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► **To cite this version:**

Anjara Nobby Rakotoarivelo, Jean-Michel Auberlet, Roland Brémond. Heterogeneous pedestrians behaviors through asymmetrical interaction. *CASA '19: Computer Animation and Social Agents*, Jul 2019, Paris, France. pp.25-28, 10.1145/3328756.3328777 . hal-04434111

HAL Id: hal-04434111

<https://hal.science/hal-04434111>

Submitted on 2 Feb 2024

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Heterogeneous pedestrians behaviors through asymmetrical interaction

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ABSTRACT

In this paper, we propose a concept to allow asymmetrical pedestrian interactions in simulation, based on ORCA model (Optimal Reciprocal Collision Avoidance). To reach our goal, we redefined two parameters of the model: the Time Horizon (TH) for anticipation and the Shared Effort (SE) for collision avoidance. In the default parameters model, the TH value is set to 1, the SE value is set to 0.5, and makes symmetrical pedestrian interactions. In the proposed model, we show how to initialize and manipulate the TH and SE parameters to create asymmetrical pedestrian interactions. We also explore the SE values and check for collisions or oscillations in the simulation results. The asymmetrical interaction allows heterogeneous pedestrian in simulation and more realistic emerging behavior in result.

CCS CONCEPTS

• **Computing methodologies** → **Intelligent agents**; *Simulation by animation.*

KEYWORDS

pedestrian modeling, asymmetrical interaction, collision avoidance, heterogeneous pedestrian, ORCA model

ACM Reference Format:

Anjara Nobby Rakotoarivelo, Jean-Michel Auberlet, and Roland Brémond. 2019. Heterogeneous pedestrians behaviors through asymmetrical interaction. In *Computer Animation and Social Agents (CASA '19)*, July 1–3, 2019, PARIS, France. ACM, Paris, France, 4 pages. <https://doi.org/10.1145/3328756.3328777>

1 INTRODUCTION

Pedestrian simulations become increasingly popular in computer graphic or urban planning application. Various application domain exists, such as: transportation, road safety, evacuation, gaming and entertainment. Each of these simulations aim to reproduce the human behavior depending on the objectives and/or prior knowledge of pedestrian behavior in the studied situation. Walking seems very easy in the real world, the pedestrian walks on the road without making any effort to achieve his travel goal. But to reproduce these

pedestrian behaviours into a virtual world is still a challenge. There are many factors to consider: culture, gender, age, preferred speed or size [1]. One of the stakes in the field of pedestrian simulation is being able to simulate the human heterogeneity during walking. Most of existing pedestrian models do not focus of this. Heterogeneity means more than its own characteristics that we quoted above, it also means different kind of behavior when people cross each other. Indeed, the pedestrians do not avoid each other in the same way, depending on their abilities, their mood, the infrastructure, his behavior and the behavior of its neighbors [6, 7].

The main contribution of this paper is to make asymmetrical pedestrian interactions and allow each pedestrian agent to execute his own type of collision avoidance. Proposed changes allow more heterogeneity and imply more realistic emerging behaviors and more realistic simulation results. To reach our goal, we extend the ORCA model [17] through two parameters: the TH parameter allows the pedestrian to detect or anticipate a collision, and the SE parameter allows the pedestrian to avoid collision with other pedestrians. It is therefore necessary to study the impact by varying these two pedestrian parameters. We illustrate our results for two pedestrians walking in the opposite direction.

The rest of this paper is organized as follow. In Section 2, we discuss related works in pedestrian simulations and pedestrian behaviors. Section 3 focuses on our proposed model. Our results are shown in Section 4. We conclude and discuss our future research works in Section 5.

2 RELATED WORKS

The model “Boids” for virtual human is proposed by Reynolds [16]. Composed of several autonomous individual agents with different characteristics, but applying the same rules: alignment, separation and cohesion. Most of this work focuses on simulating a large number of pedestrians in a virtual world [10].

The Social Force Model (SFM) is in one of the most popular in traffic simulations and crowd management simulations. Based on physics rules, using attractive and repulsive forces to reach his travel goal [9]. Several versions of the SFM model have been developed later. In one of them, the modified SFM and the other SFM with explicit collision prediction allow each pedestrian to interact asymmetrically when they cross each other. The interaction of the pedestrian depends on his behavior and the and the neighbor’s behavior. In some of their results: if a pedestrian is late, he goes directly to his travel goal, and make less effort to avoid the others. [3]. Other work developed a model based on the SFM to predict

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CASA '19, July 1–3, 2019, PARIS, France

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ACM ISBN 978-1-4503-7159-9/19/07...\$15.00

<https://doi.org/10.1145/3328756.3328777>

the place and the time for the future collision and avoid it directly [12, 18].

The famous ORCA model is widely used in computer graphics. The basic idea is to anticipate pedestrian collisions by computing his new speed and his new position according to the speed and position of his closest neighbors. In the original model, when two pedestrians cross each other, each assumes that the other avoids a collision by half [17]. However, in the real world, not everyone shares the same avoidance of effort, not everyone has the same perception, possibility or will. In recent years, several variants of ORCA have been proposed. One research uses a priority rule to allow asymmetrical pedestrian interactions [3]. According to the priority assigning to each pedestrian, each reacts differently. The one with a high priority makes less avoidance effort relative to the other and goes straight to his travel goal.

Other authors have been interested in pedestrian behavior adaptation. Pedestrians adapt their own behaviors according to the behavior of their neighbors. Pedestrian are categorized into two types “normal” and “dangerous”. When the “normal” and the “dangerous” cross each other, then, the “normal” agree to be closer to the others “normal”, and deviate more from the others “dangerous” [2]. Other works allow the pedestrian to follow another pedestrian when they have the same travel goal, and he can avoid the whole group when they cross each [13]. In other model, each pedestrian computes the “domination” of the other to make his own path planning. The higher the value of pedestrian “domination”, the more direct and rapid path planning. Conversely, if the “domination” value is low, the pedestrian tries to avoid every pedestrian and bypasses groups [15]. Other works have implemented in their pedestrian simulation passive and active pedestrian in a case of protest scenario [6].

Other researchers have focused on decision making. One work studied the case when two pedestrians cross on a narrow sidewalk, only one pedestrian can remain on the sidewalk during the interaction. The challenge is to identify the pedestrian going down. They conclude that the pedestrian with a higher level of attention and speed always who goes down on the sidewalk [4]. Another research result, the Self-stopping mechanism is developed by [14], to prevent pedestrians from pushing each other. A pedestrian has to stop if no path planning is possible anymore.

Some authors are interested in adding a personality in virtual pedestrian. The personality classification remains a difficult task. However the two most popular personality models are: the theory of personality traits [8] and OCEAN personality [5, 7]. They implement different behaviors in each personalities into pedestrian. In some of their results show that “shy” pedestrians are easy to be diverted and move farther away when they cross each other, but “tense” pedestrians are more focus and go directly on their travel goals [8].

3 PROPOSED MODEL

Our proposed model is an extension of the original ORCA model and presented as follows:

$$ORCA_{1|2}^{\tau} = \{v | (v - (v_1^{pref} + \frac{1}{2}.u)) .n \geq 0\}$$

- $ORCA_{1|2}$: P1 avoids collision with P2;
- τ : guaranteed time that P1 and P2 can keep their same speed and no collision occurs;
- v : current speed;
- v_1^{pref} : preferred speed of P1;
- u : minimal change needed for P1 to avoid collision with P2. The higher the TH, the lower the u ;
- $u = (combinedRadius * (\frac{1}{TH}) - wLength) * unitW$
- $\frac{1}{2}.u$: P1 takes half avoidance effort to avoid P2.

For the other parameters available, refer to the original paper of ORCA model. [17].

The main difference between our proposed model and the original model is the transformation of the SE model parameter into an agent parameter. Our model is presented as follow:

$$ORCA_{1|2}^{\tau} = \{v | (v - (v_1^{pref} + SE * u)) .n \geq 0\}$$

Our main goal is to have asymmetrical pedestrian interactions. To achieve our goal, we have manipulated both TH and SE parameters. The TH allows the pedestrian to anticipate collisions, then the SE allows collision avoidance.

3.1 TH definition

The parameter TH is the time to allow the pedestrian to anticipate a collision. The higher the TH, the sooner pedestrian anticipate a collision. To be able to initialize the value of TH, we have to consider different values from the literature:

- $TH \in [1, 2, \dots, 30]$ [8]
- $TH \in [1, 2, 3]$ [4]

Our goal is to study the pedestrian’s behaviors during a collision avoidance. So, our choice is to limit with the highest value of TH. Indeed, if the TH is too high, there will be no interaction because the pedestrian with highest TH will perform all avoidance effort before the other pedestrian begins [4]. Thus, in this paper, for the TH value, the minimum will be 1 and the maximum will be 3.

3.2 SE definition

The SE is the parameter to allow a pedestrian to avoid the collision. The higher the SE, the more a pedestrian collision avoidance effort bigger. To be able to initialize the value of SE, we have to consider the different values from the literature. Let P1 and P2 be two pedestrians crossing each other:

- $(SE_1 = SE_2 = 1/2)$: no oscillation and no collision occurs (default ORCA model [17]);
- $(SE_1 = SE_2 = 0)$: collision occurs, no avoidance effort;
- $(SE_1 = SE_2 = 1)$: oscillation occurs[17];
- $(SE_1 + SE_2 = 1)$ and $SE_1 \neq SE_2$: priority is given to pedestrians with a higher SE [3].

We decided to consider the SE belongs to]0, 0.1, ..., 0.9, 1[.

4 RESULTS

4.1 Model parameters

We used the Unity Engine with RVO2 Library c# from [11] to develop our simulations. Our initial parameters are represented as follows:

- TimeStep: 0.1 s
- Speed: 1.5 m/s
- Radius(R_1, R_2): 0.6m
- TH $\in [1, 2, 3]$
- SE $\in]0, 0.1, \dots, 0.9, 1[$

4.2 Asymmetry measurement

To measure the asymmetry of two pedestrians in a face to face interaction, an asymmetry A is defined as follows :

$$A_1 = \frac{\|Y_1\| * 100}{\|Y_1\| + \|Y_2\|}, \text{ and } A_2 = 100 - A_1$$

A is computed when two pedestrians P1 with coordinate (X_1, Y_1) and P2 (X_2, Y_2) cross each other at the same $X_1 = X_2$. Fig. 1 presents two trajectory curves (X, Y) of two pedestrians P1 and P2, and $A_1 = A_2 = 50$.

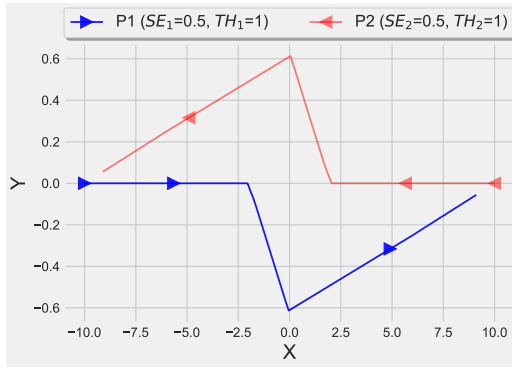


Fig. 1: Asymmetry measurement A

4.3 Impact of the TH

In this section, we studied the impact of varying the TH. So, we fixed the SE parameter to 0.5 and the TH belongs to $[1; 3]$, according to the TH definition. In all case, the pedestrian with highest TH value reacts in first. As the final conclusion in [4], the pedestrian with greater attention reacts first.

4.4 Impact of the SE

In this section, we studied the impact of varying the SE value. So, we fixed the TH parameter to 1 and the SE belong to $]0, 0.1, \dots, 0.9, 1[$, according to the SE definition. At first, we have to check if for the set of SE values, no collision, and no oscillation occurs. To detect collision, we run simulations with a low pair of the value of SE : ($SE_1 = 0.1$ & $SE_2 = 0.1$) and we gradually increase this value by 0.1 and check if collision occurs. A collision occurs if only:

$$\sqrt{(Y_2 - Y_1)^2 + X_2 - X_1)^2} \leq R_1 + R_2 \quad (1)$$

No collision occur when ($SE \geq 0.1$), so the minimum SE value is set to 0.1. Then, we need to check if oscillation occur. We run simulations from the maximum value ($SE_1 = 0.9$ & $SE_2 = 0.9$), and we gradually decrease these values by 0.1 until check if oscillations occur and stop in other cases. From ($SE_1 = 0.7$ & $SE_2 = 0.7$), we observed that the trajectories were smooth enough to consider that

no oscillations occur. Thus, we consider the maximum value of SE to be 0.7.

Table 1 shows the asymmetry A of each pedestrian when they cross each other. The dark gray values represent the A_2 for pedestrian P2 and the light gray values the A_1 for pedestrian P1. The sum of two values $A_1 + A_2 = 100$ represent the total avoidance. The diagonal of the matrix represents an equal SE in both pedestrian ($SE_1 = SE_2$). Otherwise, the higher the SE, the higher the avoidance effort.

$SE_2 \backslash SE_1$	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0.1	50	61.76	67.46	70.67	73.01	74.08	75.26
0.2	38.24	50	56.34	60.03	63.02	64.88	66.67
0.3	32.54	43.66	50	53.99	56.94	59.59	61.42
0.4	29.33	39.97	46.01	50	52.78	55.64	57.59
0.5	26.99	36.98	43.06	47.22	50	52.28	54.34
0.6	25.92	35.12	40.41	44.36	47.72	50	51.98
0.7	24.74	33.33	38.58	42.41	45.66	48.02	50

Table 1: A evaluation with TH=1 and SE=[0.1, .., 0.7]

Emerging behaviors have been observed in our result (see Fig. 2). We confront a pedestrian P1: ($SE_1 = 0.5, TH_1 = 1$) with fixed parameter, against pedestrian P2: ($SE_2 = [0.1, 0.2, \dots, 0.6, 0.7], TH_2 = 1$) with different parameter. We increased step by step, by adding 0.1 to SE_2 until 0.7. The results show that pedestrian with the same parameter do not always behave in the same way depending on the parameter of other pedestrians.

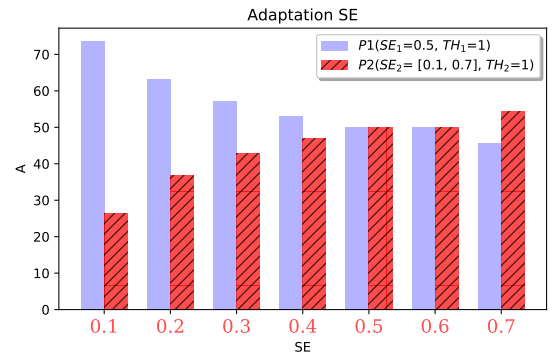


Fig. 2: Adaptation SE

- when ($SE_1 > SE_2$): P2 can't make enough effort avoidance, so P1 has to avoid more than expected.
- when ($SE_1 = SE_2$): Both P2 and P1 avoid half.
- when ($SE_1 < SE_2$): Even if P1 can avoid more, P2 already makes an avoidance effort, so P1 doesn't need to avoid much.

4.5 Impact of the TH and the SE combination

According to the impact of SE and the impact of TH, we have the following results:

- if ($(SE_1 = SE_2) \text{ And } (TH_1 > TH_2)$) $\implies (A_1 > A_2)$
- if ($(TH_1 = TH_2) \text{ And } (SE_1 > SE_2)$) $\implies (A_1 > A_2)$

- if $((TH_1 > TH_2) \text{ And } (SE_1 > SE_2)) \implies (A_1 > A_2)$

So, in this section, we simultaneously varied the values of TH and SE for both P1 and P2.

Fig. 3, we fixed the P1 parameters to $SE_1 = 0.7$ and $TH_1 = 1$, and for the P2 parameters to two different values $SE_2 = 0.1$ and $TH_2 = 1$, for the first interaction, represented by the continuous line in our figure. And $SE_2 = 0.1$, $TH_2 = 1$ for the second interaction, represented by the dashed line. P1 and P2 cross each in first and second interactions:

- $(TH_1 = TH_2 \text{ and } SE_1 > SE_2) \implies (A_1 > A_1)$ (normal case)
- $(TH_1 < TH_2 \text{ and } SE_1 > SE_2) \implies (A_1 < A_2)$

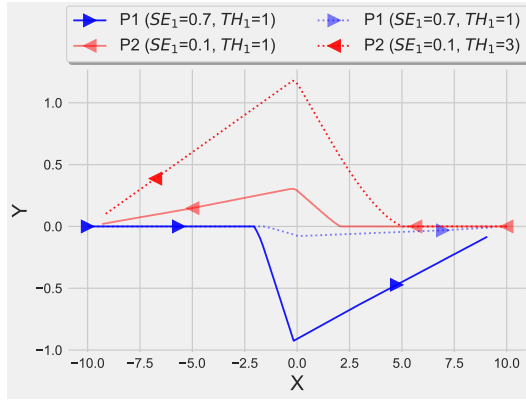


Fig. 3: Multiple interactions.

The second interaction shows that even with a high SE value, P1 makes a minimal effort to avoid the collision with P2. Indeed, the pedestrian with a high TH value always starts the collision avoidance sooner. Thus, this result shows the importance of TH against SE when both of these two parameters are varied, and highlights an unexpected behavior.

4.6 Supplementary results

We added other simulation scenario results: two pedestrians against a pedestrian and one pedestrian against a group. The video is available as additional material from this document and more details about the scenarios are presented in this video.

5 CONCLUSION

In this paper, we have developed a concept of asymmetrical pedestrian interactions in the case of collision avoidance based on the ORCA model. In the original model, the interaction is always symmetrical and each pedestrian behaves in the same way. In our proposed model, we updated the SE parameter model to an agent parameter. We studied the result of the asymmetrical pedestrian interactions by varying the two parameters TH and SE, and always checking if oscillation or collision occurs. Varying the TH allows for an asymmetry at the anticipation level and varying the SE allows for an asymmetry at the collision avoidance level.

We observed the emerging behavior in our results. A pedestrian reacts differently according to the neighbors' behaviors. Thus, a pedestrian with a high collision avoidance capability may not make

any avoidance efforts if the other pedestrian started the collision avoidance due to a higher TH value.

The main advantage of our approach is therefore simplicity. By varying only 2 parameters, we were able to increase the heterogeneity of pedestrian behaviour. This concept can be applied in many cases, in one of them: to stimulate the behavior of people with reduced mobility in a crowd. These people do not behave and do not have the same possibilities as others. The study of their behavior allows improving their living conditions. In perspective, we aim to analyze the impact of modifying both SE and TH in the case of pedestrian flows.

REFERENCES

- [1] Stefania Bandini, Luca Crociani, and Giuseppe Vizzari. 2014. Heterogeneous speed profiles in discrete models for pedestrian simulation. *arXiv preprint arXiv:1401.8132* (2014).
- [2] Laure Bourgois and J-M Auberlet. 2014. Pedestrian agent based model suited to heterogeneous interactions overseen by perception. In *Pedestrian and Evacuation Dynamics 2012*. Springer, 847–859.
- [3] Sean Curtis, Basim Zafar, Adnan Gutub, and Dinesh Manocha. 2013. Right of way: Asymmetric agent interactions in crowds. *Visual Computer* 29, 12 (2013), 1277–1292. <https://doi.org/10.1007/s00371-012-0769-x>
- [4] Cleo Deroo, Angelique Montuwyl, Beatrice Degraeve, Jean-Michel Auberlet, Anne-Helene Olivier, and Marie-Axelle Granie. 2019. Pedestrian Collision Avoidance on Narrow Sidewalk: A Meeting Between Psychology and Virtual Reality. (2019).
- [5] Funda Durupinar, Jan Allbeck, Nuria Pelechano, and Norman Badler. 2008. Creating crowd variation with the ocean personality model. In *Proceedings of the 7th international joint conference on Autonomous agents and multiagent systems-Volume 3*. International Foundation for Autonomous Agents and Multiagent Systems, 1217–1220.
- [6] Funda Durupinar, Uğur Güdükbay, Aytekin Aman, and Norman I Badler. 2016. Psychological parameters for crowd simulation: From audiences to mobs. *IEEE transactions on visualization and computer graphics* 22, 9 (2016), 2145–2159.
- [7] Funda Durupinar, Mubbasir Kapadia, Susan Deutsch, Michael Neff, and Norman I Badler. 2017. Perform: Perceptual approach for adding ocean personality to human motion using laban movement analysis. *ACM Transactions on Graphics (TOG)* 36, 1 (2017), 6.
- [8] Stephen J Guy, Sujeong Kim, Ming C Lin, and Dinesh Manocha. 2011. Simulating heterogeneous crowd behaviors using personality trait theory. In *Proceedings of the 2011 ACM SIGGRAPH/Eurographics symposium on computer animation*. ACM, 43–52.
- [9] Dirk Helbing and Peter Molnar. 1995. Social force model for pedestrian dynamics. *Physical review E* 51, 5 (1995), 4282.
- [10] Yuichi Hirokawa, Noriaki Nishikawa, Toshiyuki Asano, Masaaki Terai, and Teruo Matsuzawa. 2016. A study of real-time and 100 billion agents simulation using the Boids model. *Artificial Life and Robotics* 21, 4 (2016), 525–530.
- [11] Jamie Snape Ming C. Lin Jur van den Berg, Stephen J. Guy and Dinesh Manocha. 2016. RVO2 Library: Reciprocal Collision Avoidance for Real-Time Multi-Agent Simulation. <http://gamma.cs.unc.edu/RVO2/downloads/>. Accessed: 2019-01-01.
- [12] Ioannis Karamouzas, Peter Heil, Pascal Van Beek, and Mark H Overmars. 2009. A predictive collision avoidance model for pedestrian simulation. In *International workshop on motion in games*. Springer, 41–52.
- [13] Samuel Lemerrier and Jean-Michel Auberlet. 2016. Towards more behaviours in crowd simulation. *Computer Animation and Virtual Worlds* 27, 1 (2016), 24–34.
- [14] Daniel R Parisi, Marcelo Gilman, and Herman Moldovan. 2009. A modification of the social force model can reproduce experimental data of pedestrian flows in normal conditions. *Physica A: Statistical Mechanics and its Applications* 388, 17 (2009), 3600–3608.
- [15] Tanmay Randhavane, Aniket Bera, Emily Kubin, Austin Wang, Kurt Gray, and Dinesh Manocha. 2018. Pedestrian Dominance Modeling for Socially-Aware Robot Navigation. *arXiv preprint :1810.06613* (2018).
- [16] Craig W Reynolds. 1999. Steering behaviors for autonomous characters. In *Game developers conference*, Vol. 1999. 763–782.
- [17] Jur Van Den Berg, Stephen J Guy, Ming Lin, and Dinesh Manocha. 2010. Optimal reciprocal collision avoidance for multi-agent navigation. In *Proc. of the IEEE International Conference on Robotics and Automation, Anchorage (AK), USA*.
- [18] Francesco Zanlungo, Tetsushi Ikeda, and Takayuki Kanda. 2011. Social force model with explicit collision prediction. *EPL (Europhysics Letters)* 93, 6 (2011), 68005.