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Reply to comment

A critical analysis towards research perspectives Reply to comments on "Modeling human behavior in economics and social science"

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Received 25 September 2017; accepted 26 September 2017

Communicated by J. Fontanari

Abstract

We take advantage of the challenging comments to the modeling approach we proposed in [35] to look ahead at a number of applications of the methods to the alternative questions these comments raise. In turn, our effort results in a number of interesting and valuable research perspectives. The presentation goes along three main lines. In the first line, we summarize briefly the aims and results in [35]. In the second section we give a technical the issues raised and, finally, the focus moves to the above mentioned research perspectives.

Keywords: Human behaviors; Socio-economic systems; Kinetic models; Active particles

1. Introduction

We take advantage of the various comments to our paper [35] to elaborate further upon technicalities, and to present an additional critical analysis, and finally to look ahead of potential interesting research perspectives coming from somewhat straightforward applications of the methodology we have proposed.

DOI of original article: https://doi.org/10.1016/j.plrev.2017.06.026.
DOIs of comments: https://doi.org/10.1016/j.plrev.2017.08.009, https://doi.org/10.1016/j.plrev.2017.07.007, https://doi.org/10.1016/j.plrev.2017.07.006, https://doi.org/10.1016/j.plrev.2017.08.012, https://doi.org/10.1016/j.plrev.2017.07.005, https://doi.org/10.1016/j.plrev.2017.08.010, https://doi.org/10.1016/j.plrev.2017.08.008, https://doi.org/10.1016/j.plrev.2017.08.007, https://doi.org/10.1016/j.plrev.2017.09.002, https://doi.org/10.1016/j.plrev.2017.08.005, https://doi.org/10.1016/j.plrev.2017.08.003, https://doi.org/10.1016/j.plrev.2017.08.002.
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https://doi.org/10.1016/j.plrev.2017.09.004
1571-0645/

As mentioned, [35] is devoted to the analysis of the complex interactions between human behaviors and social-economics phenomena. This topic has been critically analyzed in [35] towards possible applications. In that paper, we discuss the idea that mathematical tools can deeply contribute to somewhat higher understanding of the dynamics of social and economic systems. In more detail, the mathematical approach mainly refers to [3], where methods of statistical mechanics and evolutionary game theory have been adopted for modeling of social systems taken as living and hence complex systems. Additional important references have addressed the mathematical theory of collective learning processes, among which [22,23] and of evolutionary game theory, among which [41,42]. Theoretical aspects have been specifically addressed by a recent literature, where a variety of applications have been developed based upon the aforementioned mathematical approach see [2,3,14,24,33,34,36].

Our paper [35] has motivated a number of sharp and interesting comments, that deserve attention and motivate further discussion, that can potentially lead to new research perspectives. These comments have all contributed to stimulate our attention towards the contents of our paper, have forced us to think to the approach we propose in new perspective, and hence have promoted reasoning on potential new and valuable research.

The rationale supporting the approach proposed in [35] stems from the idea that the development of the methods coming from the kinetic theory allows the researcher to include detailed features of living system, can provide a systemic approach, and hence a field theory, for the modeling of socio-economical systems. Such a systemic approach is not only capable to reduce the large number of variables provided for the description of a complex living system, but it is also able to capture the main complexities of living, hence behavioral systems (on the point see [24]).

We begin our discussion by briefly summarize the approach we propose, so that the reply to the various comments can be properly framed. The approach is developed along the following sequential steps:

1) The entities that comprise the system, called *active particles*, are aggregated into different groups of interest called *functional subsystems* (FS). Active particles within the same FS share a common strategy called *activity* which define their *microscopic state*. The overall state of the system is delivered by a probability distribution over the said activity variable in each FS.
2) Active particles interact within the same functional subsystem as well as with particles of other subsystems, while generally they interact also with FSs viewed as a whole being represented by their mean value.
3) The evolution of the probability distribution is obtained by a balance of particles within elementary volumes of the space of microscopic states, where the inflow and outflow of particles is related to the interactions. The dynamics of interactions at the microscopic scale are modeled by theoretical tools of *stochastic behavioral games*.
4) Mathematical models are obtained by implementing the aforementioned modeling of interactions in the general mathematical structure.
5) Validation of models follows by comparisons with empirical data and by their ability to reproduce qualitatively emerging behaviors.

The mathematical structure presented in [35] and derived according to the aforementioned rationale is as follows:

$$\begin{aligned}\partial_t f_i(t,u) = &\sum_{h,k=1}^{n} \int_{D_u\times D_u} \eta_{h,k}[\mathbf{f}](u_*,u^*)\, \mathcal{A}^i_{h,k}[\mathbf{f}](u_*\to u|u_*,u^*)\, f_h(t,u_*)\, f_k(t,u^*)\, du_*\, du^* \\ &- f_i(t,u)\sum_{k=1}^{n}\int_{D_u} \eta_{i,k}[\mathbf{f}](u,u^*)\, f_k(t,u^*)\, du^*, \\ &+ \sum_{h,k=1}^{n}\int_{D_u} \nu_{h,k}[\mathbf{f}](u_*,\mathbb{E}^1_k)\, \mathcal{B}^i_{h,k}[\mathbf{f}](u_*\to u|u_*,\mathbb{E}^1_k[f_k])\, f_h(t,u_*)\, du_* \\ &- f_i(t,u)\sum_{k=1}^{n} \nu_{i,k}[\mathbf{f}](u,\mathbb{E}^1_k), \end{aligned} \tag{1}$$

where $\mathbf{f}$ denotes the set of all distribution functions and where square brackets have been used to denote the dependence on the distribution functions which highlight the nonlinear nature of interactions. In addition, for completeness, the terms that appear in Eq. (1) are:

Please cite this article in press as: Dolfin M, et al. A critical analysis towards research perspectives. Phys Life Rev (2017), https://doi.org/10.1016/j.plrev.2017.09.004