Modelling Go Positions with Planar CRFs

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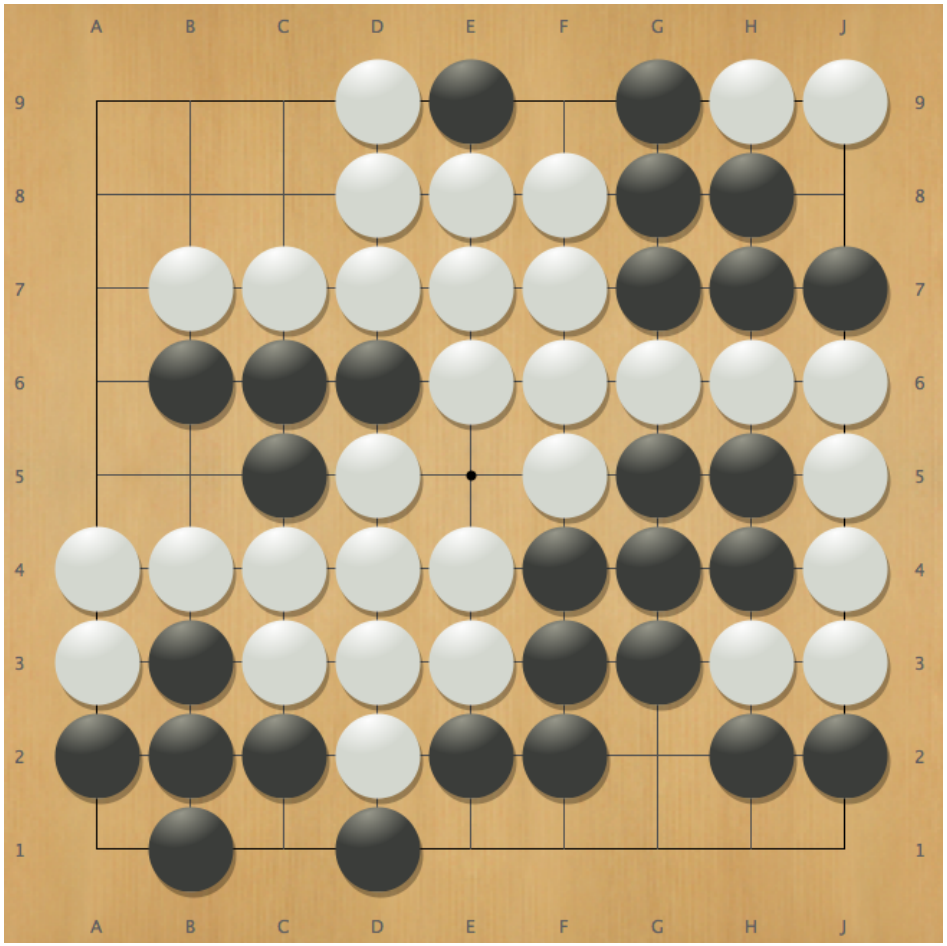
What is Go?



- Two players alternate in placing stones on the intersections of a grid
- Neighbouring stones of the same colour form a contiguous *block*
- A block can be *captured* if all its empty neighbours are occupied by opponent stones

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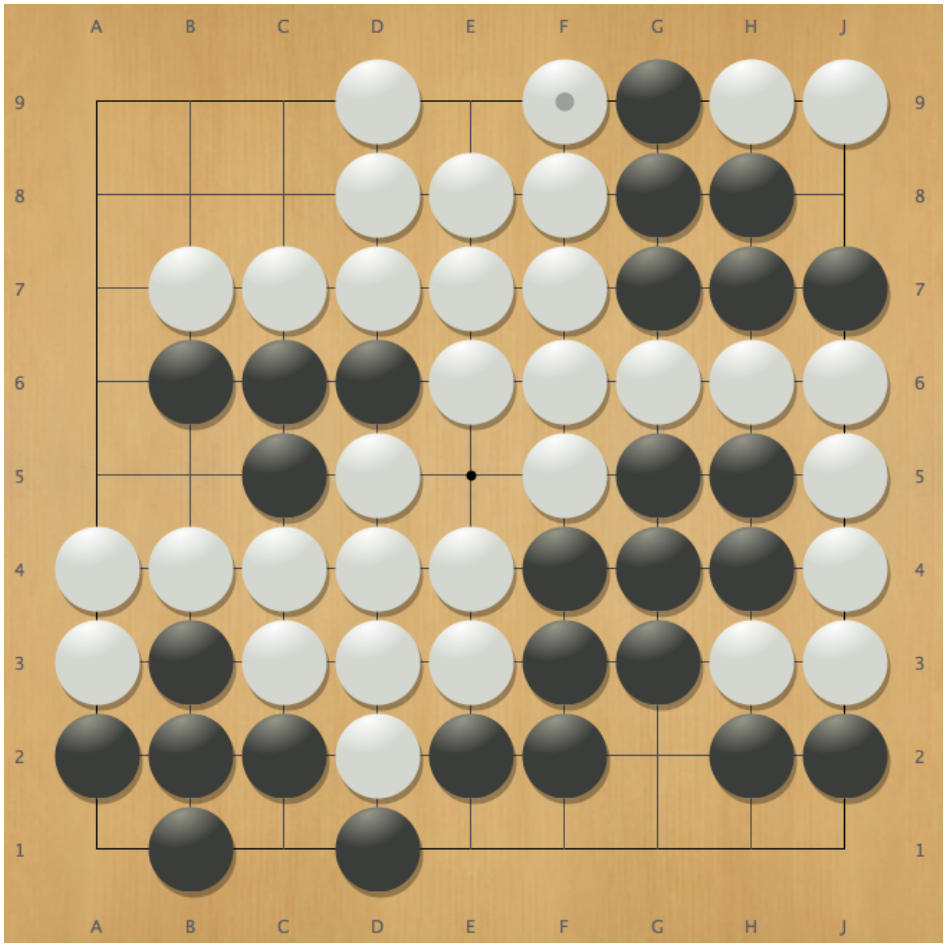

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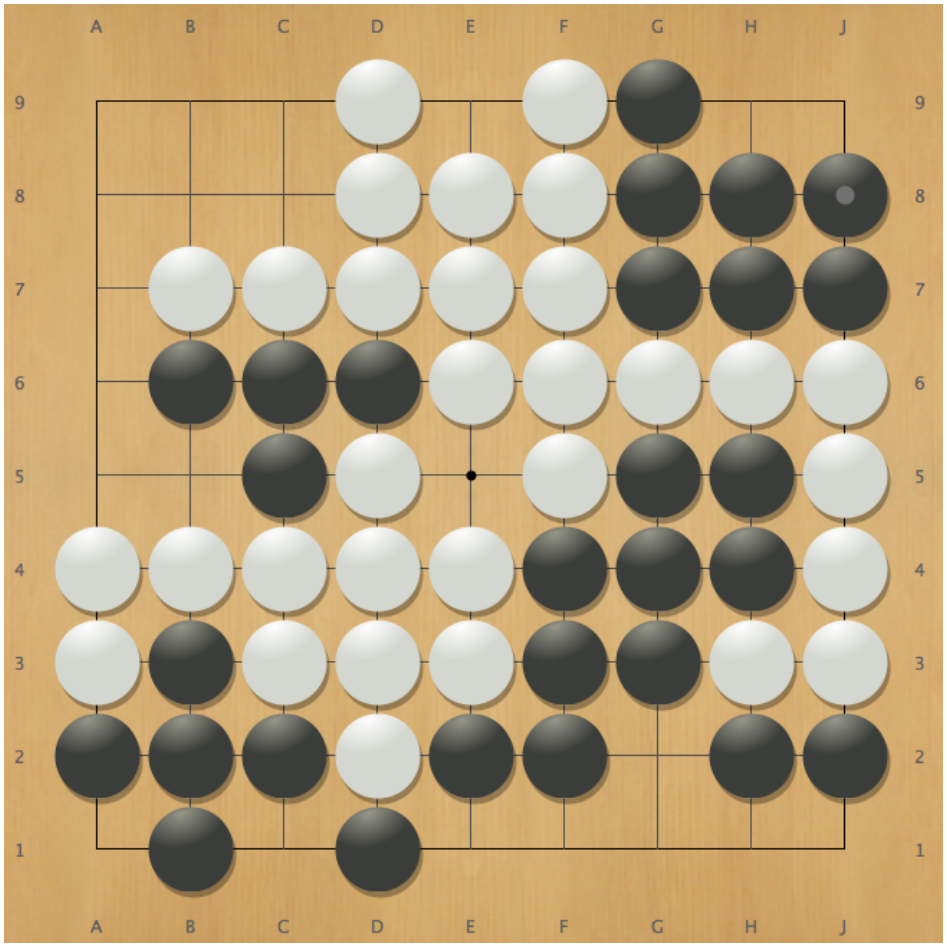

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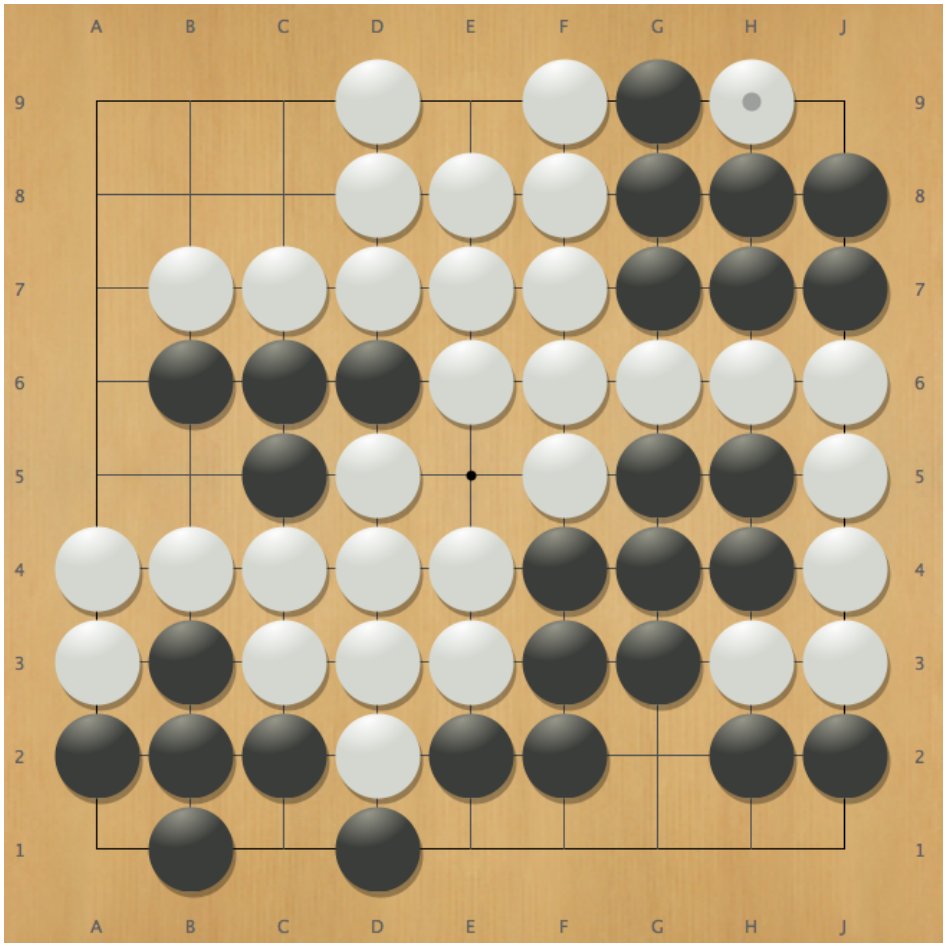

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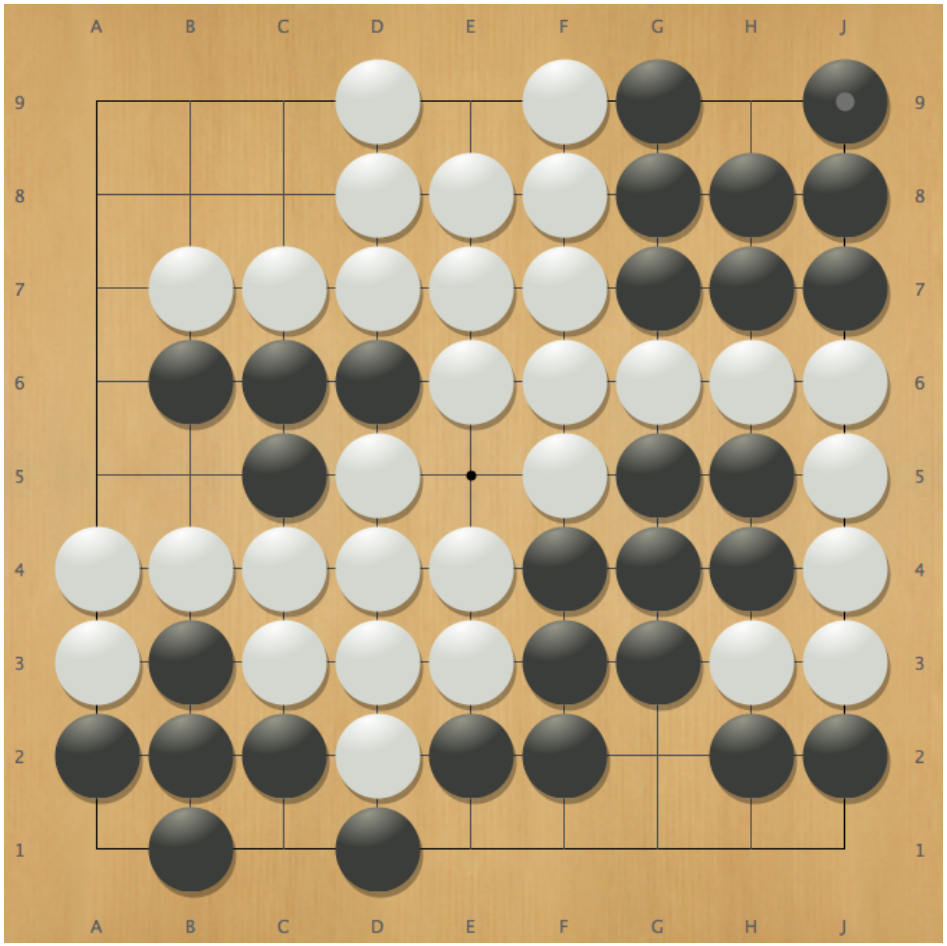

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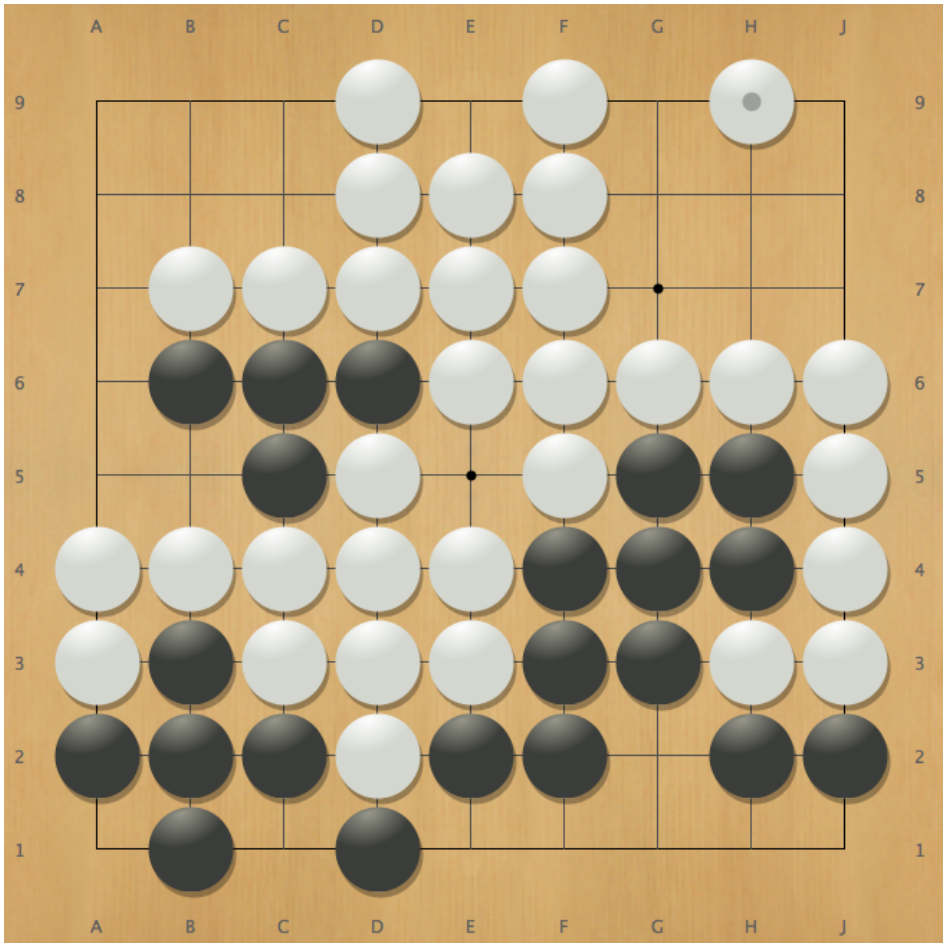

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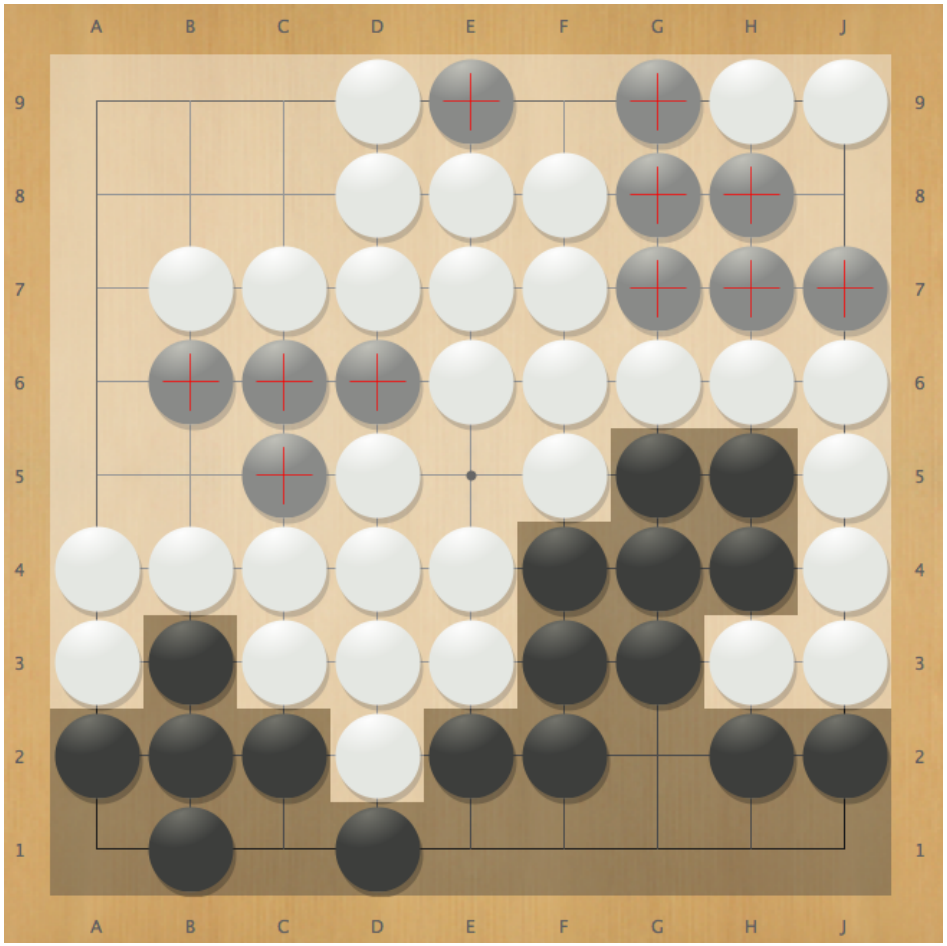


- The game terminates once players agree on the life status of blocks
- The blocks and their surrounding area count towards *territory*
- **Territory prediction:** Given a board position predict the owner of each intersection
- Challenging problem for ML!

Modelling Go

- Go is played on a grid graph G, so it is natural to model it with a graphical model such as CRF
- If we want to perform exact inference we can use the Junction Tree Algorithm (G is loopy)
- But... Junction Tree's complexity is exponential in the tree-width, which is N for $N \times N$ grid

Solution

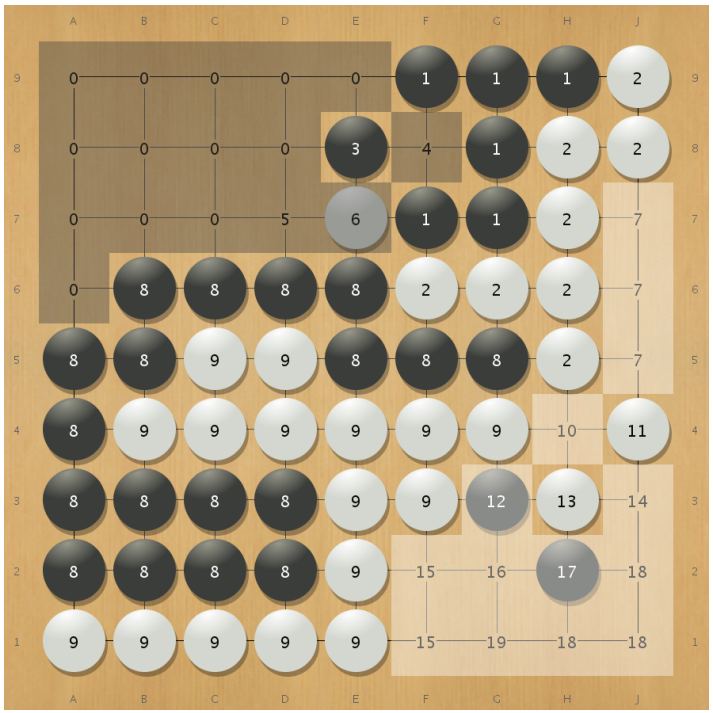
- Globerson & Jaakkola 2006 presented an exact polynomial-time algorithm for computing the partition function
- Restrictions:
  - Graph is planar: can be drawn without crossing edges
  - Binary-valued labels
  - Only edge potentials, no node potentials

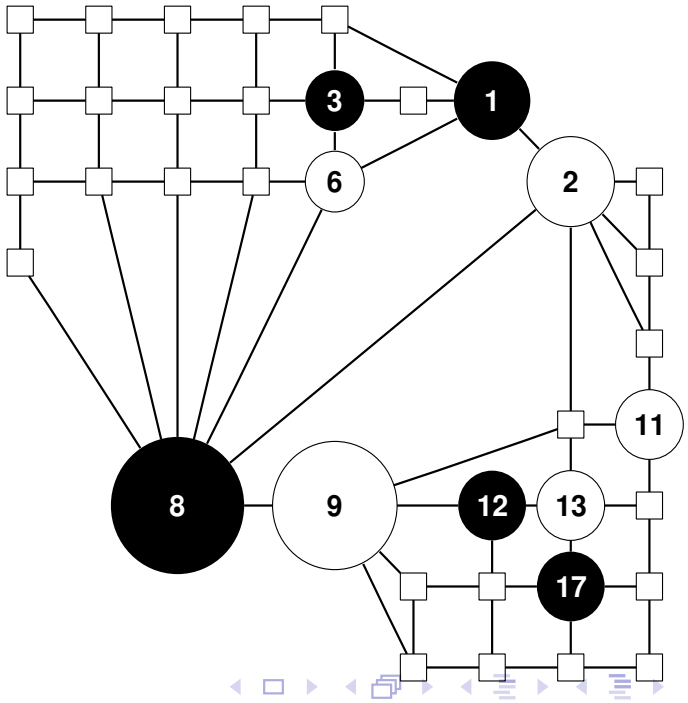
Our work - overview

- Faster and simpler version of Globerson and Jaakkola algorithm
- No need to compute the expanded dual of the original graph
- Showed how to compute gradients and thus perform parameter estimation
- Applied to territory prediction in Go

Graph abstraction: common fate graph

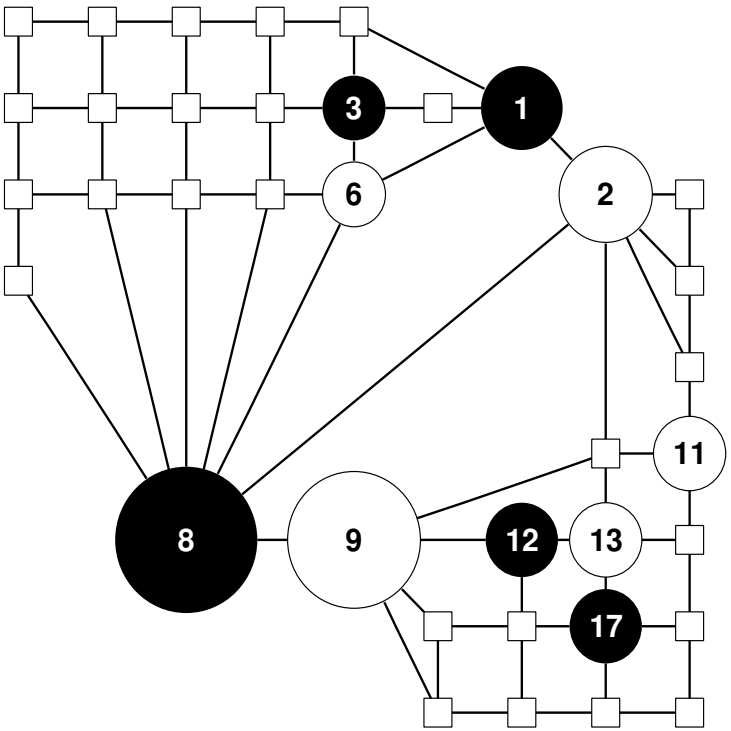
- Blocks always live or die as a unit; Grid graph G does not capture this
- *Common fate graph* G_f (Graepel et al., 2001) merges all stones of a block into a single node

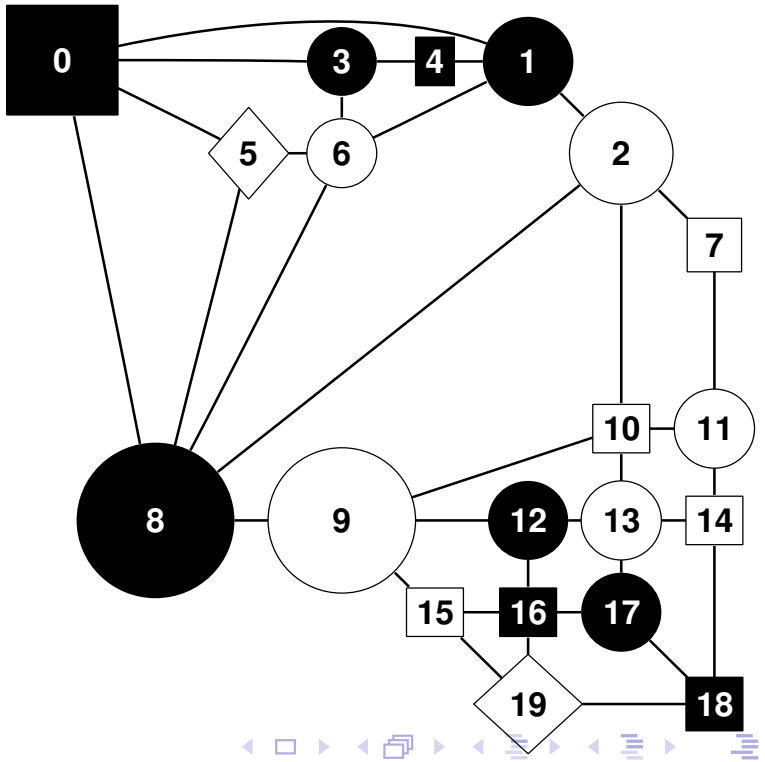




Graph abstraction: block graph

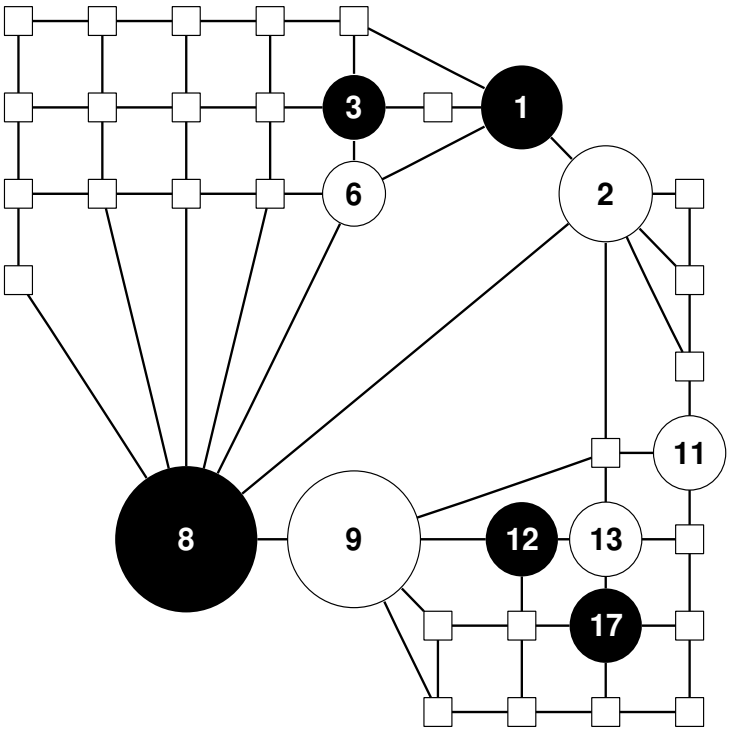
- Use Manhattan distance to classify empty regions into 3 types: *black surround* (■), *neutral*(◇) and *white surround*(□)
- Collapse empty regions of G_f to form the *block graph* G_b

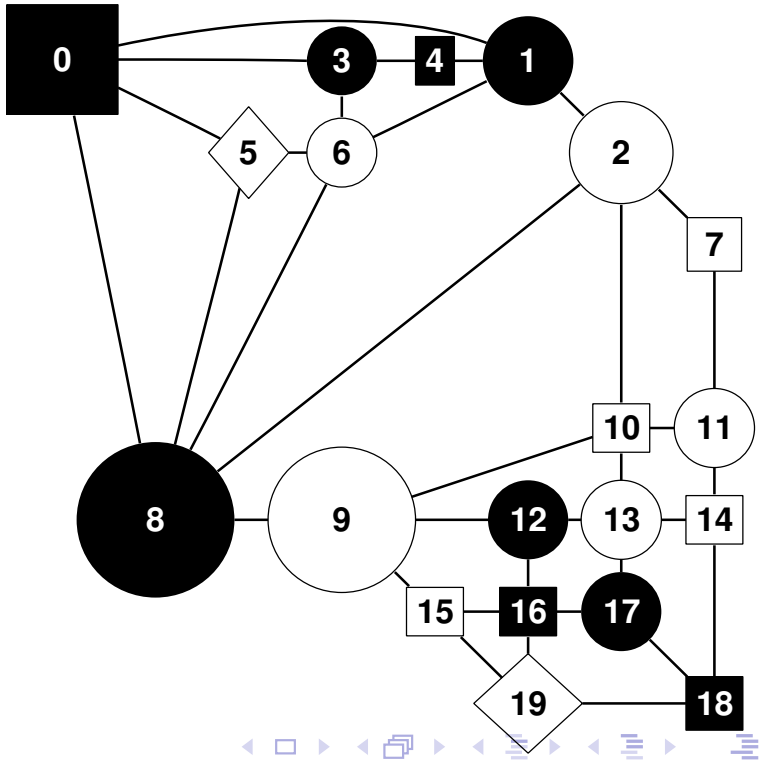




Graph abstraction: block graph

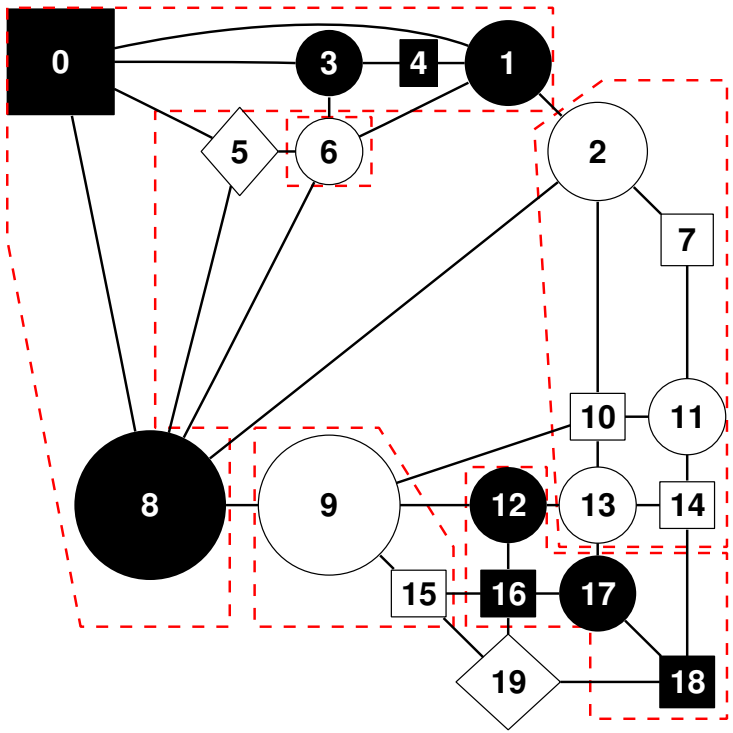
- Surrounds encode the possibility for obtaining territory
- G_b is more concise than G_f, but preserves the kind of information required for predicting territory





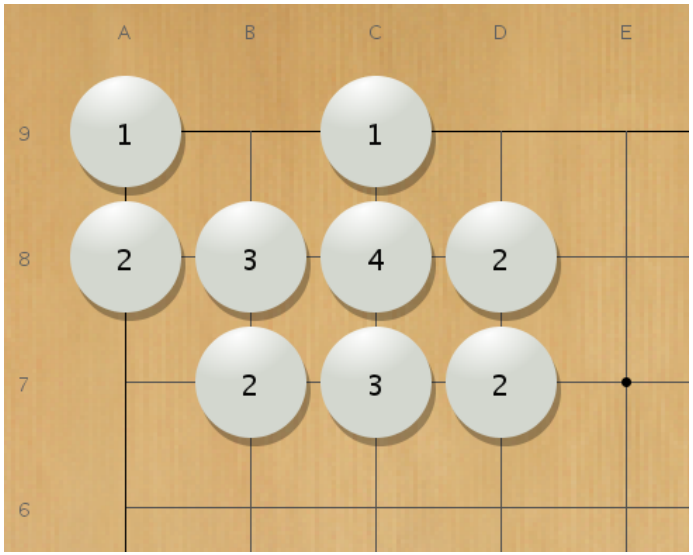
Graph abstraction: group graph

- *Group*: set of blocks of the same colour that share at least one surround
- Construct the *group graph* G_g by collapsing groups of G_b



Feature engineering: nodes

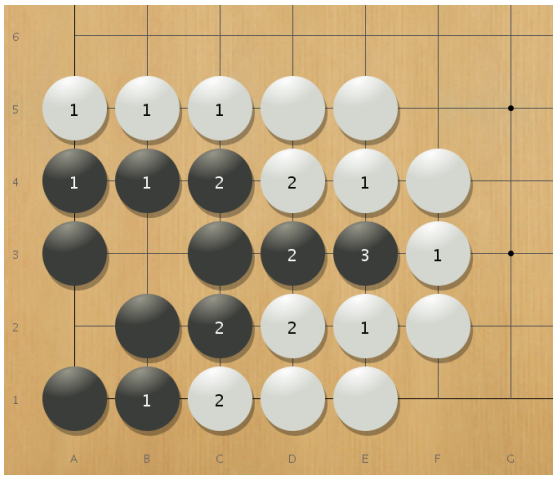
- Given a node $v \in G_b$, for each point $i \in v$ compute the number of adjacent points A_i that are also in v
- Node's feature is a vector F, where $F_k = |\{i : A_i = k\}|$
- Provides a powerful summary of the region's shape



$$F = \{2, 4, 2, 1\}$$

Feature engineering: edges

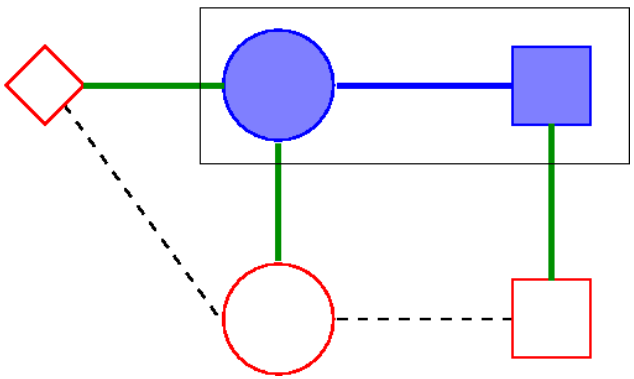
- For two nodes $v_1, v_2 \in G_b$, A_i^1 is the number of points in v_2 that are adjacent to $i \in v_1$ and vice-versa for A_i^2
- Edge's features are two vectors F^1 and F^2 that are constructed using A^1 and A^2 respectively
- Provide extra information such as the boundary shape



$$F^1 = \{3, 3, 1\}, F^2 = \{6, 3, 0\}$$

Parameter sharing

Parameter sharing takes into account all relevant symmetries



	Current Edge		Neighbour Edges	
	Param.	Feat.	Param.	Feat.
Nodes	$\vec{\theta}_{\bigcirc}$	●	$\vec{\theta}^{n}_{\diamond}$	◇
	$\vec{\theta}_{\square}$	■	$\vec{\theta}^{n}_{\bigcirc}$	○
			$\vec{\theta}^{n}_{\square}$	□
Edges	$\vec{\theta}_{\bigcirc\square}$	● → ■	$\vec{\theta}^{n}_{\diamond\bigcirc}$	◇ → ●
	$\vec{\theta}_{\square\bigcirc}$	■ → ●	$\vec{\theta}^{n}_{\bigcirc\diamond}$	● → ◇
			$\vec{\theta}^{n}_{\bigcirc\bigcirc}$	○ → ● ● → ○
			$\vec{\theta}^{n}_{\square\square}$	□ → ■ ■ → □

Experiments

- 9×9 endgame positions of van der Werf et al., 2005
- Learning
  - Use the block graph G_b
  - Optimization with LBFGS
- Prediction
  - Use the group graph G_g
  - Use CRFs MAP assignment as predicted label

Results

	Error (%)			
Algorithm	Vertex	Block	Winner	Game
Naive	6.79	17.57	30.79	75.70
Stern et al., 2004	4.77	7.36	13.80	38.30
Block graph	2.36	3.56	4.53	13.02
Block graph + neighbour features	1.87	2.76	3.42	9.60
Block graph + other enhancements	1.54	2.20	2.09	7.90
* GnuGo	-	-	-	1.32
* van der Werf et al., 2005	0.19	$\leq$ 1.00	0.50	1.10

*: employs Go-specific features and was used to label data

Conclusion

- First real application of Globerson and Jaakkola algorithm
- 2-stage graph reduction of the Go positions. The first used for learning, the later for prediction
- Generic node and edge features. Parameter sharing between equivalent node and edge types

Future work

- Find better ways to classify empty regions
- Add more domain-specific knowledge
- Extend to 19×19 games
- Incorporate into a Monte-Carlo based program

Questions?

"Some cause happiness wherever they GO, others whenever they GO" - Oscar Wilde