S-Motzkin paths with catastrophes and air pockets (very early version)

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Abstract

So called S-Motzkin paths are combined the concepts 'catastrophes' and 'air pockets'. The enumeration is done by properly set up bivariate generating functions which can be extended using the kernel method.

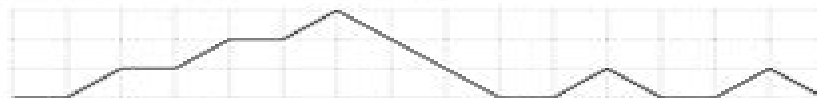**Keywords:** S-Motzkin path; catastrophe; kernel method; air pocket.

2020 Mathematics Subject Classification: 05A15.

1. Introduction

Dyck paths consist of up-steps $(1,1)$ and down-steps $(1,-1)$, start at the origin and do not go below the x-axis; they appear in many texts, we just give one major reference, [12]. Typically, the path returns to the x-axis at the end, but we also consider the scenario of open paths, where the paths end at level j, say. A popular variation of Dyck paths are Motzkin paths; the difference is just that now a horizontal step $(1,0)$ is also allowed.

In this paper, we concentrate on S-Motzkin paths, which is a subfamily of all Motzkin paths: all three steps (up, level, down) must appear n times, and, ignoring the down-steps, the sequence is $(1,0)(1,1)(1,0)(1,1)(1,0)(1,1)\ldots(1,0)(1,1)$. The follow figure shows how these paths are recognized: The two layers enforce that the flat and up steps are interlaced. Only paths that end in the origin are S-Motzkin but we consider all paths wherever they end.

Here is an example of such an S-Motzkin path with 15 steps:

Now we present a graph (automaton) to recognize exactly the S-Motzkin paths:

Figure 1: Graph to recognize S-Motzkin paths; they start and end at the special state (origin).

This subfamily of Motzkin paths originated from a question in a student competition; see [10] and [7] for history and analysis. In the following we will combine this family with *catastrophes* and *air pockets*, both originating in papers by Jean-Luc Baril and his team [5], [3]; the older paper by Banderier and Wallner [2] might be called the standard reference for lattice paths with catastrophes. The very recent papers [4,5] contain some bijective aspects. Our own paper [9] investigates the situation in the context of skew Dyck paths.

Dyck (and other lattice) paths with catastrophes are characterized by additional steps ('catastrophes') that bring the path back to the x-axis in just one step from any level $j \geq 2$. For S-Motzkin paths the definition is similar, and the graphical description in Figure 2 is easiest to understand; the catastrophes are drawn in special colors.

In the last section, S-Motzkin paths with air pockets will be discussed. Briefly, down steps of any length are now allowed, but no two down steps may follow each other.

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wave functions now widely known as the Jost functions Near the end of his life Levinson returned to research in analytic number theory and made profound progress on the resolution of the Riemann Hypothesis Levinson s papers are typically tightly crafted and masterpieces of brevity and clarity It is our hope that the publication of these selected papers will bring his mathematical ideas to the attention of the larger mathematical community *Theory of Linear and Integer Programming* Alexander Schrijver,1998-06-11 Theory of Linear and Integer Programming Alexander Schrijver Centrum voor Wiskunde en Informatica Amsterdam The Netherlands This book describes the theory of linear and integer programming and surveys the algorithms for linear and integer programming problems focusing on complexity analysis It aims at complementing the more practically oriented books in this field A special feature is the author s coverage of important recent developments in linear and integer programming Applications to combinatorial optimization are given and the author also includes extensive historical surveys and bibliographies The book is intended for graduate students and researchers in operations research mathematics and computer science It will also be of interest to mathematical historians Contents 1 Introduction and preliminaries 2 Problems algorithms and complexity 3 Linear algebra and complexity 4 Theory of lattices and linear diophantine equations 5 Algorithms for linear diophantine equations 6 Diophantine approximation and basis reduction 7 Fundamental concepts and results on polyhedra linear inequalities and linear programming 8 The structure of polyhedra 9 Polarity and blocking and anti blocking polyhedra 10 Sizes and the theoretical complexity of linear inequalities and linear programming 11 The simplex method 12 Primal dual elimination and relaxation methods 13 Khachiyan s method for linear programming 14 The ellipsoid method for polyhedra more generally 15 Further polynomiality results in linear programming 16 Introduction to integer linear programming 17 Estimates in integer linear programming 18 The complexity of integer linear programming 19 Totally unimodular matrices fundamental properties and examples 20 Recognizing total unimodularity 21 Further theory related to total unimodularity 22 Integral polyhedra and total dual integrality 23 Cutting planes 24 Further methods in integer linear programming Historical and further notes on integer linear programming References Notation index Author index Subject index **Lectures On Convex Sets (Second Edition)** Valeriu Soltan,2019-11-28 The book provides a self contained and systematic treatment of algebraic and topological properties of convex sets in the n dimensional Euclidean space It benefits advanced undergraduate and graduate students with various majors in mathematics optimization and operations research It may be adapted as a primary book or an additional text for any course in convex geometry or convex analysis aimed at non geometers It can be a source for independent study and a reference book for researchers in academia The second edition essentially extends and revises the original book Every chapter is rewritten with many new theorems examples problems and bibliographical references included It contains three new chapters and 100 additional problems with solutions Mathematics Related to Physics Raoul Bott,1994 Volume 4 **NBS-INA, the Institute for Numerical Analysis, UCLA 1947-1954** Magnus Rudolph Hestenes,1991 **Handbook**

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Real Algebraic Geometry and Ordered Structures Charles N. Delzell,James J. Madden,2000 This volume contains 16 carefully refereed articles by participants in the Special Semester and the AMS Special Session on Real Algebraic Geometry and Ordered Structures held at Louisiana State University and Southern University Baton Rouge The 23 contributors to this volume were among the 75 mathematicians from 15 countries who participated in the special semester Topics include the topology of real algebraic curves Hilbert s 16th problem moduli of real algebraic curves effective sums of squares of real forms Hilbert s 17th problem efficient real quantifier elimination subanalytic sets and stratifications semialgebraic singularity theory radial vector fields exponential functions and valuations on nonarchimedean ordered fields valued field extensions partially ordered and lattice ordered rings rings of continuous functions spectra of rings and abstract spaces of higher level orderings and real places This volume provides a good overview of the state of the art in this area in the 1990s It includes both expository and original research papers by top workers in this thriving field The authors and editors strived to make the volume useful to a wide audience including students and researchers interested in real algebraic geometry and ordered structures two subjects that are obviously related but seldom brought together   *Graphs and Combinatorial Optimization: from Theory to Applications* Claudio Gentile,Giuseppe Stecca,Paolo Ventura,2021-03-01 This book highlights new and original contributions on Graph Theory and Combinatorial Optimization both from the theoretical point of view and from applications in all fields The book chapters describe models and methods based on graphs structural properties discrete optimization network optimization mixed integer programming heuristics meta heuristics math heuristics and exact methods as well as applications The book collects selected contributions from the CTW2020 international conference 18th Cologne Twente Workshop on Graphs and Combinatorial Optimization held online on September 14 16 2020 The conference was organized by IASI CNR with the contribution of University of Roma Tre University Roma Tor Vergata and CNRS LIX and with the support of AIRO It is addressed to researchers PhD students and practitioners in the fields of Graph Theory Discrete Mathematics Combinatorial Optimization and Operations Research   **Even Convexity and Optimization** María D. Fajardo,Miguel A. Goberna,Margarita M.L. Rodríguez,José Vicente-Pérez,2020-10-27 This tutorial is the first comprehensive introduction to possibly infinite linear systems containing strict inequalities and evenly convex sets The book introduces their application to convex optimization Particular attention is paid to evenly convex polyhedra and finite linear systems containing strict inequalities The book also analyzes evenly convex and quasiconvex functions from a conjugacy and duality perspective It discusses the applications of these functions in economics Written in an expository style the main concepts and basic

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