



INSTITUTE OF COMPUTER SCIENCE
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Supervisor's report for doctoral thesis of Adéla Hladká:
Statistical models for detection of differential item functioning

The dissertation thesis of Adéla Hladká deals with the problem of detection of so-called differential item functioning (DIF). This is one of the tasks related to the evaluation of the properties of multi-item tests, which are encountered, for example, in education, psychology or in measuring the quality of life. Some years ago, DIF was studied in a diploma thesis by Vlčková (Charles University, 2014), at that time motivated by the fact that the DIF detection, an established approach in the context of national or international large-scale student assessment, was somewhat neglected in some regions (including the Czech Republic) and some study fields. The aim of this dissertation was to more deeply study some of the questions and suggestions which arose, and to propose and study possible methodological extensions to existing approaches.

The dissertation is divided into four chapters. The introduction provides the state of the art for the topic of DIF detection, it describes the structure of the thesis, its main results, and relationship of the thesis with the author's publications. The core chapters of the thesis are chapter 1 and 3, containing new approaches for DIF detection and for parameter estimation in a group-specific model, derivation of asymptotic properties, simulations and software implementation. The two core chapters are complemented with extension of the methods to polytomous data in chapter 2, and with other topics of DIF detection in chapter 4.

Chapter 1 deals with the extension of the method based on logistic regression. The results from the Hladká & Martinková (2017) article are included. Building on this work, the author further proposes a model which, in addition to group-specific item difficulty, discrimination and so-called pseudo-guessing also allows for a different degree of inattention among the groups. The chapter presents several approaches to parameter estimation, such as the method of nonlinear least squares and the method of maximum likelihood, for which the asymptotic properties are derived. In addition, two iterative algorithms are proposed that can greatly simplify the calculation of maximum likelihood estimates: the EM algorithm inspired by the work of Dinse (2011) and a completely newly designed algorithm based on the parametric link function. The DIF detection using the studied algorithms is implemented in R, largely within the author's package `difNLR`. The chapter is supplemented by two simulation studies, which show the favorable properties of the newly proposed approaches.

The second chapter extends the first chapter to the case of polytomous items. Two models for ordinal items and a model for nominal items are presented. The implementation in the package `difNLR` is demonstrated.

The initial motivation for the third chapter was an article by Srihera & Stute (2010) assigned as a topic for doctoral examination. The article offers nonparametric statistics for detecting differences in regression functions in groups, provides optimal weights for these statistics in the case of a known form of functions, and offers proof of asymptotic properties in such a case. Adéla Hladká decided to use the results of the article and adapt it to the case of DIF detection. The advantage of the

nonparametric method is the fact that it does not assume the exact shape of the item response function and can thus detect the between-group differences even in cases where the parametric approach fails. Within the chapter, the author deals with the practical problem that the shapes of the curves are not known in advance, and when replacing the optimal weights with their estimates, the asymptotic properties of the resulting statistic no longer hold. The chapter is again supplemented by a simulation study, which indicates the potential of the newly proposed nonparametric method for DIF detection.

The last fourth chapter deals with other topics of DIF detection in the cases where DIF is tested item by item. The so-called item purification method is introduced and methods of correction for multiple comparisons are also discussed. Using a simulation study, several scenarios combining these approaches are compared, including a newly proposed iterative combination of the two. In the future, for the extended logistic regression model, it might be interesting to compare the mentioned approaches with the approach where the responses to all items are analyzed by a single model including the item effect.

During the doctoral studies, Adéla Hladká worked independently, and she was actively looking for possible extensions of her work. Some of the results have already been published in impacted journals (Journal of Educational Measurement, The R journal), publications related to the thesis include article published in the prestigious educational journal *Learning and Instruction*, or a highly cited article in the *CBE Lifesciences*. She was also invited to collaborate on a book on computational aspects of psychometric methods in education, psychology and health, to be published by CRC Press.

The results of the work were presented at domestic and foreign conferences. Shortly after joining the emerging psychometric group at the Institute of Computer Science (ICS) of the Czech Academy of Sciences (CAS) under a Czech Science Foundation grant, Adéla received a prestigious Student Travel Award for the International Meeting of the Psychometric Society in Asheville, USA, which she won with the study later published in the Journal of Educational Measurement. Her work also received an award at the national statistical conference Robust. Last year, she was one of the two doctoral students nominated by CAS for the Joseph Fourier Award.

During her studies, Adéla Hladká participated in teaching at the Department of Probability and Mathematical Statistics: She led exercise sessions for graduate course *Selected topics in psychometrics*, which she enriched with a number of well-prepared assignments and practicals. At the ICS CAS, she obtained a prestigious Ph.D. fellowship, and became a valuable member of the Department of the Statistical Modelling. Besides her research work, she organized, the *Doctoral days* - 3-day conferences for doctoral students of the ICS and other institutes of the CAS. She was also a member of the local organizing team for the international workshop Psychoco 2019 with almost 100 participants from more than 10 countries, co-organized with Center of Educational Measurement and Psychometrics, established with a Charles University PRIMUS grant.

The goal of the dissertation was certainly met. New useful theoretical and practical results have been achieved. The author has demonstrated the ability of independent scientific work, diligence and initiative. I believe that the submitted work meets the requirements for a dissertation in the study field and I highly recommend to award the scientific degree Ph.D. to Adéla Hladká.

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