# REVIEW

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on the dissertation

by Pavel Todorov Stoynov

titled "Application of cellular neural networks to
partial differential equations appearing in financial mathematics"
presented for awarding the educational and scientific degree "doctor"
Scientific field: 4. Natural Sciences, Mathematics and Informatics,
Professional field: 4.5. Mathematics,
Doctoral program: "Mathematical Modeling and Applications of Mathematics"

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Accordingly with Order №88/4.05.2022, based on the decision of the SC of IMI (protocol №4/29.04.2022), I have been appointed for a member of the Scientific jury on the procedure of the defense of the dissertation. On the first session, held on 16.05.2022 I was voted to write a review (protocol №1/16.05.2022).

The review is prepared accordingly to the requirements of the Act of the Development of the Academic Staff in the Republic of Bulgaria (ZRASRB), Regulations for its implementation (PPZRASRB), as well as the specific regulations of the Bulgarian Academy of Sciences (PURPNSZAD-BAN) and the Institute of Mathematics and Informatics (PURPNSZAD-IMI-BAN).

I was provided with all the necessary documents, including

1. Dissertation.
2. Autoreview.
3. A list of the scientific contributions of the dissertation.

4. The application to the president of IMI-BAS for admission to a defense of the dissertation.

5. Professional CV.

6. Protocols for the completed exams during the doctoral education as well as a protocol of the session of the primary section devoted on a dissertation discussion.

7. A list of publications related to the dissertation, their full texts, and the corresponding citations.

# 1 General evaluation of the topic

There is a fundamental relation between the (Markovian) stochastic processes and the differential equations. For example, the density of the may be most important probability distribution, namely the Gaussian (normal) one, is in fact the fundamental solution of the heat partial differential equation (PDE). This relation can be written as *a Markovian process* $\rightarrow$ *Markov-Feller semi-group* $\rightarrow$ *the infinitesimal generator*. Namely this allows the solutions of large classes of PDE's to be derived as a mathematical expectation. The mathematical finance is an area where this relation has a direct application – the Black-Scholes style equations can be viewed as the Kolmogorov and Feynman-Kac equations in some sense. Also, the exponentially increased computing power in the recent years, makes well-founded the use of different new numerical algorithms for solving complicated differential problems.

All these confirm that the topic is actual and has a potential for interesting results.

# 2 General evaluation of the dissertation

The dissertation consists of 156 pages, including an Introduction, three chapters, a conclusion, a bibliographical reference, a list of publications related to the dissertation, and an appendix with MATLAB and R codes.

The main and critical problem of the dissertation is the observed misuse of literary sources even without being listed in the bibliography. These sources are the following three books:

- S.I. Boyarchenko and S.Z. Levendorskii Non-Gaussian Merton-Black-Scholes Theory. World Scientic, River Edge, NJ, 2002.

- R.Cont and P. Tankov. Financial Modeling with Jump Processes. Chapman & Hall/CRC Press, New York, 2004.

- Ömür Uğur. An Introduction to Computational Finance. Imperial College Press, 2009.

Whole passages are plagiarized in chapters 1 and 3 including the MATLAB code – more then 60 pages at all. The same is true for one of the presented papers – I discuss it below.

Also, the mentioned above MATLAB code is given once in the main text and a second time in the appendix. Of course, this is unnecessary.

I think that the plagiarism, even more in a such quantity, is a sufficient reason for a negative assessment for the dissertation.

## 2.1 Evaluation of chapter 1

Chapter 1, written in that way, is difficult for evaluation. A large part is plagiarized mixing different passages from the mentioned above books. The author's point of view and a logical structure are not visible – the chapter looks like an arbitrary mixture. For example, a lot of place is devoted to the additive processes in the same beginning, but these processes are not used later. The same is true for many other objects discussed in the dissertation. Another problem of this arbitrary mixture of the books of (Boyarchenko& Levendorskii, 2002) and (Cont&Tankov, 2004), is that they use a different parametrization for the characteristic triple of the Lévy processes. This difference is addressed in some parts of the dissertation, but not in all.

Also, there is no logical structure when the candidate defines the stochastic integrals. First, the presentation of the Brownian integral is taken from (Uğur, 2009). Note that the definitions of the Itô and Stratonovich integrals are interchanged. Second, the candidate works also with jump processes (Lévy, additive), but he does not define the integration w.r.t. them. Third, such jump style integrals are used in some passages taken from (Cont&Tankov, 2004). And forth, the candidate prefers to define a semi-martingale as a sum of a local martingale and a finite variation process instead of the alternative definition which, roughly said, is a process which allows integration. The second definition is natural in the asset or portfolio pricing area, and in the financial mathematics at all.

It seems that the main dissertation novelties are the so called ST-distributions and the corresponding processes. By the way, the name is not clear – what stands behind the name switch time (ST). These distributions are introduced as gamma distributions weighted by the function $(1+x)^n$. Some results for the density, characteristic function, and other stochastic objects are derived. The definition of new distributions or the generalization of existing ones is trivial by itself. A new distribution needs to exhibit some practical or scientific novelties to have any significance whatsoever. There are no such evidences provided in the dissertation.

The so called ST-processes are of some interest. They are a generalization of the Poisson processes – the next jump is modeled by a ST-distribution instead the exponential one. Hence, the ST-process is a particular case of the large class of the renewal processes. Let me note, that the Bulgarian stochastic community has significant results in this field in the person of Prof. Nikolay Yanev and Prof. Kosto Mitov. The fact that the exponential distribution is the unique continuous one which exhibits the property memoryless leads to a non-Markovian essence of the renewal processes. This leads to some theoretical difficulties since the Markov-Feller semi-group is the connection between the stochastic process and the differential equation. May be this problem can be avoided by enlarging the filtration, but this point is not discussed in the dissertation at all.

Therefore, without claiming that the generalized gamma distributions introduced in the dissertation are without scientific significance, I see no evidence of this.

## 2.2 Evaluation of chapter 2

In fact, chapter 2 is a survey on the cellular neural networks (CNN hereafter). Some classical linear CNNs of Chua and Yang as well as some nonlinear generalizations are presented. Other algorithms are considered too – polynomial CNN, feed forward CNN, linear threshold CNN, delay type CNN, moving objects detection architecture, different type cellular neural processors. My suggestion to the candidate is to refer to a literary source when he considers some modification of CNN. The working principals of the CNN are presented. A particular CNN model as a dynamical system is considered too.

The candidate suggests the use of the ST-distribution in different ways. The mentioned above disadvantage holds – the expedience and the importance of this assumption can be evaluated only after a theoretical and empirical research.

## 2.3 Evaluation of chapter 3

I think that chapter 3 should be the main part of the author's contributions in the dissertation. Unfortunately, it is composed by plagiarized statements as well as by some facts without any relation to the equations of mathematical finance. Examples for the first one are the MATLAB codes together with the corresponding algorithms (from (Uğur, 2009)), the finite difference approach applied to the pseudo-differential Black-Scholes style equation (from (Cont&Tankov, 2004)), and the pricing of barrier options (from (Boyarchenko& Levendorskii, 2002)). On the other hand, some examples of the non-related with the topic statements are the reaction-diffusion equations, oregonators, brusselators, FitzHugh-Nagumo equation, and the heat equation with $\sin(\pi x)$ for the boundary condition – a financial derivative with such pay-off does not exist.

Something more, there is not a real application of the CNN in the dissertation. The candidate uses different finite difference methods to the classical Black-Scholes equation. This equation must be used only as a benchmark since it can be solved in a closed form.

Let me mention that the introduced by the candidate ST-distributions are not used in this chapter. Namely here can be checked their importance.

## 2.4 Reffernce list

The reference list consists of 63 sources – one of them in Bulgarian, two in French, the rest are in English. 27 sources are published after 2000 year, 12 of them are published in the last decade (the most are written by the candidate and are related to the dissertation). Note that when there are several sources by one and the same author published in one and the same year, they have to be marked with a letter a., b., c. etc.

# 3 Evaluation of the Autoreview

There is a confusing disparity in the page and reference numbers reported in two places in the autoreview. First are mentioned 155 pages and 53 references, later the numbers are 151 and 78, respectively. In fact the dissertation consists of 156 pages (including the title page) and 63 reference sources.

Generally, the mentioned shortcomings in the dissertation are subsequently found in the autoreview.

# 4 Publications related to the dissertation

The candidate presents six publications for the doctoral procedure. I will not comment them in detail. Note only that the paper Stoynov, P. (2020) is largely plagiarized from (Cont&Tankov, 2004).

# 5 Conclusion

The presence of plagiarism in the dissertation is quite enough for a **negative** assessment. This is supported also by the fact that the author's contributions are scientific and practical unproven.

**Reviewer:**

**/Assoc. Prof. Tsvetelin Zaevski, PhD/**

Sofia, 8.07.2022