

# Variations on Impulse Noise Model in Digital Image Processing Field: A Survey on Current Research Inclination

Sin Hoong Teoh and Haidi Ibrahim

**Abstract**—As the information from digital images are easier to be evaluated as compared with one dimensional signals, digital images are now commonly used in many research fields. Unfortunately, similar to other digital signals, digital images are also sometimes unintentionally corrupted by unwanted signals, called noise. One of the noises commonly corrupting digital image is the impulse noise. Therefore, impulse noise reduction has become one of the active researches in these recent years. Many impulse noise models have been proposed by researchers for this research purpose. Therefore, the purpose of this paper is to investigate the popularity of these noise models. The research is done by a survey on available online materials. However, because there are more than thousands of related articles available online, the survey was carried out based on the keywords related to those articles. The research was restricted only to IEEExplore® database. The result from this survey shown that the research related to impulse noise model in digital image processing is still showing an increasing trend. Among the impulse noise models, the salt-and-pepper noise is the most used impulse noise model in current literature.

**Index Terms**—Impulse noise, salt-and-pepper noise, fixed-valued impulse noise, random-valued impulse noise, uniform noise, universal impulse noise.

## I. INTRODUCTION

With the advancement in computers and digital imaging technologies, the costs of digital cameras and computers are lowering each year, and thus these equipments are becoming affordable these days. The usage of digital images in our daily life is turning common. As more information can be extracted from digital images, as compared to one dimensional signal, many research areas, including material researches, are now utilizing digital images, such as microscopic images and X-ray images, as one of their evaluation tools. For example, Brook et al. [1] used radar images in order to inspect aeronautics composite materials and structures. Works by Kumar, Taheri, and Islam [2] used ultrasonic images in order to evaluate and detect several defects in a material. On the other hand, Thai et al. [3] utilizes video sequences to monitor special nuclear material.

Unfortunately, similar to other digital signals, digital images may suffer from unwanted signals known as noise [4]. There are a lot of noise types normally corrupt digital image [5]. One of these noise types is the impulse noise [6].

Impulse noise can be assumed as an additive noise [7], and randomly damages the pixel, at random positions [8]. Normally, impulse noise appears as black and white speckles on the image [9]. Pixels corrupted by impulse noise are normally having either extremely high, or extremely low intensity values [10]. Usually, they have very high contrast towards their clean, uncorrupted smooth surrounding areas [11]. Therefore, impulse noise, even at a low level of degradation, will damage the appearance of digital image dramatically [12]. Many important information will be altered by this noise. As a consequence, the impulse noise also might make a fully automatic vision based system to give inaccurate result.

Based on this problem, many researchers around the globe have put their serious efforts in searching suitable methods that are able to reduce the degree of degradation by the impulse noise. Such type of digital image restoration method requires the researchers to artificially add the impulse noise to set of test images in order to evaluate the performance of their proposed methods. The evaluations normally compare the filtered image with the artificially corrupted image. However, researchers have described impulse noise by many ways. There are many mathematical equations suggested by researcher in literatures to present impulse noise [13]. Several terms have been used to describe impulse noise models in reading materials, such as fixed valued impulse noise, salt-and-pepper noise, uniform impulse noise, random valued impulse noise, and universal impulse noise.

The main aim of this paper is to investigate the current research trend related to impulse noise models. First, we are interested to see whether the research regarding impulse noise in digital image processing is showing a growing trend, or a shrinking trend. Then, we are also interested to investigate which impulse noise model is the mostly used model in current literature.

The organization of this paper is as follows. After this introduction section, we will present our research approach in Section II. Then, we will present the findings from our survey in Section III. Finally, the findings will be concluded in Section IV.

## II. METHODOLOGY

As time flies, research areas regarding impulse noise are becoming very large. Currently, when we search for online reading materials from the internet regarding impulse noise, we will be suggested thousands of related literatures. With this situation, it is very impossible to check every single literature to determine which impulse model it used in its

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experiment. Fortunately, there are keywords attached to these materials. Therefore, we assume that these keywords reflect exactly the noise model used by that literature. Therefore, we will classify the research papers accordingly, based on their keywords.

It is worth noting that currently there are many scientific databases available in internet. Therefore, we need to restrict our search for online materials. To be more specific, we limit our search only to <http://ieeexplore.ieee.org/Xplore/guesthome.jsp>, which is the IEEEExplore® database. This database is one of currently reliable databases, and it is up-to-date. The user interface provided by IEEEExplore® is shown in Fig. 1. There are many features provided in this online database, which can help our research significantly.



Fig. 1. The user interface of IEEEExplore®.

The related keywords will be typed on the search box, as shown in Fig. 2. The database will then return its search results. Because we want to see the research trend over years, we will utilize the field of “publication year” which is located on the left side of the database, once the search results are been displayed, as shown in Fig. 3. From this field, we can choose to limit our search toward a specific year. The number of publications, based on its types (e.g. conference paper, journal & magazine, etc.) can be obtained from “content type” field, which is located above the “publication year” field.

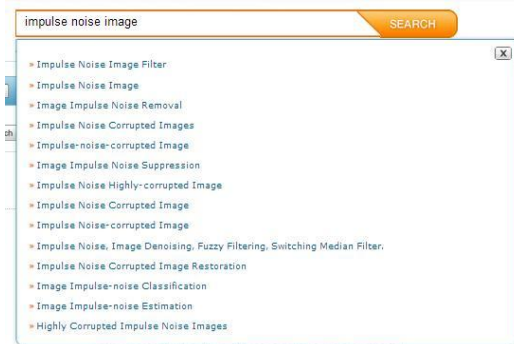


Fig. 2. The search box provided by IEEEExplore®.



Fig. 3. The “publication year” field provided by IEEEExplore®.



Fig. 4. The “content type” field provided by IEEEExplore®.

### III. RESULTS AND DISCUSSIONS

The first observation that we want to achieve through this survey is based on the research trend regarding to the impulse noise, in general, used in digital image processing field. Therefore, we typed “impulse noise image” as the keyword to the search box, shown in Fig. 2. Based on the overall search result, it is shown that the impulse noise based literatures are only available starting from year 1946. Therefore, by selecting “single year” on “publication year” field, shown in Fig. 3, number of publications for each year from 1946 to 2012 is determined. The plot of the findings, plotted as the number of publications versus year, is shown in Fig. 5. From this bar graph, we can witness that the researches related to impulse noise is started to expand dramatically since year 1985. Starting from 1985, there is a significance increment in both journals, magazines, and conference proceedings related to impulse noise based researches. Furthermore, we also can note clearly that the number of conference proceedings is more than the journal and magazine publications. Because the conference proceeding papers normally required relatively shorter time to be published, this outcome suggests that the researches related to impulse noise is expanding very fast in these recent years.

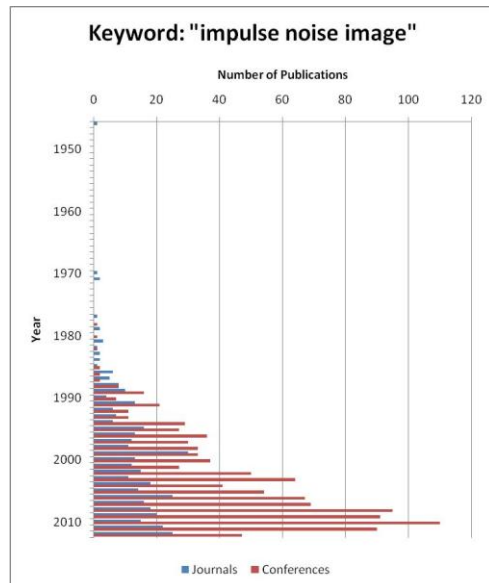


Fig. 5. The trend of research related to impulse noise.

One type of impulse noise is the salt-and-pepper noise. It can be described by either following equations [5]:

$$p(N) = \begin{cases} 0.5P & : \text{pepper}; N = 0 \\ 1 - P & : \text{noise free pixels}; 0 \leq N \leq L - 1 \\ 0.5P & : \text{salt}; N = L - 1 \end{cases} \quad (1)$$

or

$$p(N) = \begin{cases} P_1 & : \text{pepper}; N = 0 \\ 1 - P & : \text{noise free pixels}; 0 \leq N \leq L - 1 \\ P_2 & : \text{salt}; N = L - 1 \end{cases} \quad (2)$$

where  $p$  is the noise distribution,  $P$  is the noise density (i.e.  $0 \leq P \leq 1$ ), and  $P_1 + P_2 = P$ . Therefore, in order to observe the trend related to this impulse noise model, we used “salt and pepper noise image” as the keyword for the search in IEEExplore® database. The plot of the graph obtained from this keyword is shown in Fig. 6.

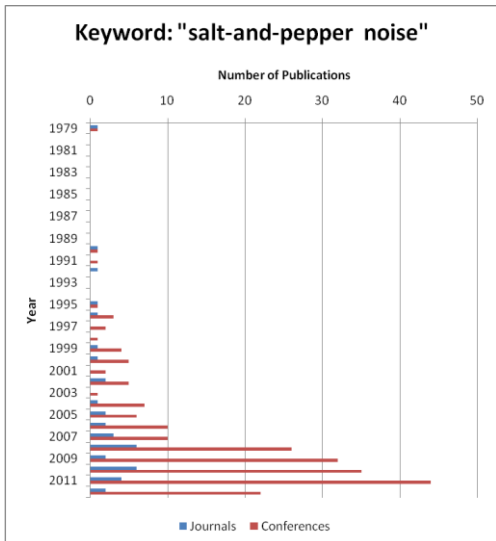


Fig. 6. The trend of research related to salt-and-pepper noise.

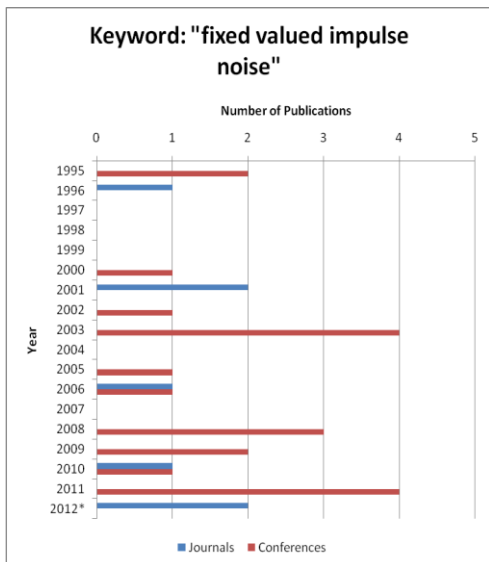


Fig. 7. The trend of research related to fixed valued impulse noise.

Salt-and-pepper noise is also known as the fixed valued impulse noise. Therefore, we also want to investigate the trend related to these terms. We use “fixed valued impulse noise image” as our keyword, and Fig. 7 shows the corresponding result. By comparing Fig. 6 with Fig. 7, we can see that the term salt-and-pepper is more popular than the term fixed valued impulse noise. This is observed from the number of publications. Furthermore, the term salt-and-pepper noise has been used since 1979, whereas the term fixed valued impulse noise started only in 1990. From these bar graphs also, we can observe that the usage of term salt-

and-pepper is showing an increasing trend, while the term fixed valued impulse noise showing an almost constant trend over time.

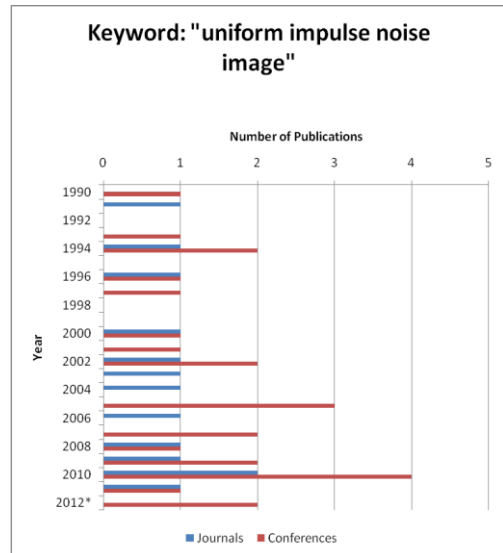


Fig. 8. The trend of research related to uniform impulse noise.

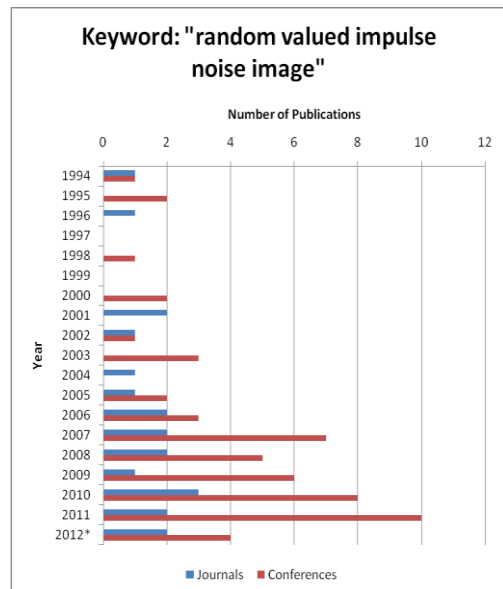


Fig. 9. The trend of research related to random valued impulse noise.

Another type of impulse noise model is known as the uniform impulse noise. This noise can be described by the following equation:

$$p(N) = P/L \quad 0 \leq N \leq L - 1 \quad (3)$$

where  $L$  is the quantization level of the image. In this noise model, the distribution of the impulse noise is equally distributed. We used “uniform impulse noise image” as the keyword to IEEExplore® database, and obtained the result as shown in Fig. 8. As the uniform impulse noise is also known as the random-valued impulse noise, we also investigate the use of this term. We use the term “random valued impulse noise” for this purpose. The graph obtained from this keyword is shown in Fig. 9.

From Fig. 8 and Fig. 9, although both the uniform impulse noise and the random-valued impulse noise are presenting the same type of impulse noise, the term random-valued impulse noise is more popular in the literature. The term random-valued impulse noise is showing an increasing

trend of its usage. On the other hand, the term uniform impulse noise is showing an almost constant pattern over time.

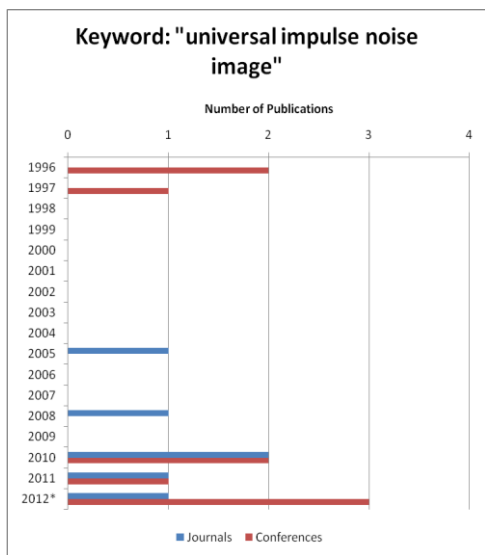


Fig. 10. The trend of research related to universal impulse noise.

Another type of impulse noise is the universal impulse noise. It can be considered as a weighted combination between the fixed valued impulse noises with the random valued impulse noise. In order to inspect the trend related to this impulse noise model, we use the keyword “universal impulse noise image” for our search. The bar graph obtained from this keyword is shown in Fig. 10. From this figure, we can observe that this type of noise model is seldom been used in research publications. However, this noise model is showing an increasing trend for the last three years.

By inspecting bar graphs shown in Fig. 5 to Fig. 10, we can see that the term salt-and-pepper noise is the most popular terms used by research literatures in this field. This is judged based on the quantity of the publications. Furthermore, this type of impulse noise is still showing an increasing trend. We also can assume that the researches related to salt-and-pepper noise, or fixed-valued impulse noise is more popular than the researches related to uniform impulse noise, or random-valued impulse noise.

#### IV. SUMMARY

This research investigates the current trend regarding to impulse noise models. It is found that the research related to impulse noise in image processing is still an interesting research field, and attracts more and more researchers in recent years. The research also shown that the salt-and-pepper noise is the most popular impulse noise model used in literature.

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