An Intelligent System for Reconstructing the Ripped-up Paper-Moneys

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Keywords: Forensic Science, Decision Support Systems, Particle Swarm Optimization, Ripped-up Paper-Moneys.

Abstract: The paper-moneys may face the problems of shreds in the unexpected accidents or human negligence. The reconstruction of ripped-up paper-moneys can demonstrate the evidences for decision makers or forensic examiners in order to exchange the complete paper-moneys. However, the reconstruction of ripped-up paper-moneys is very difficult on the basis of a lot of shreds with different distance factors that are measured from neighbouring pieces. How to identify the suitable feature weight for each distance factor is a critical issue for reconstructing the ripped-up paper-moneys. Particle swarm optimization is a search algorithm which is successfully adopted for solving many combination optimization problems in many fields. This study utilizes particle swarm optimization for exploring the proper feature weight for each distance factor to improve the reconstructed abilities. The proposed approach demonstrates the automatically reconstructing abilities which enhance the effects and efficiencies on the reconstruction of ripped-up paper-moneys.

1 INTRODUCTION

The paper-moneys are one of currencies that are often adopted in the market transactions. The paper-moneys may face the problem to come to pieces together with the other documents from the shredder in the unexpected accidents. The reconstruction of ripped-up paper-moneys is an important procedure to show the evidences of the paper-moneys for forensic examiners or decision makers. A shredder usually shreds paper-moneys into many small pieces. The reconstruction of a huge pile of ripped-up paper-moneys is difficult for experts or investigators. The reconstruction of ripped-up paper-moneys is similar to the jigsaw puzzles problem for reassembling the small pieces.

In 2004, Goldberg et al. proposed a global approach to solve the problem of jigsaw puzzles (Goldberg et al., 2004). They tried to apply automated methods for solving the reconstruction problems based on computer vision and artificial intelligence techniques. Their results show that the proposed approach is able to improve the reconstruction abilities.

Bock et al. figured out that the majority of jigsaw puzzles problems have been based on rather specific shape and colour features, as well as the relationships that may exist between several jigsaw puzzle pieces (Bock et al., 2004). That is, the ripped-up paper-moneys are hard to have the same shape in comparison with the jigsaw puzzles problems. Although some progresses have been made in devising semiautomatic methods for reducing the complexity of reconstruction problems, many reconstruction problems still remain difficult or unresolved (Smet, 2008). In practice, experts or investigators often still resort to manual reconstruction procedures or seek expensive assistance to reconstruct the ripped-up paper-moneys. They have made little scientific information available about their methods in reconstruction.

The reconstruction of ripped-up or shredded paper-moneys is time-consuming without science approach. Therefore, this study proposes the particle swarm optimization (PSO) approach to improve the reconstruction of ripped-up paper-moneys. The PSO approach is adopted to solve the combination optimization problems on the basis of ripped-up paper-moneys for enhancing the efficiencies and effects of reconstruction.

Chiu N., Pu C. and Hsieh M..
An Intelligent System for Reconstructing the Ripped-up Paper-Moneys.
DOI: 10.5220/0004409903950400
In *Proceedings of the 15th International Conference on Enterprise Information Systems* (ICEIS-2013), pages 395-400
ISBN: 978-989-8565-59-4

2 RELATED WORK

Many approached have been proposed for solving the reconstruction of ripped-up documents or fragments. In 2002, Papaodysseus et al. presented the best-first strategy for the global reconstruction of fragments (Papaodysseus et al., 2002). Their methods considered the local evaluations in selecting the most similar matching pair for reconstruction the fragmented wall paintings. Leitao and Stolfi proposed a multi-scale method for the reconstruction of two dimensional fragments (Leitao and Stolfi, 2002). Their experiments demonstrated that this technique is useful for matching a very large number of two dimensional fragments. Zhu et al. proposed a global approach for reconstructing the ripped-up documents by first finding candidate matches from document shreds using curve matching (Zhu et al., 2008). Their results indicate that the reconstruction of ripped-up documents is possibly accomplished automatic up to 50 pieces.

Moghaddam and Cheriet introduced a novel restoration and reconstruction method for document images (Moghaddam and Cheriet, 2011). A modified genetic algorithm search technique is used to find similar patches on several degraded document images. Their results are promising that the proposed method can be easily generalized to natural images whenever they contain structural information. Lin & Fan-Chiang presented an image-based technique for shredded document reconstruction (Lin and Fan-Chiang, 2012). The image-based techniques are first used to identify the shred images with high spatial proximity and evaluate the similarity between any pair of shreds. Also, a graph-based algorithm is then used to derive the best shred sorting result for document reconstruction. Their results show that the proposed method has correctly merged the majority of the shredded document. It can also be adopted to reduce the workload of a manual document reconstruction process.

Richter et al. proposed an algorithmic framework for the reassembly of shredded documents (Richter et al., 2013). They used a support vector machine classifier to find pairs of support points between fragments which are suitable for aligning their respective fragments. After identifying these points of attachment, they iteratively aligned all fragments into groups. Their experiments show that the proposed algorithm is capable of reassembling pages consisting of up to 32 pieces. The proposed algorithm also yielded satisfactory results in the face of multiple missing pieces.

Richter et al. proposed a graph-based approach to reassembling manually shredded documents (Richter et al., 2011). They evaluated a set of constraints that takes into account shape- and content-based information of each fragment. In their evaluation, the results show the effectiveness of the proposed approach in different scenarios. Perl et al. proposed optical character recognition approach for strip shredded document reconstruction (Perl et al., 2011). The reconstruction methodology recognizes characters at the stripes' borders and matches them subsequently. The optical character recognition system is exploited for recognizing partially visible characters by means of local features. Their results show the ability of matching shredded documents using the information of cut characters.

Butler et al. presented a visual analytic approach to reconstructing shredded documents (Butler et al., 2012). They represented the shredded pieces as time series and applied nearest neighbour matching techniques that enable matching both the contours of shredded pieces as well as the content of shreds themselves. Their approach combines the advantages of automated methods and enables expert input. They believe the need for interesting problem solving strategies would become paramount, which will hopefully spur more research into visual analytic methods.

Deever and Gallagher introduced a semi-automatic approach for crosscut shredded document reassembly (Deever and Gallagher, 2012). Automatic algorithms are proposed for computing features and ranking potential matches for each shred. Furthermore, a human-computer interface is designed to allow semiautomatic assembly of the shreds using the computed feature and match information. Their experiments demonstrate that the proposed approach can successful reconstruct the multiple shredded documents. It also shows the effectiveness of the proposed automatic algorithms.

The automatic reconstruction of shreds is a typical application in the field of computer vision, pattern recognition and image analysis which can be approximately viewed as the jigsaw puzzle problem. Yao & Shao proposed a shape and image merging technique to solve jigsaw puzzles (Yao & Shao, 2003). They assumed that there exist four corner points for the canonical jigsaw puzzle pieces, and the boundary curve can be separated into four edges at the four corner points. The pieces have smooth edges with well-defined corners for the jigsaw puzzles. The majority of the proposed approach has been based on specific shapes and colour features, as well as the relationships that may exist between several jigsaw puzzle pieces.

The reconstruction of ripped-up paper-moneys is somewhat similar to the problem of automatic reconstruction of jigsaw puzzles. Solana et al. focused on the discussion of feature matching for solving the document reconstruction (Solana et al., 2005). They pointed out that the act of ripping often produces irregularities in the fragment contours. There are no restrictions on the shapes of the shreds and corners for ripped-up documents or shredded paper-moneys. This characteristic is the major part of differences between jigsaw puzzles and ripped-up paper-moneys. That is, the proposed approaches for solving jigsaw puzzles make it difficult to get a perfect curve matching on the problems of ripped-up documents or shredded paper-moneys. The manual or semiautomatic reconstruction of the paper-moneys is a complex issue. How to figure out the suitable combinations of ripped-up paper-moneys is a crucial issue for reducing the reconstruction time.

3 PARTICLE SWARM OPTIMIZATION

PSO is inspired by the social behaviour of biological creatures for searching suitable solutions. This kind of searching behaviour is equivalent to search for solutions in a real-valued search space that has been solving combination problems in many fields. Senthilnath et al. utilized discrete PSO approach for matching the features on solving the multi-sensor image registration problem (Senthilnath et al., 2013). The discrete PSO is adopted to explore the three corresponding points in the sensed and reference images using multi-objective optimization of distance and angle conditions through objective switching technique. The experiments show that the proposed technique is able to register the sensed image with the reference image by matching the corner points. The discrete PSO approach is also superior to the other approaches based on the results obtained in their case studies.

Kashyap and Misra proposed a cost estimation model based on multi-objective PSO to tune the parameters of the famous constructive cost model (Kashyap and Misra, 2013). They have used PSO to build a suitable model for software cost estimation by tuning the constructive cost model (COCOMO) parameters. This cost estimation model is integrated with quality function deployment (QFD) methodology to assist decision making in software designing and development processes for improving the quality. The combination of PSO and QFD approach assists the project managers to efficiently plan the overall software development life cycle of the software product.

Xue et al. applied multi-objective PSO for feature selection (Xue et al., 2013). They investigated two PSO-based multi-objective feature selection algorithms. The two multi-objective algorithms are compared with different feature selection methods on 12 benchmark data sets. Their experimental results show that the proposed PSO-based multi-objective algorithms can achieve more and better feature subsets than other approaches in most cases.

Lee and Kim utilized the integration of multi-objective PSO with preference-based sort for solving the footstep optimization of robots (Lee & Kim, 2013). The proposed approach was applied to the path following footstep optimization for humanoid robots and the footsteps optimized for predefined paths were successfully obtained. Through their experiments, it is certain that the PSO approach can be applied to various kinds of real world applications.

In 2009, Chiu et al. combined PSO and constraint-based reasoning mechanisms to explore suitable timetables of customer service department for the timetables scheduling problems (Chiu et al., 2009). Their experimental results showed that the PSO and constraint-based reasoning can overcome the efficiency and flexibly concern under constraints in developing workforce timetables. Wang et al. proposed a hybrid PSO algorithm which employs a diversity enhancing mechanism and neighbourhood search strategies to achieve a trade-off between exploration and exploitation abilities (Wang et al., 2013). A comprehensive experimental results show that the proposed approach obtains a promising performance.

Chiu examined the benefits of improving grey relational classifier based on the PSO (Chiu, 2009). The PSO approach was utilized to investigate the best fit of weights in the grey relational analysis approach for deriving a classifier with preferred balance of misclassification rates. The results presented that the proposed approach provides a preferred balance of misclassification rates than the models without using PSO approach.

In 2013, Kaveh et al. utilized PSO method to solve binary-state multi-objective reliability redundancy allocation problems (Kaveh et al., 2013). Statistical analysis was supplied to compare the performance of their proposed algorithms. The proposed method showed relative preference in comparison with the other competing methods. Chen et al. developed PSO and neighbourhood search to obtain the near-optimal solution (Chen et al., 2013). Their experiments indicate that the developed approach not only provides good quality solutions within a reasonable amount of time but also outperforms the classic branch method.

Chiu proposed an integrated decision networks to combine the PSO and neural networks in providing the summarized suggestion (Chiu, 2011). The PSO approach was used to explore the proper combinations of suggestions in the integrated decision networks. The experimental results demonstrated that this approach is superior to the other approaches. It also can provide an appropriate summary for decision makers. The PSO approach demonstrates its abilities in investigating the suitable solutions in different fields. Therefore, the PSO approach is utilized for exploring the suitable combinations of ripped-up paper-moneys to improve the reconstruction abilities.

4 METHODOLOGY

Figure 1 shows the mechanism that applies PSO for reconstructing the ripped-up paper-moneys. The referenced database includes the digital image of complete paper-moneys for reference. The domain experts or investigators have to make sure each ripped-up paper-money if it is real. They can further identify the position of ripped-up paper-moneys in comparison with the referenced database.

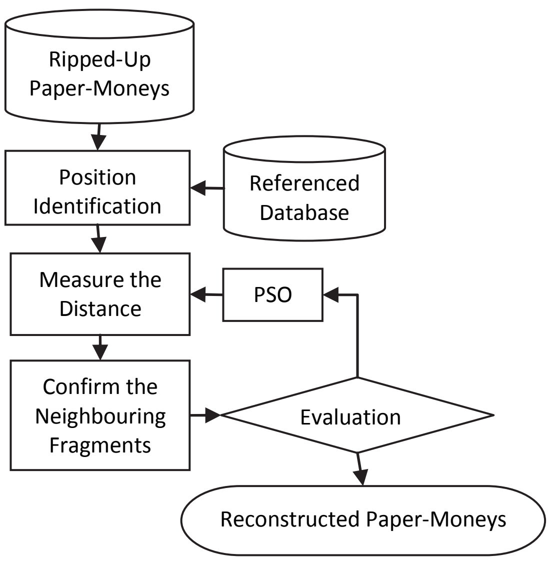

Figure 1: The mechanism of reconstruction.

The distance measurement calculates the relative distances among ripped-up paper-moneys. For different distance factors, the summarization of weighted Euclidean distance is the general distance between pairs of ripped-up paper-moneys. The nearest distance is the neighbour of the ripped-up paper-money being reconstruction. The evaluation procedure evaluates the reconstruction results of ripped-up paper-moneys. If the reconstruction results are unacceptable, the PSO is utilized to explore the feature weights of distance factors. As the features weights are different, the summarized distance from pairs of ripped-up paper-moneys may be different. These repeated procedures produce the results of finally reconstructed paper-moneys.

The measurements of different distance values from neighbouring pieces of ripped-up paper-moneys plays a crucial factor for successful reconstruction of paper-moneys. The possible feature weights of distance factors are represented as a "particle" of X_i for PSO. For n distance factors, the i^{th} particle has its feature weights of distance factors $x_i=(x_{i1}, x_{i2}, \dots, x_{in})$ and velocity $v_i=(x_{i1}, x_{i2}, \dots, x_{in})$. While flying in the problem search space, each particle generates a new solution of feature weights of distance factors using directed velocity vector. Each particle modifies its velocity to find a better feature weight of distance factors by applying its own flying experience of P_{best} and G_{best}. The P_{best} is particle best weights found in its earlier flights, and the G_{best} is global best weights found of the particles in the population. For n distance factors, the new distance factors x_i and new velocity v_i are shown in Eq. (1) and (2). *rand*() is a random value in the range between 0 and 1. C_1 and C_2 are positive constants for regulating the maximum step sizes for the particles to fly towards P_{best} and G_{best}, respectively. w is a constant during searching iteration. During the iteration, the value of each particle is calculated using this fitness function of x_i^{new}. The best value of each x_i^{new} is kept as the local best value. For the best value of all x_i^{new}, the best value is kept as the G_{best}. These investigating processes are finished while the fitness values of distance weights are satisfied.

$$v_i^{new} = w * v_i^{old} + c_1 * rand\,()*(P_{ibest} - x_i^{old}) + c_2 * rand\,()*\,(G_{best} - x_i^{old}) \quad (1)$$

$$x_i^{new} = x_i^{old} + v_i^{new} \quad (2)$$

5 EXPERIMENTS

Two colour copies of complete paper-moneys from Taiwan are simulated for the reconstruction of ripped-up paper-moneys. These two complete paper-moneys are shredded from a shredder. Figure 2 shows these two paper-moneys after shredding. For these ripped-up paper-moneys, there are 280 pieces being reconstruction.

Figure 2: The ripped-up paper-moneys.

One of paper-moneys after reassembling from these ripped-up paper-moneys is shown in Figure 3. As the piece of ripped-up paper-moneys may belong to one or the other paper-moneys, the reconstruction processes are adopted to explore the combination optimization. The reconstruction results of these ripped-up paper-moneys include some of spaces. These spaces are the pieces of ripped-up paper-moneys which are hard to identify the correct positions or damaged from the shredder. As the reconstruction of paper-moneys are based on the identification of correct positions of ripped-up paper-moneys, these results show that the identification of correct positions for the ripped-up paper-moneys plays a critical factor for the reconstruction results.

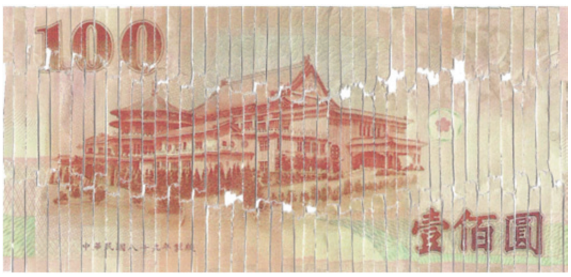

Figure 3: The reconstructed results.

6 CONCLUSIONS

The reconstruction of ripped-up paper-moneys is very important for forensic examiners or decision makers in order to confirm the amount of paper-moneys are shredded. The reconstruction of ripped-up paper-moneys is very difficult if there are many pieces of shreds being reconstructed. The automatic identification of neighbour pieces from ripped-up paper-moneys shows a potential approach for improving the reconstruction abilities. The PSO is a search algorithm which is utilized for exploring the proper distance weights for automatic identification of neighbour pieces in reconstruction of ripped-up paper-moneys.

The study presents the automatically reconstruction mechanism that provides a valuable direction for domain experts or investigators in processing of ripped-up paper-moneys. We present a study for an automatic reconstruction of ripped-up paper-moneys based on PSO approach. We are encouraged by the results of the present study and are interested in exploring if the use of different search approaches or different paper-moneys in order to validate the reconstruction abilities in the future.

ACKNOWLEDGEMENTS

We would like to thank National Science Council, Taiwan, Republic of China supporting this study under the contract number NSC 101-2410-H-231-006-.

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