Analysis of mid-air close encounters in gliding competitions and proposal for a penalty based remediation

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1 Introduction

This technical report presents details of a system to analyse track information from gliders in competition to determine frequency of close encounters, being moments in which both aircraft are at a greatly elevated risk of mid-air collision. A set of data from previous FAI World Gliding Competitions is analysed using this system to provide insights on close encounter risk factors. Finally, a system is proposed to encourage safe competition flying by penalising pilots who frequently fly close to others.

1.1 Background

With WGC 2017 being held at the author's home club at Benalla, the unfortunate occurance of two mid-air collisions, and reported crowded airspace in several task days with relatively low ceilings gave the authors the idea to make use of IGC flight logs to analyse the joint proximity of gliders participating in the competition.

An analysis system was implemented and results provided to WGC 2017 stewards and safety officers in an ad-hoc basis. Some of the results were presented to pilots of WGC 2017 in safety briefings.

Arising from the analysis capability and protest reports, were indications that particular pilots were engaging in risky behaviour. This led to the idea of introducing a scoring penalty system to shape behaviour away from that which results in 'near-misses'.

The proposed penalty system was implemented for testing and review purposes during WGC 2017.

1.2 Goals

The basic goals of the project are two-fold:

- Assess safety of gliding competitions;
- Improve safety, by using data products to help increase awareness of collision risk, and by shaping pilot behaviour by introducing a penalty system to discourage risky flying.

To achieve these goals, this study intends to use analysis of data from several previous FAI World Gliding Competitions to:

- Determine the typical risk level of competitions
- Classify risky behaviours or scenarios that frequently result in close encounters.
- Support identification of risk factors in tasking and general competition rules.
- Support development of a penalty scheme and show retrospectively, in previous competitions, how risky pilots could be identified and how penalties could have been applied.

5 Penalty schemes

Just as penalties are applied to pilots and teams for infringements of competition rules, to encourage proper sporting behaviour, fairness and safety, it is possible to apply penalties to pilots to discourage flying styles that result in high close encounter rates.

This approaches the safety problem from an economists perspective, in which undesirable behaviour is effectively taxed. The idea is to shape behaviour by introducing a consequence on scores for a pilot to have elevated close encounter rates.

Considerations that need to be made when introducing such a system include:

Ease of calculation Software such as that produced for this study allows for rapid and essentially no-cost calculation of penalties.

Robustness to abuse The system should be designed to be difficult to exploit by pilots wishing to manipulate scores unfairly.

Precision The system should be insensitive to numerical or algorithmic faults that might produce anomalous scores.

Fairness Pilots who are flying safely should not be penalised, even if they are involved in close encounters with more risky pilots.

Potential abuse of penalty schemes could include:

- 'Ganging up' to knock points off someone
- Boxing someone in; cutting them off

This list is not exhaustive, so it is recommended that further study should be conducted to test the system and anticipate challenges.

Measures available to a close encounter penalty system include:

- Accumulated depth of incursion
- Integral of depth of incursion
- Closing speed within incursion zone
- Number of aircraft affected by close encounters involving a particular pilot
- Number of close encounters by a particular pilot

For this study, the accumulated depth of incursion is used as the primary penalty measure. For a particular pilot, the incursion penalty is the sum for all close encounter episodes, of the incursion to the minimum separation within each episode.

In order to eliminate penalties from safer pilots, an incursion depth allowance can be introduced, with incursion distance up to this value subtracted from the penalty score.

It is possible to have the penalty system switch-in only once a certain total number of encounters has been exceeded. That way, if everyone is behaving well, there is no impact on scoring.

Penalty analysis do be performed live, in real time, if gliders in the competition were equipped with tracking systems that are sufficiently reliable and high enough rate; it would then be possible to issue alerts to pilots of danger and warnings to pilots that are considered to be contributing to high close encounter rates.

Another consideration that needs to be taken into account when designing a penalty function is the psychology of pilots. If the penalty function and particularly, choice of allowance, is too selective and only issues penalties very rarely, the pilots may be willing to risk incurring the penalty and therefore the system would not be effective in shaping behaviour.

5.1 Distribution of penalties

Figure 25 shows the frequency distribution of daily penalties (accumulated incursions) for all of the competitions under investigation. This data, calculated for no incursion allowance, shows that just under half of pilot days have no incursions; and 90% of pilots have accumulated incursions less than 100 m.

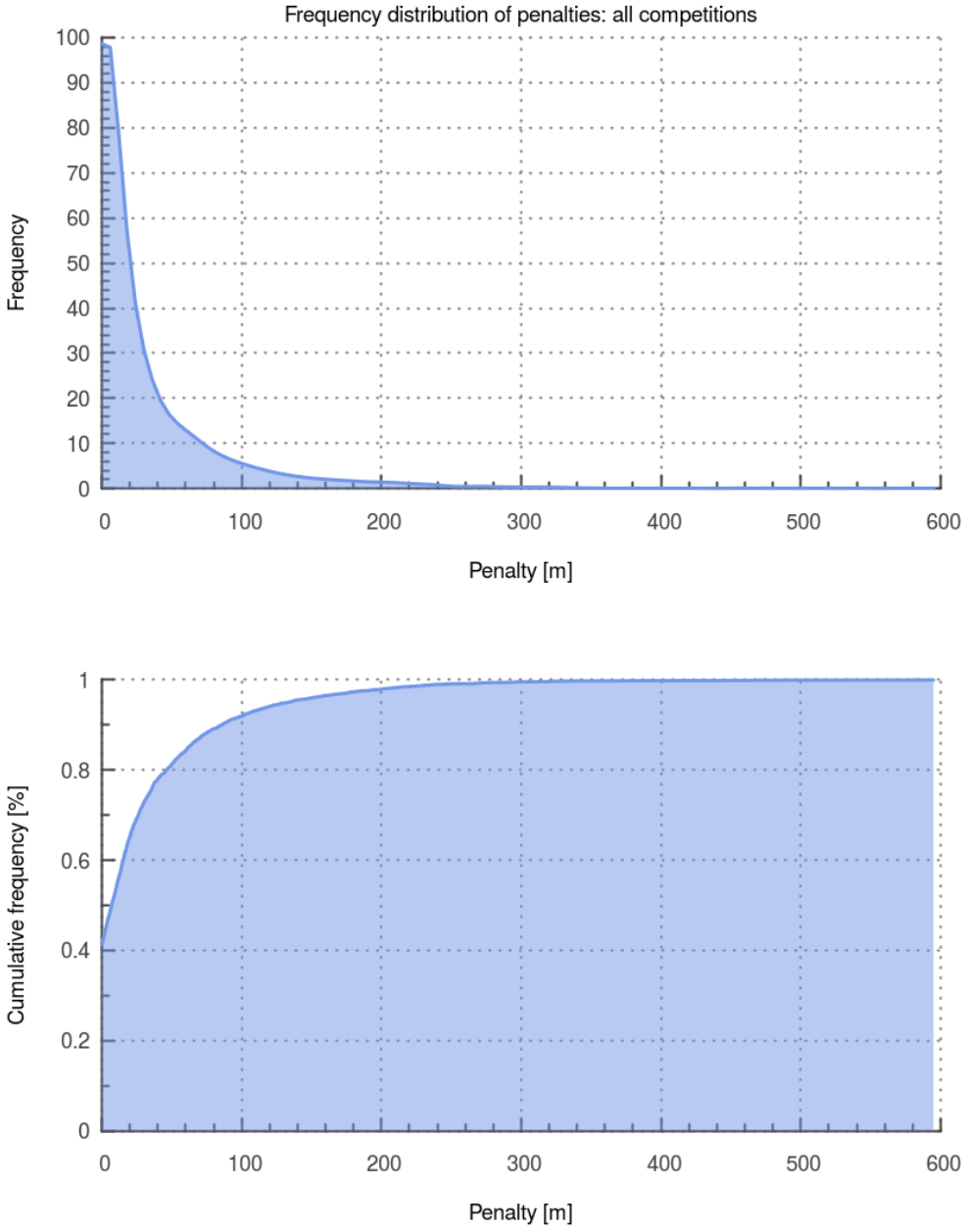

Figure 25: Frequency of penalty scores, all competitions

This limiting value of 100 m might be a suitable value for the incursion allowance, though the most appropriate number should ideally be tuned from further analysis alongwith the other parameters of the algorithm such as separation threshold.

5.2 Example penalties

Figure 26 show example penalty measures for one competition day. It is noteworthy that the three measures presented, incursion depth, number of encounters, and number of affected aircraft, all mark a similar set of pilots.

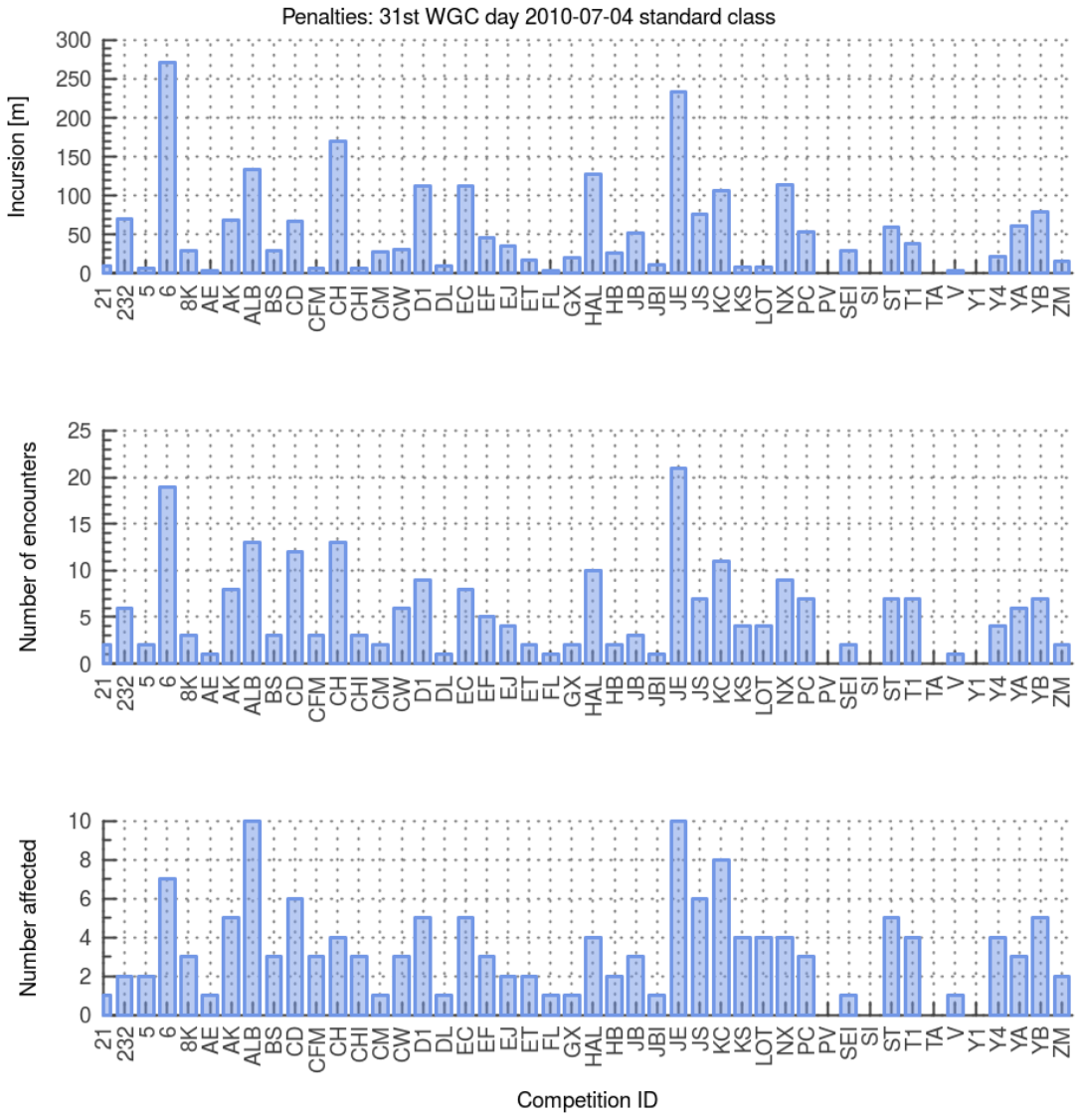

Figure 26: Example penalties, 31st WGC day 2010-07-04 Standard class

Any of these measures or a combination of them could be used to form a penalty function. Indeed, using a combination of measures may be useful to make the system more robust to abuse and tolerant of algorithmic anomalies.

6 Summary and recommendations

6.1 Summary of findings

Findings of the study, based on data from four previous World Gliding Competitions, includes:

- The trend towards greater competition numbers each competition year is likely to weakly increase the close encounter rate.
- Sites with very high working ceilings and freedom to task in all directions offer higher safety.
- Most close encounters are within a few seconds, but a significant number extend for 20 or so seconds.
- Pre-start and post-start phases are the most risky, but the risk of close encounters persists throughout tasks.
- Both aircraft circling is by far the most frequent close encounter pattern (approximately 64%).
- Both aircraft cruising is the second most frequent close encounter pattern (approximately 13%).
- Combined modes where one aircraft climbs and one transitions to and from climb make up around 7.7% of the encounters.

6.2 Administrative recommendations

1. Loggers should use 1 second fix rate always.
   - This avoids the need to interpolate between points, and the consequent error.
   - High data rate improves fidelity of source data in the event of accident investigation
2. Perform collision risk analysis (as described here) daily during competitions and make available to stewards and safety officers for monitor. This can be done automatically, that is, by incorporating it into scoring (e.g. SeeYou) or results publication systems (e.g. www.soaringspot.com). Because the software upon which this study is based is open-source, other organisations may use it as the basis or as a reference in developing their own implementation.
3. Trial use of penalty system or live use of close encounter system daily during competitions to caution risky pilots.

Rolling out a penalty system such as proposed here requires the formation of a team (sub-committee or tiger-team) with the resources to carefully test the logic of the scheme, look for potential drawbacks, guard against potential abuse, and to tune the parameters of the algorithms.

6.3 Task setting officers

This study has shown the benefit of separating tasks across classes as much as possible to increase average aircraft separation.

- If it is not possible to separate the tasks on a particular day, consideration should be made to reduce the number of classes that fly.
- Physically separate start sectors (more)
- Separate start times as much as possible

Further analysis of historical data could be used to generate guidelines to enable these factors to be used in making judgements by competition officers.

6.4 Study recommendations

Being a preliminary study, this work could be improved by more rigorous statistical analysis using a larger data set, such as adding data from regional competitions.

There would be benefit to reviewing the limitations of the study listed in Section 1.3 to identify work of priority and interest. Other enhancements could include:

- Making use of GNSS estimated position error. Note that for vehicles close to each other, they are likely to have similar satellite visibility, subject to similar atmospheric effects, and therefore have similar position error — meaning that their relative separation error is likely to be smaller than the position error magnitude.
- Making use of expected barometric error due to pressure sensor calibration drift and position error (variation due to cockpit interior static pressure).
- Incorporation of closing speed (the rate of change of separation distance) in identifying risky encounters
- Use information from the glider class or type to select appropriate distance thresholds based on the expected wing span of each aircraft.
- Extend the encounter classification system presented in Section 4.1 to perform more detailed classifications than is possible only using turn rate information.

Such work might be suitable to be performed by a student under sponsorship and guidance.