Design of Multiple Classifier Systems

Fuad M. Alkoot

Submitted for the Degree of
Doctor of Philosophy
from the
University of Surrey

Centre for Vision, Speech and Signal Processing
School of Electronics, Computing and Mathematics
University of Surrey
Guildford, Surrey GU2 7XH, U.K.

Summary

During the past decade the fusion of multiple experts has become a legitimate necessity due to its capability of achieving improved accuracy over the best single expert. The field has grown diversely and in this thesis we focus on one branch only. Based on their architecture, we can divide multiple classifier systems in two categories: Parallel Homogeneous Classifier systems, (PHC), which involve parallel component classifiers with similar output types for fusion; Complex Multistage Classifiers which are characterised by a complex internal architecture where the decisions may not reach the fusion rule in parallel or if they are in parallel may not be of homogeneous type. The fusion methods used in PHC systems can be grouped in to two, Simple methods not requiring any training and Complex methods. The focus of this thesis is on the simple fusion methods. In addition some aspects of PHC system design are also addressed.

In a PHC environment one could search for deficiencies in order to improve the overall classification rate. There is a need to better understand the existing methods to help in selecting the optimum technique for the problem at hand. This understanding may also lead to advances in classifier fusion methods and hence to improvements in their performance. The comparative survey of the simple methods concludes that the strategies perform variably and indicates the need for their detailed analysis and investigation. The theoretical derivation of these strategies is presented followed by an analytical analysis of the sensitivity of Sum and Product to estimation errors. Then the results of the analytical study are validated experimentally for different noise conditions. The experimental study has uncovered the veto effect to be the reason behind the poor performance of Product under high noise conditions. The experimental evaluation is extended further when we investigate Sum and Vote experimentally and theoretically to find when and why one strategy outperforms another.

The experimental findings relating to the veto effect has lead to proposing the heuristic *Modified Product* and the theoretically based *moderated Product*. In general the fusion strategy and fusion component experts are related and upgrading the fusion strategy may solve some of the deficiencies of the component experts. However, upgrading the component experts of the PHC system may lead to a further improvement in the overall system performance. This is obvious in the modified bagging methods which we propose. Random feature subset based bagging is another solution to improve the $k-NN$ PHC system.

One can also search for novel methods of designing PHC systems, such as the combiner system based feature selection method to build the ensemble component experts. The proposed method is viewed as a complement to the conventional method of designing PHC systems, which is based on optimising the component experts independently, before fusing them in the system.

Key words: PHC systems, Classifier Combination, Classifier Fusion, Bagging, Moderation, Product, Sum, Vote, Veto, Small Sample classification

Acknowledgements

I am in debted to my Supervisor Professor Josef Kittler and would like to thank him not only for the guidance but also for the wonderful personality. I appreciate his patience when I was absorbing knowledge and his tolerance when I was panicking. I benefited tremendously, and from him I learned the art of exploring ideas and evaluating them. Again, thank you Josef for the wonderful three years which led to my life long dream becoming a reality. I would like to thank the examiners Professor Robert Duin and Dr. Terry Windeatt for accepting the task of examinnig me and for their encouraging remarks, suggestions and comments during the exam.

Many thanks to all researchers and staff of CVSSP. Seminars, discussions and help were very much appreciated. Particularly, I would like to name Dr. William Christmas for answering many of my uncommon questions and Dr. M. Ahmadzadeh who gave the stressful days a taste of fun and helped when Unix was not so friendly, even when he was suffering from the stress associated with PhD research.

A big thanks to PAAET and IDB for the trust they placed in me and hope finishing in three years is a nice present to give back. From PAAET I would like to sincerely thank Dr. H. Almodaf head of PAAET and K. Alabdullah Head of TNI. for arranging the scholarship granted by IDB.

I would like to thank my parents, the source and the centre of my success, but can not do justice in a single page. I can not forget the numerous encouragements since childhood among many factors that lead to my success. Fathers guidance and mothers passion were my source of energy in life. Their faces and advice were always with me. The list of persons I would like to dedicate this work to is very long, however, I would like to mention my brothers, sisters, two uncles and aunts that were also sources of inspiration and encouragement since childhood. The beginning was my brother Fadel's battery and bulb followed by my fathers gift; the story of Edison, when I was 10 years old.

Also, I would like to thank, with love, my dear, dedicated and patient wife, Poyeh Farhadzadeh, for the unwavering support during my PhD research. Can I do justice in a sentence? No, but I think without her this work would not have succeeded in three years. Hopefully, now that I have reached my childhood dream she can start a normal life with me, or is it just the start?! My consolidation is that although the research is in, however the stress will be out. Equally I would like to dedicate this work to my two lovely daughters Yasmeen and Zahra as well as whomever the future may bring in to our nest. I hope I can be a real father now, and Yasmeen and Zahra can enjoy what they were used to before the commencement of my PhD research. That is being with and being spoiled by thier father, every day.