*" saying:

> "The natural crowd is the Open crowd; there are no limits whatever to its growth; it does not recognize houses, doors or locks and those who shut themselves in are suspect. "Open" is to be understood here in the fullest sense of the word; it means open everywhere and in any direction." [...] "In contrast to the open crowd which can grow indefinitely and which is of universal interest because it may spring up anywhere, there is the Closed crowd. The closed crowd renunces growth and puts the stress an permanence. The first thing to be noticed about it is that it has a boundary. It creates a space for itsef which it will fill." [...] "(Closed crowd) is protected from outside influences which could become hostile and dangerous and it sets its hope on *repetition*" ["Crowds and Power pp. 16-17"]

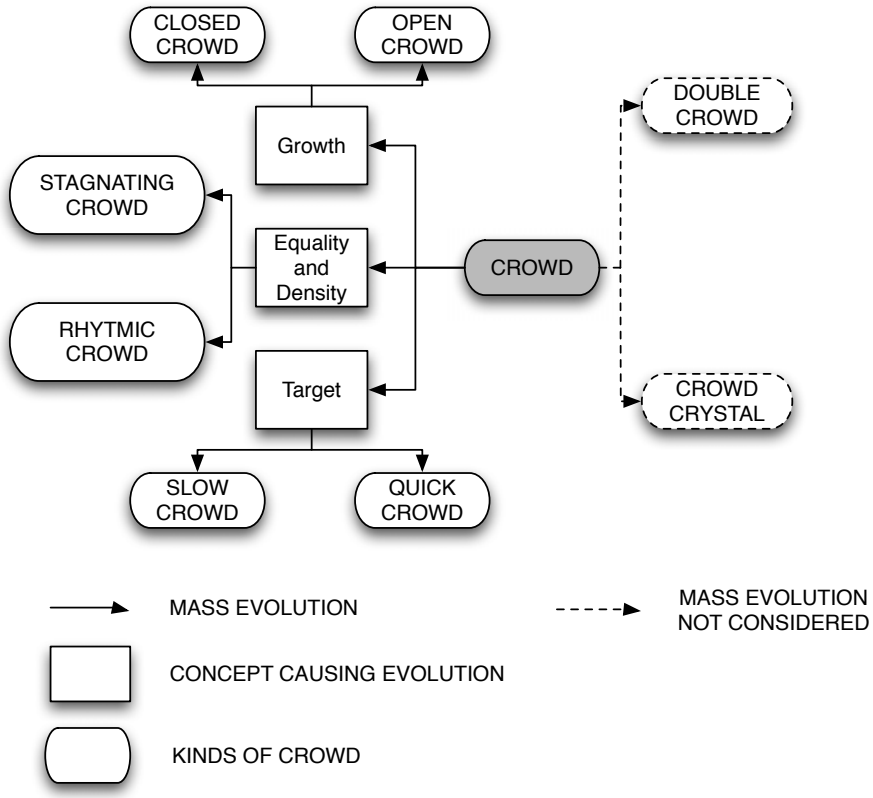

Fig. 2. A graphical representation of crowd classification according to Canetti.

and also

> "I designate as *eruption* the sudden transition from a closed into an open crowd." [...] "A crowd quite often seems to overflow from some well–guarded space into the squares and streets of a town where it can move about freely, exposed to everything and attracting everyone." ["Crowds and Power pg. 22"]

Canetti's classification is performed considering some key characteristics and two possible opposite attitudes of a crowd for each of these characteristics. Some of the characteristics considered are:

- attitude to grow;
- attributes of density and equality;
- nature of the target.

The kinds of crowd identified are (see Figure 2):

- Open and Closed Crowds mainly differ for their attitude to grow; the attitude of Open crowds is to grow without limits, while Closed crowds are limited into a given spatial area;
- Stagnating and Rhythmic Crowds mainly differ for the attributes of density and equality; Stagnating crowds start their aggregation process towards density increase, while the elements of Rhythmic crowds focus on equality to feel themselves as part of a group;
- Slow and Quick Crowds mainly differ for the nature of the target; Quick crowds need a near target reachable in little time, while Slow crowds can acquire also a remote goal.

4 From Theory to Practice: an Ontology for Classifying Crowds at Concerts

The crowd model introduced above has been exploited to develop a OWL ontology for crowds classification. This ontology has been designed and implemented by means of Protégé, the well known standard de facto ontology editor, and exploiting fuzzy logic to represent concepts of Canetti's crowd classification model. The only two kinds of crowd which can be considered separately are open and closed crowds, thus they have been defined as roots of two subtrees in the proposed taxonomy (see Figure 2).

To this aim, a case study has been chosen to start: the analysis of crowds taking part in musical concerts. These crowds are characterized by different behaviors according to several variables: the price to pay for the event, the location of the event, the musical genre (e.g. opera, rock music, pop music), the duration of the event and so on. This case study allows obtaining quite easily quantitative information necessary to characterize crowds (e.g. the number of people, the medium density and so on).

The first step in the definition of such ontology has been the clear identification of significant features in the Canetti's theory. Starting from the analysis of this work as explained in previous section, these characteristics have been summed up as follows:

- *spatial limitation*, which can assume the value *present* (e.g. if the crowd is inside a building like a stadium), *absent* (e.g. if the crowd is located in open space like a park) or *not influent* (if this feature is not important to characterize the kind of crowd);
- *attitude to grow* that can be *high* (if new individuals tend to increase the crowd population continuously), *medium*, *low* (if new individuals tend to increase the crowd population rarely) or *not influent* (if this feature is not important to characterize the kind of crowd);
- *density* that can be *high* (if the number of individuals per unit of space is greater than a given threshold), *medium*, *low* (if the number of individuals per unit of space is smaller than a given threshold) or *not influent* (if this feature is not important to characterize the kind of crowd);
- *movability*, which can assume the value *present* (e.g. if the individuals of the crowd move according to external solicitations, like e.g. a rock concert), *absent* (e.g. if external solicitations to move are not present of captured by the crowd, like e.g. a scientific conference) or *not influent* (if this feature is not important to characterize the kind of crowd);
- *duration* that can be *high* (if the crowd disappears after a long period of time), *medium*, *low* (if the crowd disappears after a short period of time) or *not influent* (if this feature is not important to characterize the kind of crowd);
- *target closeness* which can be *near* (if the crowd goal will be reached in a while), *far* (if the crowd goal will not be reached in a while) or *not influent* (if this feature is not important to characterize the kind of crowd).

	Open	**Closed**	**Stagnating**	**Rhytmic**	**Slow**	**Quick**
Spatial Limitation	absent	present	-	-	-	-
Attitude to grow	high	med/low	-	low	high	med/low
Density	-	-	high/med	low	high/med	low
Movability	-	-	absent	present	-	-
Duration	-	-	-	med/low	high	low
Target closeness	-	-	-	near	far	near

Table 1. Relations among crowd features and kinds of crowd: the symbol - means *not relevant*

Table 1 summarizes the relations among these feature and the main kind of crowd described by Canetti. A deeper analysis of such features allows pointing out interesting relationships among the different types of crowd, for which there

exists some intersections depending on the value of specific attributes. In particular, in order to characterize these intersections, it is important to analyse the values of *attitude to grow*, *density*, *duration* and *target closeness* attributes. In fact, while it is simple to evaluate spatial limitation and movability, since they can only assume boolean values, the comparison of others is more complicated due to their level of uncertainty that make difficult to establish which category a crowd belongs to. For this reason, our ontology exploits fuzzy logic to describe the values of the four uncertain features. Membership functions have been experimentally designed on the basis of the case study.

Definition 1 (Attitude to grow) *The membership functions for the attitude to grow concept are defined as follows:*

$$y_{low} = \begin{cases} 1 & if \quad x < 5 \\ \dfrac{10-x}{5} & if\, 5 \leq x \leq 10 \\ 0 & if \quad x > 10 \end{cases}$$

$$y_{medium} = \begin{cases} 0 & if \quad x < 8 \\ \dfrac{x-8}{5} & if\ 8 \leq x \leq 13 \\ \dfrac{18-x}{5} & if\, 13 < x \leq 18 \\ 0 & if \quad x > 18 \end{cases}$$

$$y_{high} = \begin{cases} 0 & if \quad x < 15 \\ \dfrac{x-15}{5} & if\, 15 \leq x \leq 20 \\ 1 & if\, 20 < x \leq 30 \end{cases}$$

where x is the number of people added to the crowd in a minute

Definition 2 (Density) *The membership functions for the density concept are defined as follows:*

$$y_{low} = \begin{cases} 1 & if \quad x < 2 \\ 3 - x & if\, 2 \leq x \leq 3 \\ 0 & if \quad x > 3 \end{cases}$$

$$y_{medium} = \begin{cases} 0 \quad if \quad x < 2 \\ x - 2 \; if \, 2 \leq x < 3 \\ 1 \quad if \, 3 \leq x \leq 4 \\ 5 - x \; if \, 4 < x \leq 5 \\ 0 \quad if \quad x > 5 \end{cases}$$

$$y_{high} = \begin{cases} 0 \quad if \quad x < 4 \\ \dfrac{x-4}{2} \; if \, 4 \leq x \leq 6 \\ 1 \quad if \, 6 < x \leq 9 \end{cases}$$

where x is the number of people per m^2

Definition 3 (Duration) *The membership functions for the duration concept are defined as follows:*

$$y_{low}(x, 1.5, 0.5) = \frac{1}{1 + \left(\dfrac{x - 1.5}{0.5}\right)^2}$$

$$y_{medium}(x, 5, 2) = \frac{1}{1 + \left(\dfrac{x - 5}{2}\right)^2}$$

$$y_{high}(x, 18, 6) = \frac{1}{1 + \left(\dfrac{x - 18}{6}\right)^2}$$

where x is the duration an event expressed in hours

Definition 4 (Target closeness) *The membership functions for the target closeness concept are defined as follows:*

$$y_{near}(x, 4.3, 2) = \frac{1}{1 + \left(\dfrac{x - 4.3}{2}\right)^2}$$

$$y_{far}(x, 110, 50) = \frac{1}{1 + \left(\dfrac{x - 110}{50}\right)^2}$$

where x is the timing necessary to reach the target expressed in minutes.

The definition of the membership functions above has allowed implementing a software to automatically classify an instance of crowds starting from quantitative data quite easy to acquire. This software has been integrated into the Protégé ontology (see Figure 3).

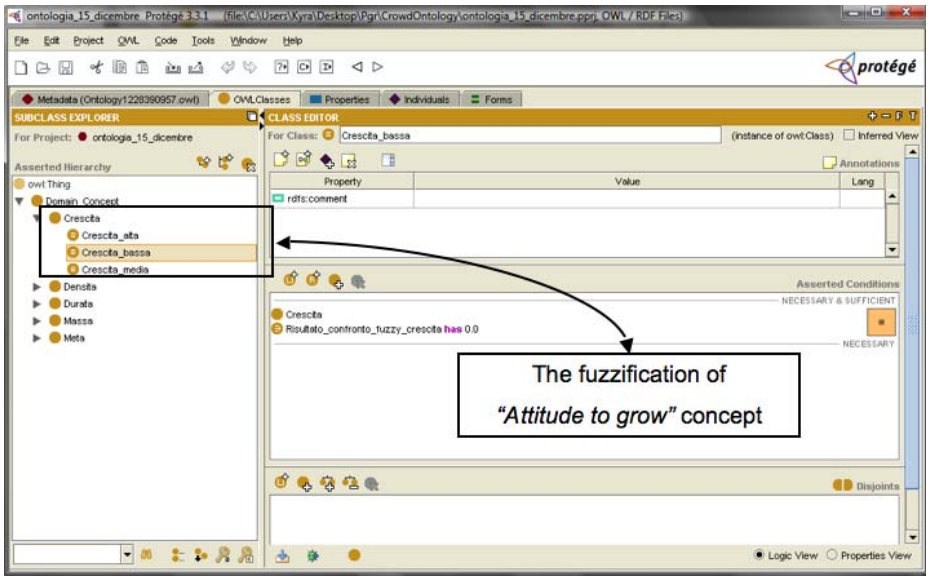

Fig. 3. The Protégé interface with an example of concept fuzzification.

5 Concluding remarks

In this paper we have presented an ongoing research project aiming at the development of a computational framework to analyse the behavior of crowds, based on the integration of ontologies and SCA approaches.

The crowd classification is the first step: with reference to the theory of crowds by Elias Canetti, the main concepts to characterize instances of crowds have been identified as well as the possible categories. Then, a distinction has been made between crisp concepts, like movability and spatial limitation and uncertain ones, which are attitude to grow, density, duration and target closeness. This distinction is the key to the crowd classification: by means of fuzzy logic for membership functions have been implemented to establish the degree of truth of a specific instance of crowd to the Canetti's kinds of crowd. The membership functions have been experimentally defined, through the examination of different types of musical events. The function have been exploited to implement a software that has been integrate into Protégé, obtaining a sort of fuzzy classifier.

This classifier will be soon integrated with an existing SCA platform for the simulation of crowd behavior: in this way, starting from quantitative and objective information (like e.g. the number of people at the concert or how the density change form a point to another according to the singer set list) should allow implementing useful functionalities both from the organizational and security point of views: about the organization, the possibility to simulate how the crowd behavior change according to external factors will be very useful to decide how managing the concert evolution; about the security, the possibilty

to simulate the crowd behavior before the event begins will allow identifying the most probable critical points to monitor in order to guarantee audience safety and order.

These functionalities address future work, thank to the collaboration with the staff of the Italian singer Lorenzo Cherubini and districts of Italian police.

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