Comparing Two Major Programming Contests: IOI vs. ICPC

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***Abstract*—The International Olympiad in Informatics (IOI) and the International Collegiate Programming Contest (ICPC) are two of the most esteemed competitions in the world of competitive programming, each serving distinct educational and developmental purposes. This article provides a comprehensive comparison of the IOI and the ICPC, highlighting their structural differences, target demographics, and problem-solving approaches. The IOI focuses on individual performance among high school students, fostering innovation and creativity, while the ICPC emphasizes teamwork and collaboration among university students. Through an analysis of competition formats and problem types, this study elucidates the strengths and challenges inherent in both competitions. Ultimately, we aim to demonstrate how the IOI and the ICPC contribute to jointly advancing computational thinking and programming expertise, shaping the next generation of technology leaders and problem solvers.**

I. Introduction

In the realm of competitive programming, two prestigious events stand out: the International Olympiad in Informatics (IOI) and the International Collegiate Programming Contest (ICPC). Both competitions challenge participants with complex problem-solving tasks and algorithmic challenges, yet they cater to different audiences and emphasize unique skill sets. The IOI primarily targets high school students, fostering a spirit of innovation and creativity in young minds, while the ICPC is designed for university students, promoting teamwork and collaboration under pressure.

This article delves into the key similarities and differences between these two iconic competitions, exploring their structure, problem types, participant demographics, and the impact they have on the development of computational thinking and programming skills. By understanding the nuances of each event, we can appreciate their contributions and insights to the field of computer science and the cultivation of future tech leaders.

II. Overview of the IOI

This section describes the organization of the IOI, including its committees and participants, and the competition structure.

A. The Organization

The International Olympiad in Informatics (IOI) is a pre-college level annual competition and is one of the major international science competitions including Math (IMO), Biology (IBO), Physics (IPhO), Chemistry (IChO), and Computer Science (IOI). The first IOI was held in 1989 in Bulgaria and there are 98 member countries and regions as of 2025, where a member country/region is defined[1] as a country/region which participated in the last three IOIs.

Several committees[2] work together to ensure the success of IOI. The International Committee (IC) is responsible for overseeing and supervising the IOI competition by finding and supporting future host countries, solving potential political problems encountered during the organization of an IOI, and adjusting the format and content of the IOI to ensure that the IOI goals are met. The IC committee membership is composed of organizers from future IOI hosts and members elected for a service duration of 3 years by the General Assembly (GA). The GA is formed by a single representative from each member country. GA meetings are held in conjunction with the competition, which spans a period of one week every year.

The International Scientific Committee (ISC) is responsible of overseeing the competitions at the IOI. The committee's main duty is to collect and select a set of problems for the competition, including the substitute tasks for the case when a task is not approved by the GA before the competition day and needs to be replaced by an alternative task. Competition problems are collected from the competitive programming community via a public call for tasks about 8-9 months before

[1]https://ioinformatics.org/page/members/7
[2]https://ioinformatics.org/page/committees/6

the competition (see https://ioi2025.bo/call-for-tasks.html for an example call for tasks). The ISC is also in charge of resolving issues that can arise during the competition about contest problems.

The International Technical Committee (ITC) works with each host country to ensure continuity and quality control of the IOI competition environment including hardware and software, such as the installed integrated development environments (IDEs) and editors, the evaluation environment (such as the Contest Management System (CMS) [1]), networks, and their security. The committee also provides support in technical matters to the ISC and to future hosts.

Each delegation is composed of four contestants, a team leader, and a deputy team leader. The main responsibilities of team leaders during a competition week include: supervising the delegation's contestants, participating in General Assembly (GA) meetings, and translating competition task documents to the delegation's native language one day before each contest day.

Team selection processes and potential feeder competitions to the main IOI event vary widely among countries and regions (see [2] and [3]). In the United States, the USACO organization[3] manages training and selection of the US delegation for both the IOI and the EGOI (European Girls' Olympiad in Informatics). In China, a multi-tiered system of provincial and national Olympiads identifies the top students, with the national training camp ultimately selecting the IOI team. Russia follows a similar model, with the All-Russian Olympiad in Informatics (VOI) serving as the main feeder contest. South Korea and Poland also rely on national Olympiads and intensive training camps to select and prepare their delegations. In some countries, such as in Türkiye, government agencies sponsor and oversee the training process, whereas in others, such as in the United Kingdom[4] , non-profit volunteer organizations manage team selection and training.

B. The Competition

A typical IOI competition week is composed of the registration day, the practice and opening ceremony day, and two excursion/activity days – one prior to each of the two competition days – and finally ended by the awards and closing ceremony and departure days. Team leaders usually spend the evening prior to each contest day discussing, revising, and approving the tasks, replacing the tasks with back-up tasks proposed by the the International Scientific Committee (ISC) when needed, and translating the tasks to their native language as they are being revised in a long GA meeting that starts after dinner and extends until midnight (or sometimes a couple of hours after midnight), occasionally accompanied with cheers from the GA when the ISC announces: "Problem X is final!". Contestants spend the evenings before competition days in quarantine, typically participating in fun activities with other delegations together with their assigned local team guides. Each competition day typically has three problems for contestants to solve and lasts for 5 hours, starting mid-morning (at 9/10 am). Each contest day ends with potential appeals after allowing contestants access to their contest environment and approval of that day's results by the General Assembly following a summary of the contest by the International Technical Committee (ITC).

[3]https://usaco.org/index.php?page=history

[4]https://www.olympiad.org.uk/overview.html

Contestants compete individually on their designated workstations. Bringing any form of documentation, printed or electronic, is not allowed. However, language-specific documentation, i.e., C++ Standard Template Library Reference Manual, is available on contestants' machines. Contestants cannot see the scoreboard during the competition and only receive feedback on their own submissions. For a complete set of competition rules, please refer to https://ioi2025.bo/contest-rules.

One of the major differences from other programming competitions is the constraint that solutions must be written in the C++ language.

A problem solution, once submitted, is scored by evaluation against a hidden set of test cases. Each problem may contain a number of subtasks, and the final score for each subtask is the maximum of the scores for this subtask across all submissions. The final score for each problem is the sum of the scores for its subtasks. There is a limit on submissions per task per minute, which is lifted in the last 15 minutes of the contest. An additional restriction of at most 50 submissions for each problem also applies. Neither submission times nor number of submission are considered in ranking contestants.

C. The IOI Syllabus

The IOI organization maintains a syllabus to guide trainers and contestants [4]. The syllabus is a document that is updated regularly and classifies several Computer Science and Mathematics topics into categories indicating the extent of their inclusion or exclusion in the IOI. At the extremes of the classification spectrum, there are topics that are included in an unconstrained fashion and topics that are explicitly excluded. However, there are also cases where inclusion of a topic in a problem requires additional definitions, and others where the exclusion of a topic is open to discussion. These additional categories provide flexibility and help avoid strict boundaries that could potentially limit the creativity of problem setters.

The topics included in the IOI syllabus mostly overlap with the ICPC syllabus outlined in Section III-B; however, some notable exclusions in the IOI syllabus are:

- Geometry in three or more dimensions
- Halfspace intersection, Voronoi diagrams, Delaunay triangulations
- Linear algebra, calculus and statistics
- Minimizing multi-variate functions using numerical approaches
- Clustering algorithms
- Network flow
- String algorithms and data structures (KMP, Rabin-Karp hashing, suffix arrays/trees, suffix automata, Aho-Corasick)
- Complex heap variants such as binomial and Fibonacci heaps
- Using and implementing hash tables (including strategies to resolve collisions)

D. A Sample IOI Problem

Various types of problems have been used in the past IOIs, from output-only problems to interactive problems. Some problems do not have subtasks, but instead partial points are given based on how close a solution gets to an optimal one. For example, in the IOI 2013, "Art Class" was a problem involving image classification where participants were scored based on the percentage of images correctly classified. In this section, we show an example IOI problem below, one that appeared in IOI 2024 Egypt. The problem, Nile, has seven subtaks. Among the 365 contestants, all of the 34 gold medalists were able to fully solve this problem, the minimum score by any of the 62 silver medalists was 67 (averege: 95.02), and the minimum score by any of the 95 bronze medalists was 34 (average: 84.85). Below is an *abbreviated* problem description and details of the subtasks for the problem **Nile**[5].

> **Goal:** Your goal in this problem is to find the optimum way to transport N artifacts through the Nile on a boat that can carry at most two items at a time. Each item has a weight, and if two items are put on the same boat, the difference between their weights should be at most D, which is specified in Q queries made for a specific set of items. The cost of individually transporting an item on a boat, A_i, is different from transporting it together with another item, B_i, and the lists of costs for each item are given as arrays. You have to pay the sum $B_i + B_j$ when transporting items i and j together, and it is also given that $A_i > B_i$ for any given item, i.

To solve an IOI problem, instead of writing complete C/C++ programs, students write code that should implement one or more required functions. In the case of the problem above, the submission should implement a single function that takes four input vectors (weights, individual transport costs, shared transport costs, and the Q queries that specify the weight difference requirement D) and returns a vector that gives the optimum cost of transport for each of the Q queries.

The time limit for this problem is 2 seconds, and the memory limit is 1 GB. The constraints on the test cases are given below:

- The number of items is at most 100K
- The number of queries is at most 100K
- The weights, costs, and weight difference limits are all non-negative and are at most 10^9

The subtasks are each defined by specifying additional constraints. Each subtask is given a score value such that the scores sum to 100. The subtasks for this problem are given in the table below:

[5]https://www.acmicpc.net/problem/32266

Subtask	Score	Additional Constraints
1	6	At most 5 queries and 2000 items, each item weighs 1
2	13	At most 5 queries, item weights are $W_i = i + 1$
3	17	At most 5 queries, all individual transport costs are 2 and shared costs are 1.
4	11	At most 5 queries and 2000 items
5	20	At most 5 queries
6	15	All individual transport costs are 2 and shared costs are 1
7	18	No additional constraints

As seen in the table above, subtasks could be easier to solve by isolating certain characteristics of the problem, e.g., by making all weights equal to each other, the students can focus on a heuristic that considers item costs only. Although only 126 out of 365 contestants were able to receive full credit on this problem, 261 contestants were able to get a score of 50 or more (see https://stats.ioinformatics.org/results/2024).

For the solution of the problem, please refer to https://github.com/ioi-2024/tasks/blob/main/day1/nile/nile_editorial.pdf.

E. IOI Statistics

Approximately 90 countries[6] participated in the IOI for each of the last 10 years (see https://stats.ioinformatics.org/olympiads/). Since 1989, 112 different countries have participated in the IOI; 31 different countries have hosted the IOI during that time span, and the top-10 most successful countries (in terms of the total number of medals earned) are listed in the table below.

Country	Gold	Silver	Bronze	Total
China	102	28	12	142
Poland	44	52	35	131
Romania	34	60	37	131
Bulgaria	27	55	45	127
Republic of Korea	49	50	28	127
Vietnam	21	51	54	126
Iran	32	67	24	123
United States of America	68	39	16	123
Russia	68	40	12	120
Taiwan	25	62	30	117

It is important to note that significantly more medals are distributed in the IOI compared to the ICPC World Finals. In every IOI, about one twelfth of the contestants (about 25-30) receive gold medals, two twelfths receive silver medals, and three twelfths receive bronze medals with the constraint that at most half of the contestants receive a medal.

The top-3 gold winning countries are China, the USA, and Russia. Although contestants represent their countries,

[6]According to S2.1 of the IOI Regulations: "For the IOI, a Country is a state that has an officially recognised relationship with the United Nations, UNESCO, or which has already taken part in one or more past IOIs".

the competition is individual and there is a hall of fame that shows the top-100 perfoming contestants at: https://stats.ioinformatics.org/halloffame/. The top of the hall of fame is Gennady Korotkevitch, the infamous "tourist", who participated in seven IOIs representing Belarus and was able to earn gold medals six times in a row from 2007 to 2012. Note that some countries have limitations on how many times an individual can compete as part of their delegation, e.g., only once in China and twice in the Republic of Korea.

III. Overview of the ICPC

The International Collegiate Programming Contest (ICPC) is the premier global programming competition for university students. It is one of the most prestigious and longest-running competitive programming contests, alongside high school-level competitions such as the International Olympiad in Informatics (IOI). The ICPC traces its origins to a competition held in 1970 at Texas A&M University and has since grown into a worldwide contest with thousands of teams from over 100 countries participating each year.

The ICPC is structured into multiple levels of competition. Universities first organize their own *Local Contest* to select one or more teams, each consisting of three students, that will compete in a multi-university *Regional Contest*. Regional contests frequently span multiple states, provinces, territories, or even countries. Universities may field several teams at these levels, but only one team per university is typically eligible to advance to the ICPC World Finals.

Quite recently, the Regional Contests have been organized into eight geographical ICPC Regions: Africa and Arabia, Asia East, Asia Pacific, Asia West, Europe, Latin America, North America, and Northern Eurasia. Each Region now holds a *Regional Championship*, which determines a set of approximately 15 teams that will advance to the *ICPC World Finals*. The selection rules vary: in some Regions, the Championship serves as a playoff among the top teams from each Regional Contest, while in others, the best team in each Regional Contest is auto-qualified and the Championship decides the remaining slots. In the United States, for instance, teams advance from local and regional qualifiers to the North America Championship (NAC), which determines the representatives for the World Finals.

Historically, the best team(s) from each Regional Contest would qualify directly for the World Finals, but the regionalized structure now standardizes advancement across the globe. The ICPC World Finals remains the culminating contest, bringing together the top 130–140 universities worldwide.

Several committees ensure the smooth organization and execution of the ICPC:

1) **The Executive Committee** oversees the overall strategy and direction of the contest, ensuring that ICPC's mission of fostering algorithmic problem-solving skills and teamwork among university students is upheld.
2) **The Operations Team** works closely with the host institution to plan and execute the World Finals, handling logistics, sponsorships, and event management.
3) **The Judging Team** is responsible for designing and selecting contest problems. This committee consists of experienced competitive programmers, former ICPC participants, and academic experts who ensure that the problems are diverse in difficulty and cover a broad range of algorithmic topics.
4) **The Systems Team** works with host universities and sponsors to maintain a fair and standardized contest environment, managing the contest management system, testing environments, and ensuring robust technical infrastructure.

Contest problems cover a broad range of algorithmic and mathematical topics, and solutions are judged by an automated system for both correctness and efficiency.

The ICPC fosters a strong community of problem solvers, many of whom go on to become leaders in academia, research, and the technology industry. With its emphasis on teamwork, problem-solving, and innovation, the ICPC continues to be a flagship competition for university students passionate about algorithmic programming.

A. The Competition

A typical ICPC World Finals week consists of registration, an official practice session, an opening ceremony, a contest day, and concludes with the awards ceremony and departure. In addition to the main contest, the schedule often includes excursions, networking events, and technical symposiums such as the ICPC Competitive Learning Institute (CLI) Symposium. The contest itself is a five-hour competition where teams of three students work together on a single computer to solve algorithmic problems.

Before the contest, the judges finalizes the problem set, ensuring a balanced mix of algorithmic challenges covering topics such as graph theory, dynamic programming, data structures, and computational geometry. The problems undergo rigorous testing, and the final selection is translated into multiple languages before the competition. Teams do not have access to the problems until the contest begins.

During the competition, teams have access only to a standard programming environment without internet connectivity. They may bring a 25-page team reference document (TRD). Each problem submission is judged against a set of hidden test cases, and teams receive real-time feedback on whether their solution is correct, incorrect, or suffers from issues like runtime errors or time limit exceeded. Unlike some other contests, ICPC follows a penalty-based ranking system where the primary ranking criterion is the number of problems solved, with time penalties used as tiebreakers. The contest environment provides a live scoreboard during most of the contest. During the final hour of the contest, however, the scoreboard is frozen and no longer updated, increasing the suspense as teams make last-minute submissions.

A key distinguishing feature of the ICPC is its team-based format, requiring collaboration under strict time constraints. The use of C, C++, Java, Kotlin, or Python3 is permitted. Teams must carefully allocate time and divide tasks efficiently to maximize their performance. The competition concludes with an analysis session, followed by the awards ceremony recognizing the top teams ("Medalists"), the top team from each ICPC Region, the first team to solve each problem, and other category-specific winners.

For a complete set of competition rules, please refer to https://icpc.global/regionals/rules.

B. The ICPC Syllabus

Currently, there is no officially recognized syllabus for the ICPC. However, the ICPC Curriculum Committee[7], of which the authors are members, has developed a suggested syllabus that outlines key topics and concepts relevant to competitive programming at the ICPC level. This suggested syllabus serves as a guideline for training and preparation, covering fundamental and advanced topics in algorithms, data structures, computational problem-solving techniques, and mathematical foundations. While not yet officially adopted, this syllabus continues to evolve based on feedback from the competitive programming community, advancements in the field, and ongoing discussions within the committee. In the future, it may develop into an official ICPC syllabus, providing a structured framework for contestants, coaches, and educators worldwide.

C. A Sample ICPC Problem

We have selected **Carl's Vacation**[8] as an example ICPC problem. This problem, from the 2022/2023 World Finals (held in Luxor, Egypt), has a nearly identical difficulty to the **Nile** problem chosen as an IOI example. This problem is also a representative ICPC problem because it involves 3D geometry, a topic excluded in the IOI syllabus.

Carl's Vacation

Time limit: 1 second

Carl the ant is back! After traversing meandering paths (Problem A, 2004 World Finals) and wandering over octahedrons (Problem C, 2009 World Finals) it is time for a little vacation — time to see the sights! And where better to see the sights than at the tips of tall structures like, say, pyramids!! And where better to see tall pyramids but Egypt!!! (This is so exciting!!!!!)

After taking in the view from the tip of one pyramid, Carl would like to go to the tip of another. Since ants do not do particularly well in the hot sun, he wants to find the minimum distance to travel between the tips of these two pyramids, assuming he can only walk on the surfaces of the pyramids and the plane which the pyramids sit upon. The pyramids are, geometrically, right square pyramids, meaning the apex of the pyramid lies directly above the center of a square base.

Input

The first line of input contains five integers x_1, y_1, x_2, y_2, h where x_1, y_1, x_2, y_2 $(-10^5 \leq x_1, x_2, y_1, y_2 \leq 10^5$ and $(x_1, y_1) \neq (x_2, y_2))$ define an edge of the first pyramid, with the body of the pyramid lying to the left of the directed vector from (x_1, y_1) to (x_2, y_2), and h $(1 \leq h \leq 10^5)$ is the height of the pyramid. The second line of input describes the second pyramid in the same format. The intersection of the bases of the two pyramids has 0 area.

Output

Output the minimum distance Carl travels between the tips of the two pyramids. Your answer should have an absolute or relative error of at most 10^{-6}.

Sample Input 1	Sample Output 1
0 0 10 0 4 9 18 34 26 42	60.866649532

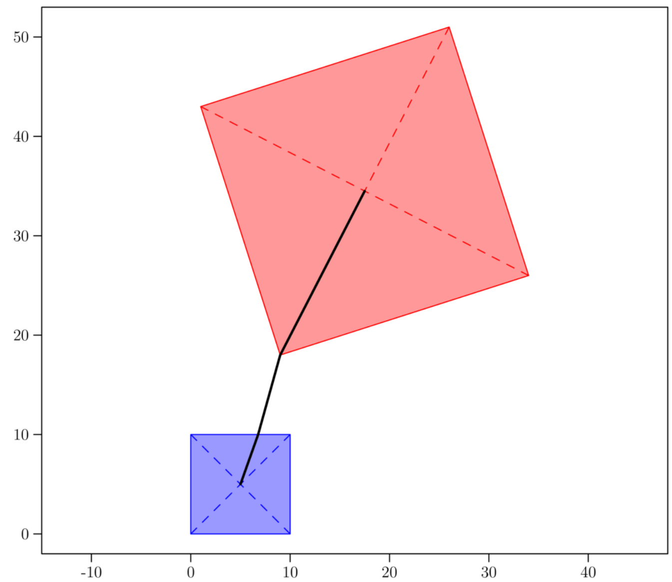


Fig. 1. Illustration of two pyramids corresponding to Sample Input 1. The black line shows the shortest path between their apexes.

It is worth noting that where IOI problems require a solution to just provide one or more required functions taking inputs as arguments and returning a result, the solution to each ICPC problem must provide the entire program, reading and parsing the input for a given test case from `stdin`, performing the required processing, and then writing the corresponding output to `stdout` in precisely the format specified.

D. ICPC Statistics

ICPC is the world's largest and most prestigious collegiate programming competition, with participation from over 50,000 students across 100+ countries representing 3,000+ universities each year. The competition spans multiple rounds, beginning with local and regional contests that lead to the highly competitive ICPC World Finals. Teams that advance to the World Finals represent the top fraction of participants, often less than 1% of the initial pool of contestants.

General ICPC Statistics:

- **Founded:** 1970
- **Participating Universities:** 3,000+ from over 100 countries
- **Annual Student Participants:** Over 50,000
- **Regional Contests:** Approximately 100 worldwide

[7] https://curriculum.u.icpc.global/
[8] https://www.acmicpc.net/problem/31894

- **ICPC World Finals Teams:** Around 140 (selected from 50,000+ students)
- **Problem Count in World Finals:** typically 11-15
- **Fastest Accepted Solution in World Finals:** Usually within 12 minutes (fastest is 5 minutes, which has happened at least 3 times)
- **Record for Most Problems Solved in World Finals:** 13 (St. Petersburg National Research University of IT, Mechanics and Optics, 2015)
- **World Finals Hosting Locations:** Over 20 cities worldwide

Performance Statistics:

- **Most Wins by a University:** ITMO University (Information Technologies, Mechanics and Optics University) - 7 Titles
- **Fastest Regional Qualification:** Some teams qualify within 1-2 hours of the contest
- **Typical Cutoff for Advancing to World Finals:** 1st place in Regional Contest or Top- 16 at Regional Championship

IV. Analysis and Discussion: Comparing the IOI and the ICPC

A. Individual versus Team Based Competition

A major and fundamental difference in terms of competition structure between the IOI and the ICPC is the way contestants compete: individually or as a team. The restriction of one computer per team in the ICPC encourages teams to develop alternative on-paper problem solving strategies. Different tasks can be distributed or delegated between team members, including ranking the problems by difficulty, thinking about edge cases for specific problems, identification of potential bugs by reading printed code, and matching topics/code on the TRD with the problems.

It is important to note that individual contestants in the IOI do not have the luxury of neglecting topics, nor having strength in one topic compensate for weakness in another (nor do you have teammates that can compensate).

In the ICPC World Finals, each team tries to solve 11-15 problems in 5 hours; whereas in the IOI, the target is to solve 6 problems in 10 hours (across the two contest days). In the ICPC, even though there are three contestants on a team, it is a contest with significantly more problems in less time. Concretely, the IOI presents 6 problems to be solved with 10 person and 10 machine hours, or 0.60 problems/person-hour and 0.60 problems/machine-hour. The ICPC, in turn, presents almost twice as many problems ($\sim$11.93 problems on average) to be solved in 15 person hours and 5 machine hours, or 0.80 problems/person-hour and 2.39 problems/machine-hour.

B. Distribution of Contestant Scores

With a larger problem set, the difficulty of the problems in the ICPC is more varied, and there are usually a few very hard problems from open-ended topics. On the other hand, although the number of problems in an IOI contest is small, the structure of a problem with different subtasks makes it easier for contestants to attempt easier, smaller scale, or more constrained versions of problems. Figure 2 shows the score distributions of the contestants in the last 10 IOIs between 2015 and 2024. We observe a sigmoid-like shape with drops at the left and right tails of the distribution.

Although scoring is more discrete in the ICPC World Finals, we observe a similar score distribution in the last 10 ICPC World Finals, as shown in Figure 3. We can hypothesize that the large number of problems in an ICPC contest has a similar effect on contestants' performance compared to the partial scoring mechanism in the IOI.

C. Contest Environment

One major difference in the contest environment is the strict prohibition of any outside source material in the IOI, whereas the teams are allowed to bring a 25-page Technical Reference Document (TRD) in the ICPC. The contestants of the IOI, therefore, need to memorize implementations of complex data structures and algorithms such as segment trees, disjoint set union, and binary lifting.

Another important difference is the restriction of the submitted code to the C++ language in the IOI. There have been discussions in the IOI community to allow for other programming languages. Java was an allowed language prior to 2021 when the current C++ only policy was instituted.

One final note about the contest environment is about the availability of the full scoreboard to the contestants during the competition. In the ICPC, all contestants can view the scoreboard – updated in real-time – and see which teams have solved which problems, allowing them to alter strategy based on the solved problems. The scoreboard is frozen in the final hour of the competition, but the teams continue to receive individual feedback on their own submissions. In the IOI, throughout the whole competition, the scoreboard is not available to the contestants and feedback is limited to a contestant's own submissions.

D. Data Collected for Analysis

To facilitate the analysis presented below in Sections IV-E, IV-F, and IV-G, we collected a sizeable amount of data for both IOI and ICPC World Finals competitions.

The data collected includes:

- **IOI Results** - Full results for every IOI competition from 2003-2024 were collected from https://clist.by.
- **ICPC World Finals Scoreboards** - Full scoreboards for every world finals between 2011-2024 were collected from https://clist.by.
- **Problem Topics and Difficulties** - For both IOI and ICPC World Finals Problems, we collected topic and difficulty data from https://acmicpc.net (topics and difficulty scale shared with https://solved.ac).
- **Individual (IOI/ICPC) and Team (ICPC) Profiles** - The Competitive Programing Hall of Fame website (https://cphof.org) has profiles for individual contestants and for many World Finals teams. For the profiles that include codeforces.com (CF) or atcoder.jp (AT) handles, we additionally collected complete profile longitudinal data

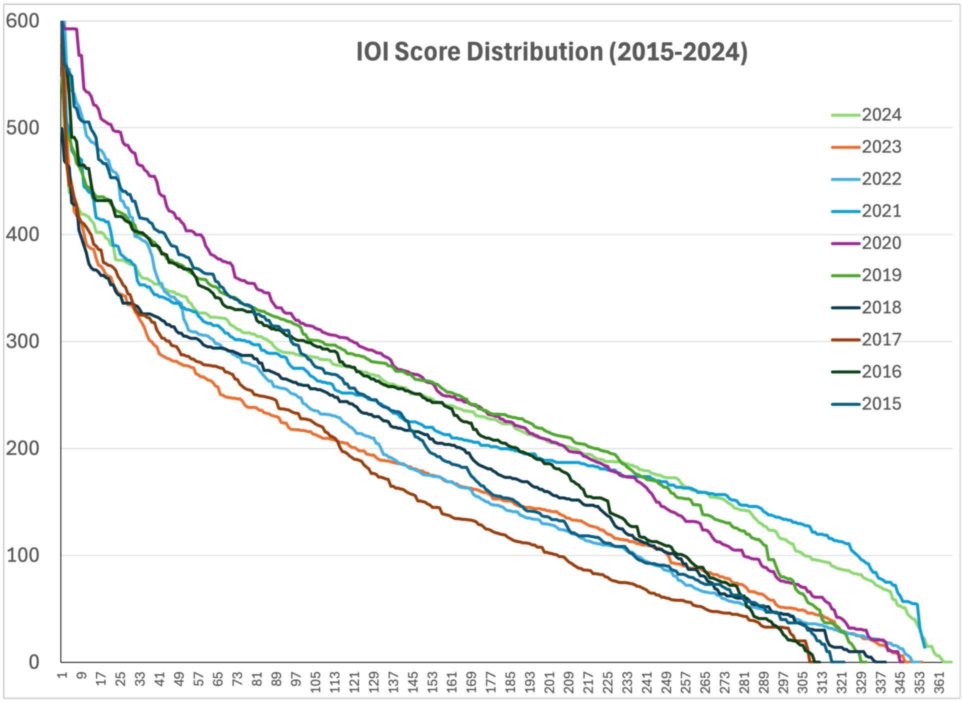


Fig. 2. Scoring distribution in the last 10 IOIs.

(every single rating change), which allows the calculation of an individual's precise rating at the time of any given contest.

We are publicly sharing this data with the community for further study and analysis – it can be found at https://github.com/icpc/cli/tree/main/ioi-vs-icpc. All of this data is publicly available already, but not centrally-gathered and organized in a single place. Please contact the authors if you have ideas of additional data that could be incorporated, or if you know where to find data that is missing (e.g. results from prior years).

E. Topics Covered

An interesting dimension to consider when comparing the IOI and the ICPC is topical coverage and focus. As mentioned earlier, the IOI has a Syllabus (see Section II-C) which dictates what topics are allowed for IOI problems and which are not. The ICPC does not have any formal constraints or restrictions on problem topics.

For contests between 2011-2024, we have collected data on the topics relevant for each IOI or ICPC WF problem (all that were available). We have adopted the topic labels from the Baekjoon online judge (https://acmicpc.net) and solved.ac (https://solved.ac) websites. With the exception of a half-dozen or so problems with missing topic data, each problem has between 1 and 16 topic labels (most problems have only 3-5 relevant topics). There are 112 distinct topics noted across 84 IOI and 167 ICPC WF problems.

Figure 4 shows the full data for these 14 years of both IOI (on the left in green) and ICPC WF (on the right in blue). In the middle you will find frequency data for both contests showing, for each topic, what fraction of the last 14 years' contests had a problem for which the topic was relevant.

There are some interesting observations beyond the absence of topics like *Max Flow* and *Strings* that are explicitly excluded from the IOI. Some relevant labels may be missing from problems, for example *Backtracking* occurs in 12/14 ICPC WF contests but was not noted in any IOI contests. Similarly, *Probability Theory* and *Number Theory* occur in 6/14 ICPC WF contests but are not noted on any IOI problems. It is interesting that topics such as *Segment Tree*, *Disjoint Set* and *Constructive* show up more consistently on IOI contests than they do on ICPC WF (even with 6 problems per IOI contest vs ∼12 per ICPC contest).

There are also some interesting temporal trends worth noting. Across the 14 years we compared data for, *Divide and Conquer* problems occurred on 5 of the first 7 IOI contests, but only once in the most recent 7 years. Conversely, topics like *Segment Tree With Lazy Propagation* and *Smaller to Larger Technique* have occurred with increasing frequency (2 and 0 in the first 7 IOI contests considered vs. 7 and 4 in the most recent 7 years).

On the ICPC WF side, *Sweeping* occurred in 9 of the first 10 contests, but has not occurred (at least has not been noted) in the any of the most 4 World Finals. Topics like *Dijkstra's*, *Shortest Paths* and *Case Work*, respectively occurred in 6, 5 and 4 of the earlier 7 contests, but only 2, 1 and 1 of the most recent 7 contests. On the flip side, *Probability Theory* and *Number Theory* have increased in frequency, from occurring in only 1 and 2 of the first 7 contests up to occurring respectively in 5 and 4 of the most recent 7 contests.

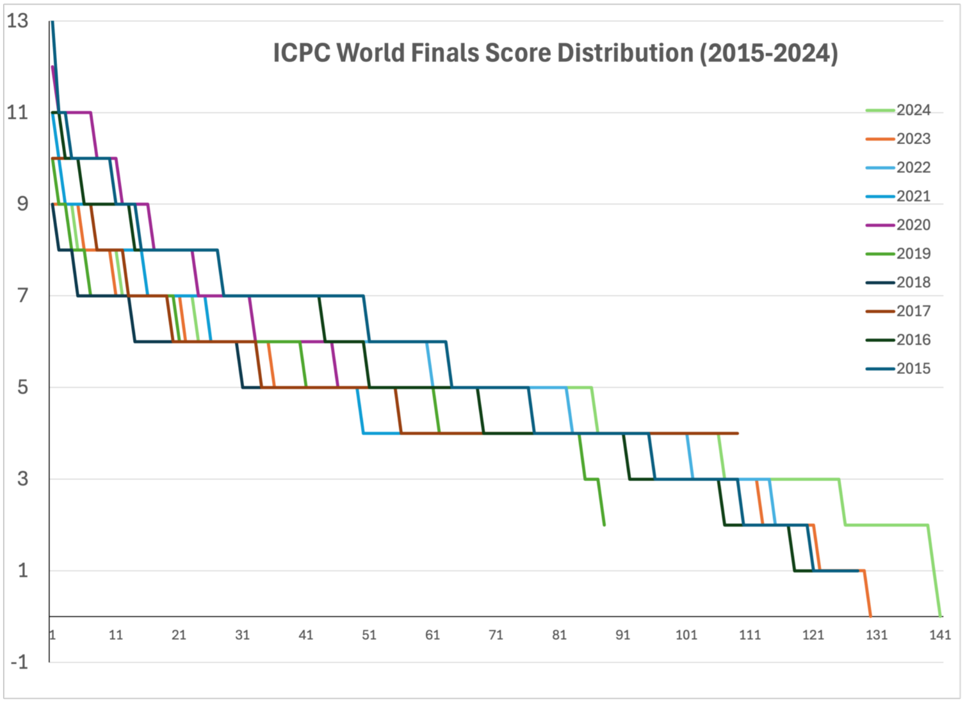
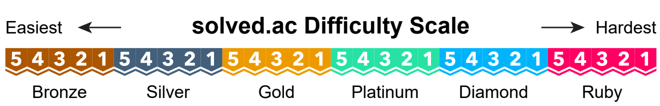


Fig. 3. Scoring distribution in the last 10 ICPC World Finals.

F. Problem Difficulty

There is value in considering the difficulties of the respective IOI and ICPC problem sets. Before looking at and analyzing the data that was collected, let's discuss the difficulty scale we've utilized. As above with topics, we have adopted The Baekjoon online judge (https://acmicpc.net) and solved.ac (https://solved.ac) difficulty scale where problem difficulty estimates are crowdsourced on a scale of 1-30. The figure just below shows the difficulty spectrum with six difficulty tiers: *Bronze*, *Silver*, *Gold*, *Platinum*, *Diamond*, and *Ruby* (hardest). Within each tier are 5 levels: 5 is easiest, 1 is most difficult. So the difficulties range from  at the easiest end to  at the most difficult end.



In Figure 5, 14 years of IOI and ICPC WF problems are, respectively, shown on the left in green, and on the right in blue. Each column represents a contest year and the rows are decreasing difficulty (from *Ruby-1* at the top to *Bronze-5* at the bottom). Problems from a given year with a given difficulty are shown with individual rectangles (sometimes darker indicating multiple problems of the same difficulty in a given year's contest). The green or blue line plotted on each side tracks the difficulty over time of the mean difficulty for a year's problems.

One important note is that subtasks for a given IOI problem are condensed into a single "problem" with its difficulty corresponding to that of the most difficult subproblem. This omission of easier subtasks, coupled with the fact that partial scoring on harder problems is possible in IOI problems helps explain the absence of easier problems and the trend toward more difficult ones (some of which may have hidden easier subtasks).

Keep in mind, too, that IOI contests have 6 problems while ICPC WF contests have 11-15 problems (during these years). This explains the greater abundance of problems on the ICPC side. The fact that there are 6 problems in 10 hours for IOI and 11-15 problems in 5 hours for ICPC WF also addresses the wider variance in ICPC WF difficulties relative to those in IOI contests. It also seems that there seem to be fewer Platinum-level problems for IOI in recent contests relative to earlier ones – the difficulty ranges are particularly tight in 6 of the last 7 IOI contests.

G. Contestant Performance

The final section of discussion and analysis is focused on a key question: *How does IOI participation/ranking influence ICPC WF performance?* We have focused our analysis here on IOI and ICPC medalists and what, if any, correlation may be present. We note that correlation is not equivalent to causation, however, it's unlikely that high correlation occurs without any causal relationship.

While there are certainly other angles to pursue this question from, we have explored two directions: (1) the probability of an ICPC WF medal for a given IOI ranking; and, (2) the presence/absence of IOI medalists on ICPC WF medal-winning teams.

To estimate the probability of winning a World Finals medal given a particular IOI ranking (see Figure 6), we simply take all individuals who competed in both contests and find all individuals with a given given IOI ranking. Among these individuals who attained this given IOI ranking, some

Fig. 4. **Topic Frequencies across IOI and ICPC World Finals (WF).** This figure shows all topics and their occurrences for IOI and ICPC World Finals problems between 2011-2024. Topics are listed vertically in order of decreasing frequency. Horizontally columns are: IOI contests (chronological order); Overall **IOI** and **ICPC WF** frequency (fraction of respective contests where the topic occurs); and ICPC WF contests (reverse chronological order).

fraction (perhaps zero) earned Gold/Silver/Bronze medals or no medal. Some rankings, particularly the highest ones (lowest rank numbers), have many individuals, so the probabilities we hope are reasonably accurate. Other IOI rankings have few or, perhaps even, no individuals who earned a medal at World Finals. It's also crucial to note that these calculations completely neglect the strength of an individual's teammates on their World Finals team.

In Figure 7, we present detailed data showing the composition of the medal-winning teams in all ICPC World Finals between 2011-2024. Most years 12 teams are awarded medals: gold medals are given to the teams placing 1st-4th; silver medals to those placing 5th-8th; and bronze medals to those placing 9th-12th. There are a few anomalies to that normal pattern: in 2010, the 8th- and 9th- placed teams had identical time penalties and both were given silver medals; in some years 1 or more additional teams were given a bronze medal.

So, to understand the figure, a team has a background rectangle color showing the medal that their team was awarded. Each of the 3 contestants on a team is represented by a circle. Within each individual's circle, there is a number indicating the total number of IOI medals earned (0-7) and the color corresponding to the highest medal that individual earned ($Gold > Silver > Bronze$). A given individual may only compete in two ICPC World Finals – individuals who are competing in their second World Finals are shown with a second circle surrounding the first.

There are several interesting takeaways from this data shown in Figure 7: (1) there is a strong correlation between IOI medalists, especially IOI gold medalists, being present on ICPC WF medal-winning teams; (2) there are many medal-winning teams whose team members appear to have little if any IOI experience (no IOI medalists, these students have likely just trained hard during their university years); and, (3) There is an impressive abundance of WF teams near the top, especially in the top 6-7 WF places, who have one or more second-time participants (just look at the white double-ringed circles). Additionally, further analysis would provide a more precise picture, but there is anecdotal evidence that schools who consistently earn WF medals frequently have teams with IOI medalists on them – though it is not clear how much this is cause, effect or both.

V. Guidelines for IOI Students Transitioning into ICPC

IOI students usually continue their journey in the world of competitive programming after transitioning into college life. Some challenges and suggestions to overcome them are listed below:

1) *Finding a team to compete on.* If the school already has a history of competing in the ICPC, there are usually student clubs that oversee team training and selection, and one needs to get in touch with such organizations within the school. However, if no such student club exists, the student may need to start one. Getting in touch with a faculty member who specializes in algorithms and data structures may be a good starting point.
2) *Learn new topics that are not included in the IOI syllabus.* One needs to learn new topics such as: String algorithms, network flow, three-dimensional geometry, and learn to work on open-ended problems.
3) *Lean how to work as a team.* It may be a good idea to specialize in one or more of the following areas: edge case finding, typing fast, debugging, math, or problem solving. Having complementary areas of topical expertise

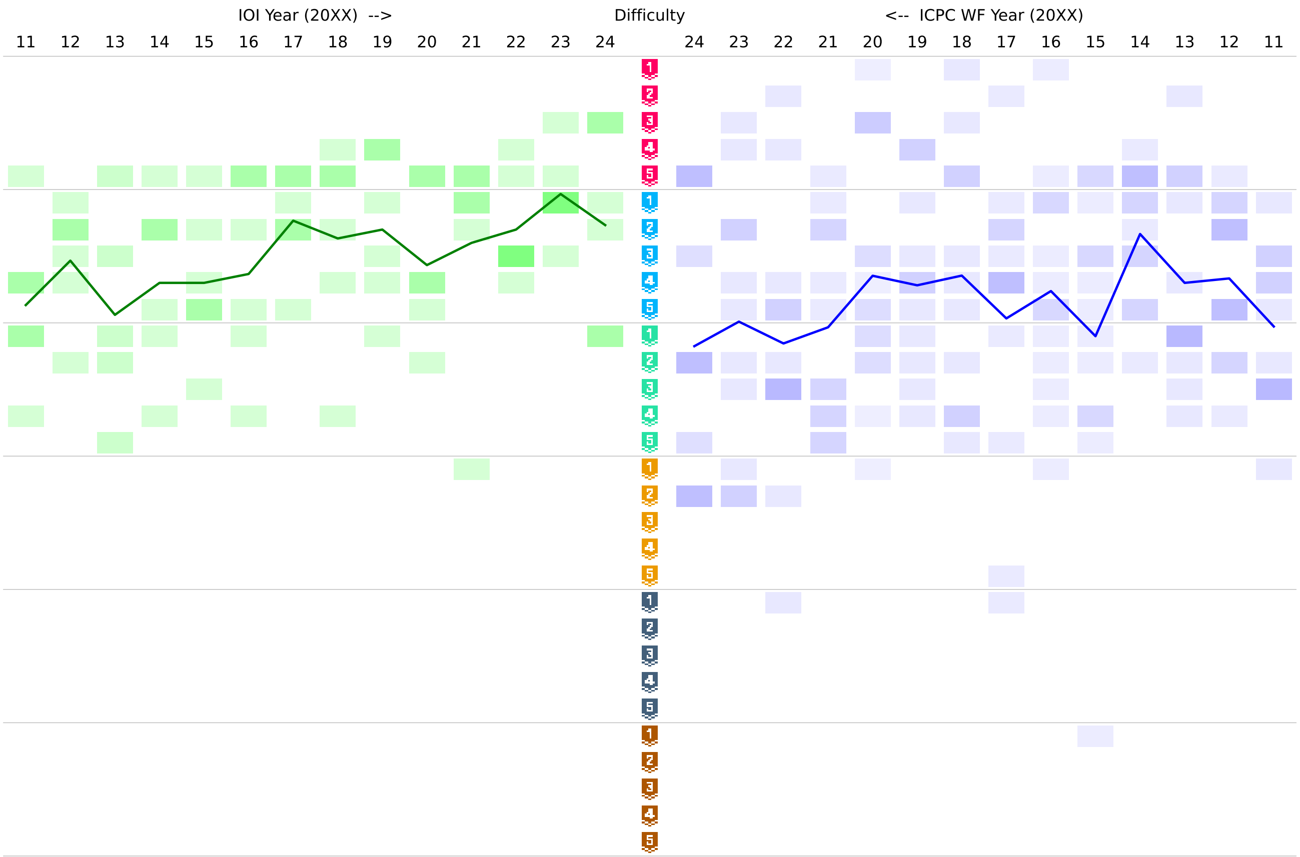


Fig. 5. **Difficulties of IOI and ICPC World Finals Problems** - This figure shows the problem difficulties for **IOI** and **ICPC WF** contests between 2011-2024. The difficulties use the **solved.ac** difficulty scale (see Section IV-F for details), where Bronze-5 is easiest and Ruby-1 is the hardest. In the figure, problems from a given year with a given difficulty are shown with individual rectangles (sometimes darker indicating multiple problems of the same difficulty in a given year's contest). Keep in mind that IOI contests have 6 problems and ICPC WF have 11-15 problems (during these years). The line on each side shows the mean difficulty of the problems across years.

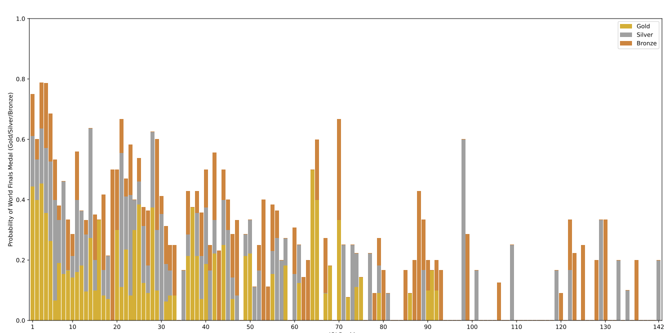


Fig. 6. **Probability of ICPC World Finals Medal given IOI Ranking.** This illustrates the probability, given a contestant's IOI performance/ranking, that they will earn a medal as an ICPC World Finalist. Note: (1) that these calculations are done independent of an ICPC contestant's teammates; and, (2) that for certain IOI Rankings there may be relatively few data points.

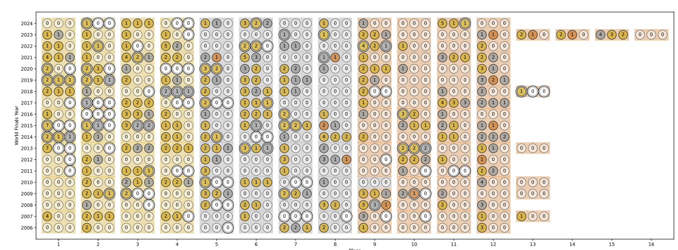


Fig. 7. **IOI Experience of ICPC World Finals Medalists.** This figure shows the composition of ICPC World Finals Medalist teams over the last 19 years. WF years are listed vertically (2024 at the top), WF place is listed horizontally (1st place at left). Each medal-winning team is represented by 3 circles (one for each team member), with the medal won indicated by the background rectangle under a team. For each team member's circle, there is a number indicating the total number of IOI medals earned (0-7) and the color corresponding to the highest medal earned $(Gold > Silver > Bronze)$. A given individual may only compete in two ICPC World Finals – individuals who are competing in their second WF have a second circle surrounding the first.

(e.g. geometry, dynamic programming, number theory, graph theory, etc.) also makes a team stronger.

4) *Learn how to best prioritize and multitask 12-13 problems compared to the 3 problems/day in the IOI.* One may need to read a lot of problems and study previous World Finals problems to get an understanding of their difficulties.

VI. Conclusions

In this article, we provided a comparison of the IOI and the ICPC, highlighting their similarities and differences. Through an analysis of competition formats and problem types, we presented the strengths and challenges inherent in both competitions. It is evident that there is a lot to learn from both competitions in terms of how to train individually versus as a team. Hopefully, this article will serve as a guide to both the coaches and the contestants in their journey through the world of competitive programming.

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