Classification using IDK Cascades
or
Why are AI Components Different?

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► First Question – What is a typical AI Components?

► An Answer – A Classifier

► What characterises a Classifier? – Non-deterministic behaviour

► Second Question – Is this a problem for Safety-Critical Real-Time Systems?

IDK Classifiers – an exemplar AI Component

- An IDK classifier outputs either a real class or IDK – I Don't Know

- If it outputs a real class then its confidence is above a defined threshold

- Training data is used to compute the likelihood of any particular classifier outputting a real class – this is a prediction expressed as a probability

- A Cascade of IDK Classifiers is needed to provide resilient behaviour

IDK Classifiers

- ▶ An IDK classifier will have a WCET and additionally a typical (or average) execution time TCET

- ▶ The completed classification may have a deadline

- ▶ The synthesised Cascade must meet any deadline constraint and minimise the expected total WCET or TCET

Results so far ....

- Optimal cascades obtained for (i) totally independent classifiers, (ii) dependent classifiers, and (iii) arbitrarily correlated classifiers

- Binary (true/false) IDK Classifiers with constraints on false-negative and false-positives outputs

- Faulty classifiers (that can output a real but wrong class) and hence the need to produce fault-tolerant cascades

- Going forward, there are lots of open issues ...

Publications

S. Baruah, A.Burns and Y. Wu, Optimal Synthesis of IDK-Cascades, Proc. 29th International Conference on Real-Time Networks (RTNS), pp184-191, 2021. —- independent classifiers, minimise execution time of cascade, with or without overall latency constraint.

S. Baruah. Real-Time Scheduling of Multistage IDK-Cascades, Proc. 24th IEEE International Symposium on Real-Time Distributed Computing (ISORC), pp 79-85. June 2021. —- dynamic scheduling to minimise expected duration of cascade with a hard deadline.

S. Baruah, A. Burns, R.I. Davis and Y. Wu, Optimally ordering IDK classifiers subject to deadlines. Real-Time Systems Journal, Vol 59, pp1 to 34, 2023. —- extended to include fully dependent classifiers.

T. Abdelzaher, K. Agrawal, S. Baruah, A. Burns, R.I. Davis, Z. Guo and Y. Hu, Scheduling IDK Classifiers with Arbitrary Dependences to Minimize the Expected Time to Successful Classification, Real-Time Systems Journal, Vol 59, No 3, pp348 to 407, 2023. —- extended to include arbitrary dependencies.

T. Abdelzaher, S. Baruah, I. Bate, A. Burns, R.I. Davis and Y. Hu, Scheduling Classifiers for Real-Time Hazard Perception Considering Functional Uncertainty, Proc 31st International Conference on Real-Time Networks and Systems (RTNS). 2023. —- a focus on binary classifiers (hazard or not), hard constraint on false negatives, minimise false positives.

S. Baruah, A. Burns and R.I. Davis, Optimal Synthesis of Robust IDK Classifier Cascades, ACM Transactions on Embedded Computer Systems, Vol 22, No 5, 26p, Sept, 2023. —- applies the Algorithms using Predictions framework, the probability that a classifier will succeed is interpreted as a prediction.

S. Baruah, I. Bate, A. Burns and R. Davis, Optimal Synthesis of Fault-tolerant IDK Cascades for Real-time Classification, Proc. 29th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS), 2024. —- introduces the notion of faults (a non-IDK, real, output may be wrong) and fault-tolerance (more than one real output is required).