Chapter 36
Cuckoo Search Based Decision Fusion Techniques for Natural Terrain Understanding

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ABSTRACT

This paper proposes two novel nature inspired decision level fusion techniques, Cuckoo Search Decision Fusion (CSDF) and Improved Cuckoo Search Decision Fusion (ICSDF) for enhanced and refined extraction of terrain features from remote sensing data. The developed techniques derive their basis from a recently introduced bio-inspired meta-heuristic Cuckoo Search and modify it suitably to be used as a fusion technique. The algorithms are validated on remote sensing satellite images acquired by multispectral sensors namely LISS3 Sensor image of Alwar region in Rajasthan, India and LANDSAT Sensor image of Delhi region, India. Overall accuracies obtained are substantially better than those of the four individual terrain classifiers used for fusion. Results are also compared with majority voting and average weighing policy fusion strategies. A notable achievement of the proposed fusion techniques is that the two difficult to identify terrains namely barren and urban are identified with similar high accuracies as other well identified land cover types, which was not possible by single analyzers.

INTRODUCTION

Earth observation is emerging at a faster pace than ever before. In recent years, the advent of more influential sensor systems and techniques empower us to excerpt more detailed information from the observed data. However, to attain better *terrain understanding* (Wilkinson, 2005) development of effective data analysis techniques is required, which can utilize the full potential of the observed data. *Terrain understanding* is a significant task in remote sensing as it spans its applications ranging from civilian to surveillance and military, like urban monitoring and planning, catastrophe assessment, water

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body management etc. Although techniques stretching from classical statistical methods to modern computational approaches have been developed for this purpose but no single terrain analyser was found to be capable of identifying widely different terrains present in any region with desired accuracy, even after all parameters/architectures of the scheme have been fully optimized (Zhao, 2010). This motivated developers to shift their focus to design the ensemble of classifiers, which adopts some effective fusion technique to combine the knowledge provided by different experts (i.e. terrain analyzers) about the terrain type. The important prospect of fusion is focused on exploiting the complementary knowledge provided by different experts to obtain better overall understanding of the terrain type.

Image fusion is an amalgamation of two or more different images to create a new image after applying certain algorithm (Genderen, 1998). Image fusion can be achieved at three different processing stages - low level (Information/pixel level), intermediate level (feature level) and high level image fusion (decision level), according to the stage at which the fusion is carried out. Each of the three levels received remarkable attention by the researchers (Aery, 2012; Wang, 2005). In this paper, a *decision level fusion technique* is developed using a nature inspired optimization technique called Cuckoo Search.

Nature inspired meta-heuristics are adopted because of its power to emulate the pre-eminent features in nature, such as synchronization, parallelization, distributiveness, scalability, robustness, adaptability, manageability, redundancy, cooperation, and coordination (Kari, 2008; Yang, 2010). Cuckoo search (Yang, 2009) is one of the latest techniques which have proved its proficiency in widely different problem domains with respect to the other well-known techniques of this pool. Four different nature inspired terrain classifiers were applied to real datasets of multispectral satellite images of Alwar region (Rajasthan, India) and Delhi region, India. The experts' outputs obtained are fused using the proposed CSDF and ICSDF methods to extract maximum information. Experimental results demonstrate, (i) Identification of two otherwise difficult to identify terrains with higher accuracy and (ii) Substantially improved overall accuracy of the proposed schemes over those obtained by individual analyzers as well as classical majority voting policy (Mahmoud, 2004) and statistical weighing policy (Tzeng, 2006) fusion techniques.

Rest of the paper is organized as follows. Next section presents a brief discussion of decision level image fusion and the related techniques explored till date. Motivation to carry out this work is presented in the third section. Fourth section presents proposed generic system architecture of the fusion scheme along with the detailed workflow. Section five describes the proposed cuckoo search based decision fusion algorithms CSDF and ICSDF along with their mathematical formulation. Experiments undertaken for the validation of the developed algorithm are described in section six. Section seven presents the results obtained with CSDF and ICSDF methods. These are also compared with the results of other classical decision level fusion techniques as well as individual terrain analyzers used as base classifiers. Various well established metrics like Kappa coefficients, user's and producer's accuracy are calculated for comparing overall accuracies and terrain wise accuracies of algorithms. Conclusion is presented in the last section.

DECISION LEVEL IMAGE FUSION

Decision fusion combines the results of various classifiers having similar or diverse feature sets to produce a better result (Genderen, 1994). The final decision is arrived, by taking advantage of complementary information provided by the constituent experts and hence increases the overall accuracy of the system. The objective of these techniques is to determine the global optimum information class decision $\mathbf{Xo} \in$