Looking for a Challenge?

The Ultimate Problem Set from the University of Warsaw Programming Competitions

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/ Preface to the Second Edition

The collection of algorithmic problems in this second edition of *Looking for a Challenge? The Ultimate Problem Set from the University of Warsaw Programming Competitions* was first published in 2012. On May 17 of that year, the University of Warsaw hosted the 36th World Finals of the annual ACM International Collegiate Programming Contest (ACM-ICPC). The team from St. Petersburg State University of IT, Mechanics and Optics was the overall winner.

The University of Warsaw team, comprising Tomasz Kulczyński, Jakub Pachocki, and Wojciech Śmietanka, placed second among 112 teams of the best student programmers selected from 8000 teams, coming from 2219 universities in 85 countries. Together with other Polish student competitive programmers, they participated in and co-organized numerous programming contests regularly carried out by the faculty, staff, and graduate and undergraduate students in the Faculty of Mathematics, Informatics and Mechanics of the University of Warsaw (MIMUW). These contests have provided students in Poland and around the world the opportunity to learn and hone their skills in algorithmic problem solving and programming, both core elements of computer science. For many participants, the MIMUW contests laid a path to further successes in the most prestigious programming competitions, and – more importantly – launched their outstanding scientific and professional careers.

Although the structure and contents of the book have not changed from the first edition, the editors, Tomasz Idziaszek, Jakub Łącki and Jakub Radoszewski, have made corrections and minor revisions in many places. The editors would like to thank careful readers whose comments led to these improvements.

To reflect the progression and highlights in their professional careers since 2012, we have also updated biographical notes of the authors of the solutions included in this book.

Szymon Acedański: academic teacher in MIMUW; founder and CTO of InviNets, a software company developing applications for the Internet of Things; member of the Main Committee of the Polish Olympiad in Informatics.

Marcin Andrychowicz: received his Ph.D. degree (cryptography) in 2016 from MIMUW; silver medalist of the ACM-ICPC World Finals in 2013; finalist of the Google Code Jam 2016; currently working at OpenAI in California.

Piotr Chrząstowski: academic teacher in MIMUW; member of the Main Committee of the Polish Olympiad in Informatics.

Marek Cygan: academic teacher in MIMUW; in 2018 received a post-doctoral degree (habilitation) in computer science; recipient of a Starting Grant from the European Research Council in 2015; co-founder of NoMagic.AI, a company specializing in robotics software.

Tomasz Czajka: developer at SpaceX since 2014, working on computer systems for the Falcon and Dragon rocket and spacecraft; the second-place winner of the 2014 Facebook Hacker Cup.

Krzysztof Diks: academic teacher in MIMUW; since 2016, Chair of the Polish Accreditation Committee; 20-time participant in the ACM-ICPC World Finals as a co-coach and academic advisor of the University of Warsaw competitive programming teams: between 2012 and 2017, teams from the University of Warsaw won two gold, three silver and one bronze medal, including two overall runner-up titles (2012 and 2017).

Andrzej Gąsienica-Samek: founder and president of the software company Atinea; creator and developer of the Insta.Ling and instaKod educational portals for teaching and learning foreign languages and programming.

Tomasz Idziaszek: received his Ph.D. degree (theory of infinite tree languages) in 2014 from MIMUW; currently working at Codility on developing algorithmic problems and testing programming skills; since 2013, Scientific Secretary in the Main Committee of the Polish Olympiad in Informatics.

Grzegorz Jakacki: co-founder (2008) and CEO of Codility, a platform for assessing the level of programming competency; among Codility customers are Amazon, Intel, Microsoft, Nokia, PayPal, Samsung, Slack, Tesla.

Tomasz Kociumaka: Ph.D. student in MIMUW; recipient of a competitive research grant from the Ministry of Science and Higher Education (2013); co-author of more than 50 scientific publications; silver medalist of the ACM ICPC World Finals (2013 and 2014); finalist of the Google Code Jam and the Facebook Hacker Cup (2015).

Eryk Kopczyński: academic teacher in MIMUW; enjoys continued success in programming competitions, including the 2017 finals of the Facebook Hacker Cup and the Yandex.Algorithm contest.

Marcin Kubica: academic teacher in MIMUW; member of the Main Committee of the Polish Olympiad in Informatics; since 2015, Chief Software Engineer at Codility.

Tomasz Kulczyński: software engineer at Google Warsaw since 2012; co-founder of CodiLime; finalist of the Facebook Hacker Cup (2013 and 2016).

Jakub Łącki: received his Ph.D. degree (dynamic graph algorithms) in 2015 from MIMUW; since 2016 working for Google Research in New York; since 2014, member of the Scientific Committee of the International Olympiad in Informatics.

Krzysztof Onak: researcher at the IBM T.J. Watson Research Center, Yorktown Heights, USA.

Jakub Pachocki: graduated in 2013 with a bachelor degree from MIMUW; received his Ph.D. degree in 2016 from the Carnegie Mellon University; since 2017, researcher at OpenAI; the winner of Google Code Jam 2012; the second-place winner of the Facebook Hacker Cup in 2013 and finalist in 2014 and 2015.

Paweł Parys: academic teacher in MIMUW; winner of the 2012 Cor Baayen ERCIM Award for a promising young researcher in computer science and applied mathematics; finalist of the Facebook Hacker Cup in 2013.

Jakub Pawlewicz: academic teacher in MIMUW.

Marcin Pilipczuk: academic teacher in MIMUW; in 2017 received a post-doctoral degree (habilitation) in computer science; recipient of a Starting Grant from the European Research Council in 2017.

Michał Pilipczuk: academic teacher in MIMUW; received his Ph.D. degree in 2013 from the Bergen University, Norway; winner of the 2016 Cor Baayen ERCIM Award for a promising young researcher in computer science and applied mathematics.

Jakub Radoszewski: academic teacher in MIMUW; received his Ph.D. degree (algorithms on texts) in 2012 from MIMUW; since 2016, vice-chair of the Main Committee of the Polish Olympiad in Informatics.

Wojciech Rytter: professor in MIMUW; member of the Main Committee of the Polish Olympiad in Informatics; active creator of challenging and inspiring problems for programming competitions.

Krzysztof Stencel: professor in MIMUW; member of the Main Committee of the Polish Olympiad in Informatics.

Wojciech Śmietanka: graduated in 2012 from MIMUW; co-founder of CodiLime; after working as a software engineer at Google Zurich, now in London at Quadrature Capital, an investment management company.

Tomasz Waleń: academic teacher in MIMUW; member of the Main Committee of the Polish Olympiad in Informatics; co-founder and developer at Codility.

Jakub Wojtaszczyk: works at Google Warsaw; creator and co-author of the system supporting programming contests in distributed programming; a judge in the ACM-ICPC World Finals.

Filip Wolski: between 2012 and 2016, employed by leading high-frequency trading firms, including Teza Technologies; since August 2016, AI researcher at OpenAI.

Presenting this second, revised edition, we hope that its collection of problems will continue stimulating readers to plumb the depths of algorithmics and programming. Furthermore, we trust that studying the solutions designed by the authors will yield valuable insights and allow readers to augment the skills necessary for tackling science and engineering challenges in their professional careers.

Krzysztof Diks,
Warsaw 2018

/ Introduction

This book outlines the most significant moments and achievements in the almost 20-year history of Polish algorithmic and programming contests organized or co-organized by staff and students of the Faculty of Mathematics, Informatics and Mechanics at the University of Warsaw. The history of competitions in Poland is all about the people—both organizers and contestants. The fact that Poland was chosen to host the International Olympiad in Informatics in 2005, and the 2012 World Finals of the ACM International Collegiate Programming Contest, says a lot about the quality of programming contests that have been held in Poland over the years.

Participants in Polish competitions have numerous international achievements on their résumés. The most important ones include: first place for Filip Wolski and Tomasz Kulczyński in the International Olympiad in Informatics in 2006 and 2007 respectively, as well as the two-time victory of the University of Warsaw in the World Finals of the ACM International Collegiate Programming Contest thanks to Tomasz Czajka, Andrzej Gąsienica-Samek and Krzysztof Onak in 2003 and Marek Cygan, Marcin Pilipczuk and Filip Wolski in 2007. Polish contestants have had their fair share of successes—including victories—in other competitions as well, such as TopCoder Open, Google Code Jam, Facebook Hacker Cup and Microsoft Imagine Cup. These achievements would not have been possible without the level of challenge presented by programming contests held in Poland, which have enabled talents to be identified and given adequate opportunity for development.

Competitions in informatics

The role of competitions in selecting and educating particularly gifted high school and university students cannot be overestimated. These educational events require knowledge and skills greatly exceeding what is taught in schools and universities. A good competition is one that relates to the core of the discipline it concerns, and knowledge and skills acquired through participation therein are