Playing Angry Birds with a Domain-Independent PDDL+ Planner

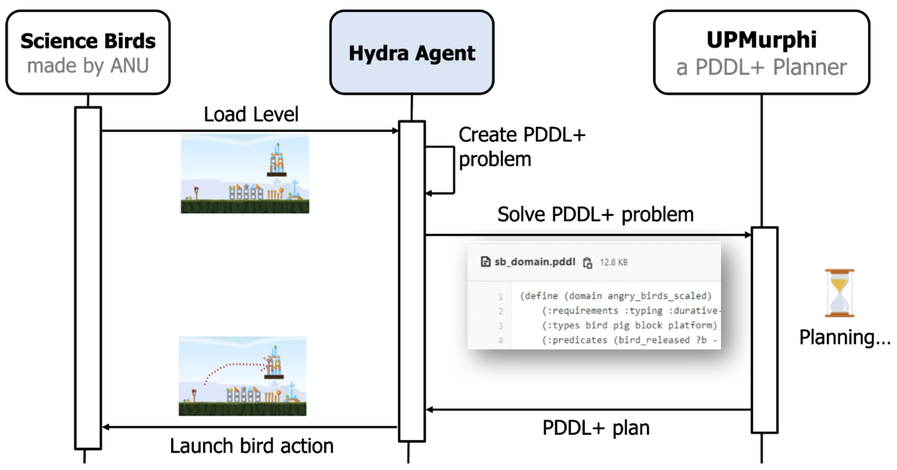
Wiktor Piotrowski, Roni Stern, Matthew Klenk, Alexandre Perez, Shiwali Mohan, Johan de Kleer, Jacob Le
Palo Alto Research Center, Ben-Gurion University of the Negev

Angry Birds

One of the most popular mobile games in the world, Angry Birds has recently experienced a surge in interest from AI researchers. The game asks players to strategically slingshot birds into porcine enemies who are protected by various block structures. A very intuitive interface and simplistic gameplay caused the game to skyrocket in popularity among mobile phone users. However, this problem is prohibitively difficult for autonomous agents lacking contextual knowledge and spatio-temporal reasoning. The complexity of Angry Birds arises from the game's innate characteristics:

- long term effects of actions.
- non-deterministic environment.
- large state and action space.
- non-linear continuous system dynamics and cascading discrete events.
- levels containing a large number of objects.

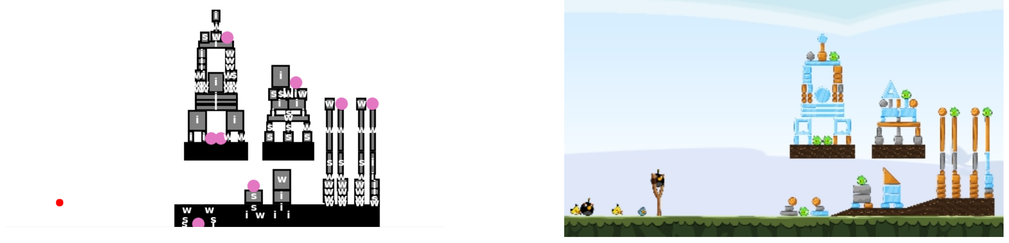
To overcome the above challenges, most existing AI agents for the game utilize encoded domain-specific strategies. We present **Hydra**, a planning-based domain-independent approach to playing Angry Birds.



PDDL+ Model of Angry Birds

PDDL+ is a highly expressive modeling language designed for planning in hybrid systems. Its features and characteristics are tailor-made for accurately modeling the mixed discrete/continuous nature of Angry Birds without the need for semantic attachments or multi-step reasoning. Simultaneously, PDDL+ enables ways of mitigating the domain's innate complexity and helps in ensuring that the resulting problem is solvable.

PDDL+ model visualized, compared to the actual Angry Birds level.



However, PDDL+ problems are still among the most challenging in any planning paradigm, particularly suffering from state space explosion. As a consequence, the Angry Birds PDDL+ model is a result of various design decisions aiming to strike a fair balance between accuracy and solvability of the model.
The PDDL+ model of Angry Birds consists of various types of happenings:

- 4 Object types (birds, pigs, blocks, platforms) with associated functions & predicates.
- 2 Process types (aiming of the slingshot, and the flight of launched birds).
- 10 Event types (collisions, explosions, structure collapses, etc.).
- 1 Instantaneous Action (release active bird from slingshot).

To ensure solvability, the current PDDL+ model abstracts parts of its components and dynamics. The motion of blocks is ignored, as tracking each individual block would require a multitude of computationally-expensive concurrent processes and even more associated events. Special "tap" powers of different birds are also not modeled in planning. Finally, solving an entire Angry Birds level containing multiple birds and pigs is often unfeasible under our current computational constraints. As a result, the problems are simplified by splitting them into *single-shot* episodes where only one bird exists and the goal is to kill at least one pig (instead of all pigs). For particularly difficult levels, the problem can also be further simplified by ignoring all blocks in the level (*single-shot-no-blocks*).

Evaluation

The evaluation of Hydra was conducted against two champion agents from the AI Birds competition (Eagle's Wing and DataLab), as well as a baseline agent created by ANU (organizers of the AI Birds competitions). Each agent played the same set of 100 automatically-generated Angry Birds levels. The Hydra agent solves the generated Angry Birds problems using UPMurphi, an off-the-shelf non-heuristic PDDL+ planner. By default, we simplify all problems by splitting them into *single-shot* episodes, and if no plan is found, we further simplify to a *single-shot-no-blocks* variant. If both approaches fail, we execute a pre-defined default shot. Results are compiled in the table below.

Agent	Problems Solved	Avg. Score per Level
ANU	**49**	45,112
Hydra	44	**47,516**
DataLab	26	46,668
Eagle's Wing	16	39,152

Contact

- {wiktorpi,rstern,aperez,smohan,dekleer,jale}@parc.com; klenk.matt@gmail.com
- www.parc.com

References

BOROVICKA, T.; SPETLIK, R.; RYMES, K. *DataLab Birds Angry Birds AI.* [S.l.], 2014.
FOX, M.; LONG, D. Modelling mixed discrete-continuous domains for planning. *Journal of Artificial Intelligence Research*, v. 27, p. 235–297, 2006.
PENNA, G. D. et al. Upmurphi: a tool for universal planning on pddl+ problems. In: *International Conference on Automated Planning and Scheduling*. [S.l.: s.n.], 2009.
RENZ, J. et al. Ai meets angry birds. *Nature Machine Intelligence*, Nature Publishing Group, v. 1, n. 7, p. 328–328, 2019.
STEPHENSON, M.; RENZ, J.; GE, X. The computational complexity of angry birds. *Artificial Intelligence*, v. 280, p. 103232, 2020.
WANG, T. J. *Description for Eagle's Wing, an AI Angry Bird Playing Agent.* [S.l.], 2017. Http://www.aibirds.org/2017/eaglewing2017.pdf.