

# $S$ -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.

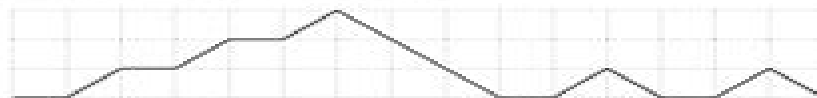
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## 1. Introduction

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  $(1, 0)(1, 1)(1, 0)(1, 1)(1, 0)(1, 1) \dots (1, 0)(1, 1)$ . 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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