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Review paper

Information Granulation as a Viable Tool for Biometric Recognition

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ABSTRACT: Granular Computing (GrC) as advanced by the works of Zadeh, it is widely used in pattern recognition to solve classification problems. When a problem is complex and it involves high dimensional data, it is best solved by a granular computing approach. Problem such as classification of biometric data is a complex problem due to high dimensionality of images involved as well as uncertainty in the feature representations. Information granulation uses granules to solve complex problems that are regarded as uncertain and imprecise. This paper attempts to explore the relevance of information granulation from literature point of view, and as well present how viable it is if used in biometric recognition tool development.

Keywords: Information granulation; biometric; recognition; granular computing

INTRODUCTION

The main technique behind the granular computing paradigm is information granulation (Pedrycz and Homenda, 2013). Zadeh, (1997) proposed information granulation as a strategy for solving complicated problems that are considered ambiguous and imprecise by using granules. These information granules are generated using a variety of formalisms, including fuzzy sets, shadowing sets, and rough sets, and are defined in terms of similarity, functionality, closeness, and indistinguishability (Pedrycz, 2014; Salehi et al., 2015; Yao., 2000). Researchers have used a variety of ways to execute information granulation, particularly in security settings, as shown in (Table 1). The generation of information granules using the existing granulation process, which includes granule creation, representation, and knowledge discovery, remains a vital process (Wang et al., 2018; Zhu et al., 2017a). Even major contributions by researchers in fields such as system artificial intelligence, data mining, system modeling, and cybersecurity are insufficient to persuade. The granulation of information provides a coarse view of the data by showing only what the user wishes to see at a given point in time. The main difficulty in the information granulation technique is locating a "optimal information granule" (Pedrycz et al., 2015) that is both efficient and accurate. Table 2 shows some information granulation strategies that illustrate distinct approaches to producing an ideal granule to address difficult challenges. The rationale behind this principle is that an information granule, as proposed by (Pedrycz and Homenda, 2013), specifies that a granule should contain as many experimental data as possible (coverage) and be as detailed as possible in terms of interpretation and knowledge discovery. Many academics have been drawn to the work of (Pedrycz and Homenda, 2013) because of its well-established mathematical technique in granule computation. To further analyze the information granulation technique, it is divided into two types: principle-based and formalism-based. The former employs the principle of justifiable granularity (PJG), which explains the production of an ideal information granule through the existence of available data and suitable meaning. In the latter case, researchers generate information granules directly using reasoning formalisms such as fuzzy, rough, and set intervals (Isah, Selamat, Ibrahim, and Krejcar, 2020). A bottom-up or top-

Table 1: Information granulation in areas of research.

Paper	Problem	Idea	Discussion
(Nápoles, Grau, Falcon, Bello, and Vanhoof, 2016)	Inability of to protect computer networks from intrusions.	An intrusion detection system using fuzzy cognitive maps.	Rough cognitive networks are plausible models for better discrimination between normal and abnormal traffic.
(Zhu et al., 2017)	Impediments in communication channels.	An encoding and decoding system for security of data along communication channel.	Needs a higher information granule order for overcoming information loss.
(Cabrerizo, Morente-Molinera, Pedrycz, Taghavi, and Herrera-Viedma, 2018)	Using linguistic preference for Decision making.	A modelling resolution process of decision making using linguistic preference.	Use of optimization techniques to optimize consistency.
(Wang et al., 2018)	Design of an optimal granule to aid general application development	A flexible method with adaptive weighting scheme	An efficient way of constructing information granule in the presence of experimental data.

Table 2: Techniques of data granulation.

Paper	Technique	Solution Approach	Discussion
(Liu and Cocea, 2017)	Fuzzy information granulation (FIG)	Positioning the research of sentiment analysis in the context of information granulation.	Fuzzy IG addresses the limitations of interpretability and computational complexity
(Anh, Vo, and Pedrycz, 2017)	K-means algorithm	A new strategy in building information granule	It reduces computational time and increase performance
(Guan and Guan, 2014)	Fuzzy rough sets	An extension of fuzzy rough sets using partition interval in decision systems	Can be used in machine learning methods of data pre-processing.
(Ray, Ganivada, and Pal, 2016)	Combination fuzzy-rough sets and self-organizing maps.	A granular self-organizing map clustering in selecting feature sets of microarray data.	Concept of fuzzy sets integrated with SOM to capture uncertainty and underlying clusters in data.
(William-West and Singh, 2018)	Rough sets modelling	Generalizing rough set approximations in hypergraphs.	An algorithm is developed that describes information granules in hypergraphs.
(D'Aniello, Gaeta, Loia, and Orciuoli, 2016)	Fuzzy c-means	Uncertainty measurement in situation awareness	High degree of flexibility in the creation of information granules depending on situation.

down method could be used depending on the nature and complexity of a challenge.

Related works

Several cybersecurity studies have employed information granulation-based solutions to improve system and user security (Fujita et al., 2018b), Li et al., (2014), Sun et al. (2015), and Al-Shammaa and Abbod, (2015), Pawlicki et al. (2018). However, the prevalence of undetected assaults as a result of system design and development problems (Knowles et al., 2015) has made cybersecurity a complicated and uncertain phenomenon that necessitates computational intelligence tools to uncover a long-term solution.

Although information granulation is widely used in the security domain, it has a limited presence in high-level security applications used in cybersecurity to avoid unauthorized access, which could be a serious challenge given the complexity and uncertainty of the data and information presented to cybersecurity systems (Fujita et al., 2018a). Researchers are still using information granulation strategies to handle complicated challenges from the perspective of uncertainty and impreciseness in cybersecurity (Nápoles et al., (2016); Fujita et al., (2018b), and (Sareen et al., (2017); Salehi et al., (2015). Table 3 shows different information granulation techniques used in cybersecurity.

Still focusing on the usability of information granulation techniques, (Li et al., 2014) effectively expressed finger properties utilizing bottom-up information granulation methodologies, achieving higher accuracy and recognition rate. Overall, research from the literature reveal how information granulation approaches were used to minimize cybersecurity interventions such as intrusions (Nápoles et

Table 3.: Presence of information granulation in cybersecurity solutions.

Paper	Method	Cyber-system	Discussion
(Li et al., 2014)	Similarity fusion	Finger-based biometric authentication	Finger features are granulated into three levels for higher recognition rate
(Sun et al., 2015)	A granular computing based Neuro-fuzzy modelling	Electrical power output prediction	For accuracy and interpretability of information granules
(Al-Shammaa and Abbod, 2015)	ANFIS and SVM	Medical data classification system	Classifier performance is compared.
(Vimitha and Jayasree, 2018)	neighbourhood sets	Biometric	Feature extraction
(Fujita et al., 2018b)	Principle of justifiable granularity	Critical infrastructure	Fusion of different attack models.
(Alpar and Krejcar, 2018b)	Fourier and fuzzy	Biometric	Accuracy is tested
(Alpar and Krejcar, 2018a)	Interval-fuzzy	Biometric	Segmentation improvement.
(Kolda, Krejcar, Selamat, Brida, and Kuca, 2018)	Visual analysis	Biometric	Optimization analysis.
(Yang, Wei, and Shi, 2018)	Hierarchical model	Biometric	Hierarchical Feature extraction
(Salehi, Selamat, Krejcar, et al., 2015)	Fuzzy sets	Spam detection	Hybridization of PSO and K-means to optimize IG.

al., 2016), access control (Gaiyan Bai, 2016), critical infrastructure (Fujita et al., 2018b), and spam detection (Fujita et al., 2018b). However, the prevalence of undetected attacks and unauthorized access due to flaws in cybersecurity system design and execution remains unsolved. To the best of our knowledge, no research has been undertaken on biometric fusion in cybersecurity application development employing the notion of justified granularity-based information granulation. It is hoped that this research will add to the literature on the application of computational intelligence technologies to improve the recognition accuracy of biometric systems.

Information granulation in biometrics

Granular computing has also sparked interest in biometric applications (Yang et al., 2016), (Peng et al., 2014b) (Peng et al., 2014a). The fusion of finger-based biometric features was tested in (Yang et al., 2018) to achieve good performance in image inspection and recognition. To create granules, the authors used circularized information granulation based on finger minutiae. However, using the original pixel-based granules, the technique has proven to be time demanding. A similar strategy was used in (Peng et al., 2014b) to combine finger-vein, finger-knuckle-print, and fingerprint for effective recognition utilizing a hierarchical granulation process. The disadvantage is that the database is tiny, which results in poor generalization performance. A bottom-up granular approach was attempted in (Peng et al., 2014a) to generate multi-level feature granule for finger vein, finger knuckleprints, and fingerprints, but the approach is not generalizable. It is worth noting that this is the first study to apply GSVM in a finger-vein pattern classification challenge.

For high-level security applications such as medical, financial, military, and airspace control, the necessity for trustworthy and precise biometric-based solutions is critical. However, there are limitations to these highly rated biometric-based security systems, indicating the need for additional research.

Findings from the literature revealed the shortcomings of commonly employed classifiers at score level fusion, which demonstrate reduced performance as a result of non-realistic thresholds that trade-off between the erroneous acceptance rate and false rejection rate. A careful examination of the mechanisms utilized in threshold selection reveals that, due to the uncertainties and complexities involved, even adaptive techniques perform poorly in high-level security situations. To be more specific, relevant literature studies show that, in addition to the ability to deal with uncertainty and complex difficulties, granular computing technologies can be utilized to create intelligent security systems. Even though the production of an ideal granule remains an open subject, information granulation is nevertheless widely used by researchers dealing with difficult challenges. Another significant issue noted in the literature is the generation of an information granule in the presence of several data sources, which correlates with multimodal systems.

A research foundation has been laid in this study to overcome these challenges, both for finding the right information granule, which if designed effectively will lead to a robust biometric fusion strategy, and to further provide trade-off in the selection of appropriate threshold to overcome the prevalence of undetected attacks and degraded performance.

Conclusion

Because of the level of coverage and specificity found during the granulation process, the use of information granulation in biometrics has produced a viable approach to biometric recognition.

Several studies have demonstrated the reliability of biometric recognition techniques that utilize information granulation. Despite the fact that the granulation process is critical and necessitates the creation of ideal granules, it is effectively used to create useful recognition tools.

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