

# Automated Generation of Planar Geometry Olympiad Problems



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## Motivation

The **International Mathematical Olympiad** is the most prestigious mathematical contest.



<http://imo-official.org/>

- 100+ countries
- 600+ participants
- 6 difficult problems
- 2 planar geometry problems
- **Writing these problems** is:
  - Difficult
  - Time-consuming
  - Requires years of experience

## Main challenges

- **Very little prior work** in automation
- Multitude of possible problems
- Only a minority of them is suitable
- **No universal way** of recognizing them

## Methods

### 1. Generation of geometry problems

- Complex algorithm with **efficient memory usage**
- Allowed for arbitrarily long-running experiments
- **Formally proven** to be correct

### 2. Filtering unsuitable problems

- Utilizes **geometry theorem proving** methods
- Filtered out **95%** of the easy problems in the performed test-case experiment

### 3. Ranking of the remaining problems

- **Heuristic** ranking system
- **4 rated aspects** selected based on the author's years of **experience** in writing geometry problems

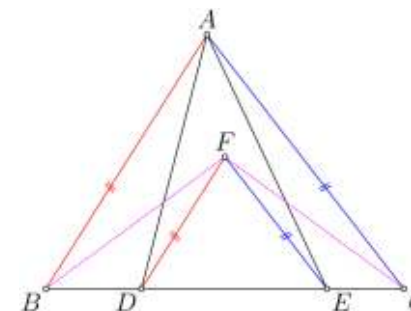
## Implementation

- C# .NET Core 3.1
- **No external libraries** for the main logic
- Visualization via MetaPost and TeX
- <https://github.com/PatrikBak/GeoGen>

## Results

- Tested in long-running (40+ hours) parallel generations (45,000+ CPU hours)
- More than **100,000 problems**
- **5 problems** proposed to the **International Mathematical Olympiad 2020**
- **1 problem** accepted to the **Czech-Slovak-Polish Match 2020**
- **4 problems** accepted to the **Czech-Slovak Olympiad 2020**

## Accepted problem



Let  $ABC$  be an acute triangle. Suppose that points  $D$  and  $E$  lie on the side  $BC$  such that  $D$  is between  $B$  and  $E$ ,  $AD = CD$ , and  $AE = BE$ . Point  $F$  is a point satisfying  $FD \parallel AB$  and  $FE \parallel AC$ . Prove that  $FB = FC$ .