Search problems

• Many AI problems involve understanding the structure of a particular search space

• Two problems
1. Pancake sorting (related to transforming sequences using reversals)
2. Games (Who wins a particular game? And how?)
Pancake problem

The chef in our place is sloppy, and when he prepares a stack of pancakes they come out all different sizes. Therefore, when I deliver them to a customer, on the way to the table I rearrange them (so that the smallest winds up on top, and so on, down to the largest at the bottom) by grabbing several from the top and flipping them over, repeating this (varying the number I flip) as many times as necessary. If there are \( n \) pancakes, what is the maximum number of flips (as a function \( f(n) \) of \( n \)) that I will ever have to use to rearrange them?

Harry Dweighter (Jacob Goodman), *Amer. Math. Montly*, 1975
Obvious solution

• Bring the largest pancake not in order to the top and then flip it
Some Bounds

• Gates and Papadimitriou (1979): \[ f(n) \leq \frac{5n + 5}{3} \]

• Heydari and Sudborough (1997): \[ f(n) \leq \frac{18n}{11} + O(1) \]

In general, computing \( f(n) \) is an NP-hard problem. The answer is known for \( n \leq 19 \).
Pancake/spatula flips are reversals

- Given the permutation 654312, some reversals are
  - 456312 comes from 654312
  - 134562 comes from 654312
Some connections

Genome rearrangements: These rearrangements are done using "reversals", which are a more general version of pancake flips.

Proposed as an alternative to hypercube for interconnecting processors in parallel computer since they have sublogarithmic diameter and are sparse.
Signed (burnt) version

• Pancakes have an orientation

• Reversals now change signs

• We have results that allow us to understand some of the cycle structure of this graph. For the signed case, for instance, there are no k-cycles if $k \leq 8$

Games

• Games have always played a prominent role in AI

• Two important milestones in AI
  2. AlphaGo (2015--)
Misère play

• Swap the winning/losing condition

• Example: One symbol tic-tac-toe

If

\[
\begin{array}{ccc}
  X &   &   \\
  X &   &   \\
  X &   &   \\
\end{array}
\]

then

\[
\begin{array}{ccc}
  X &   &   \\
  X &   &   \\
  X &   &   \\
\end{array}
\]

is a losing position for the first player
A new approach on games

• Recent developments of deep learning to games in normal play (AlphaGo, AlphaZero, etc...)

• Can we use similar techniques to study Misère play?
  • Simple game first: One symbol tic-tac-toe. We know the winner for $n \times n$ boards with $n < 7$
  • Can we combine deep learning and theoretical observations to decide who wins a game?
  • There is some evidence this can be done...