

Nonlinear Relational Markov Networks with an Application to the Game of Go

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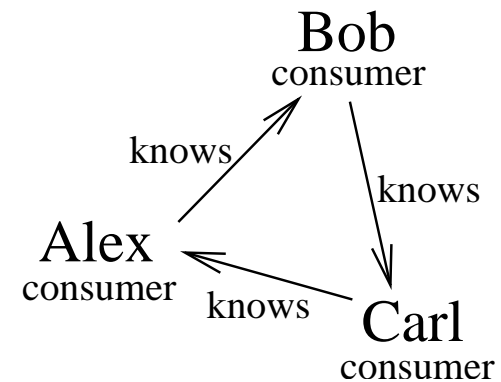
ICANN 2005

Relational Markov Networks

- Relational database contains labels and attributes in several tables

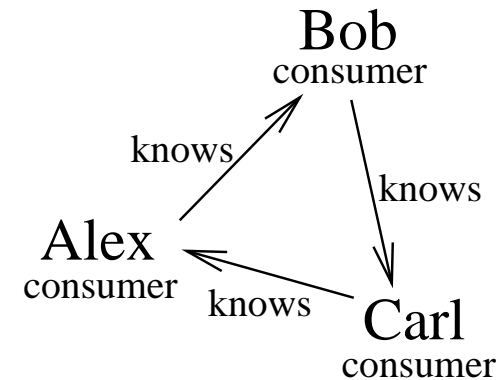
knows		
who	whom	how
Alex	Bob	friend
Bob	Carl	neighbour
Carl	Alex	colleague

consumer		
who	smoker	...
Alex	no	...
Bob	no	...
Carl	yes	...



- **Template** $(\text{con}(X), \text{knows}(X, Y), \text{con}(Y))$ has three occurrences
- Let us make a transformation to get rid of labels
 - a table for each template

knows			consumer		
who	whom	how	who	smoker	...
Alex	Bob	friend	Alex	no	...
Bob	Carl	neighbour	Bob	no	...
Carl	Alex	colleague	Carl	yes	...



$(\text{consumer}(X), \text{knows}(X,Y), \text{consumer}(Y))$

	consumer		knows	consumer	
	smoker	...	how	smoker	...
$X = \text{alex}, Y = \text{bob}$	no	...	friend	no	...
$X = \text{bob}, Y = \text{carl}$	no	...	neighbour	yes	...
$X = \text{carl}, Y = \text{alex}$	yes	...	colleague	no	...

- Find a potential for attributes in the transformed tables
- Each row corresponds to a clique in a Markov network

Continuous Values

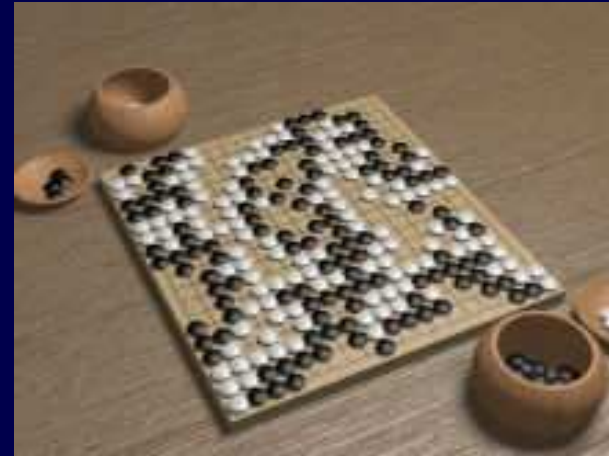
- Some of the attributes are continuous valued
- Find a multivariate pdf:
 - Gaussian (only linear dependencies)
 - Nonlinear factor analysis (Multilayer perceptron network from latent variables to observations)
 - Mixture model, Self-organising map, etc.
- Bayes Blocks software library used
 - Variational Bayesian treatment
a parametric distribution is fitted to the true posterior

Learning and Inference

- Learning and inference is done as in the flat case (non-relational) except that some variables are bound to each other
- Variational Bayesian learning provides a cost function that is minimised → convergence guaranteed regardless of loops
- Further work
 - cooperative learning
 - finding the **best** set of templates

Go

- Invented in China 3000+ years ago
- National game of Japan
- Increasingly popular around the world
- Empty board, stones added alternately (never moved)
- **Goal:** exert more influence on territory than opponent
- **Means:** capturing by surrounding groups of stones
 - 4-connected stones of the same colour form groups
 - A group needs to be 4-connected to an empty point to survive

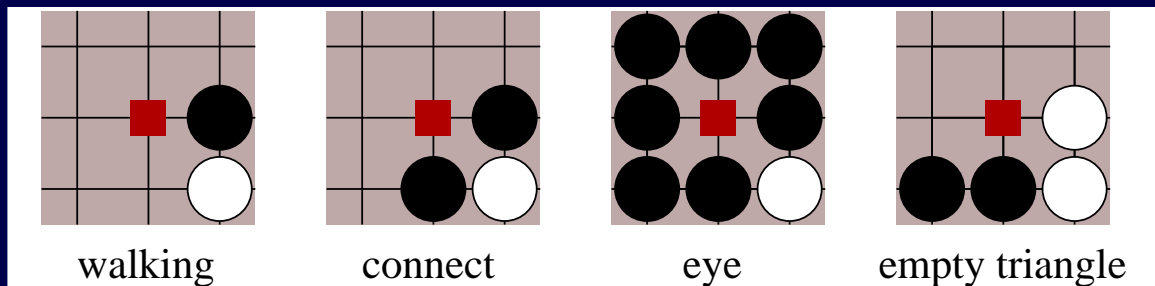
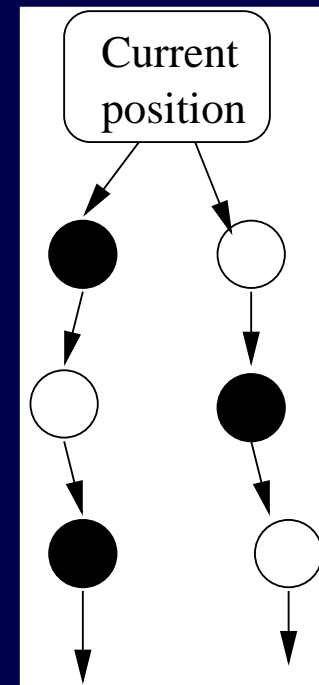


Computer Go

- Computers are easily beaten by human amateurs
- Second-most researched game after Chess
- Static board evaluation is difficult (visual nature)
- Large branching factor
- State of the art: Pattern databases, local searches, etc.

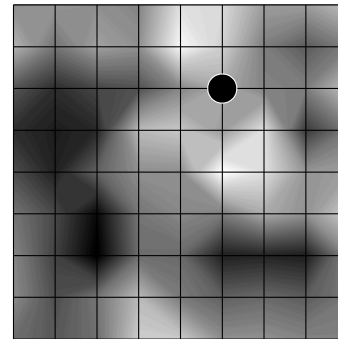
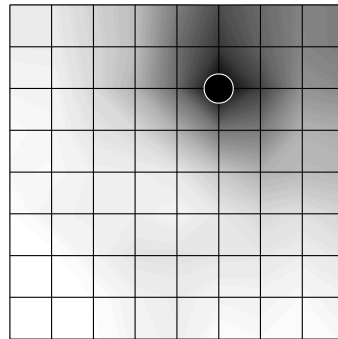
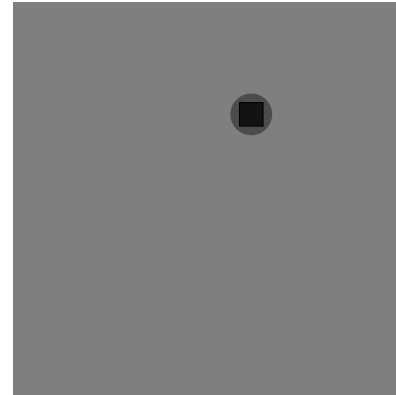
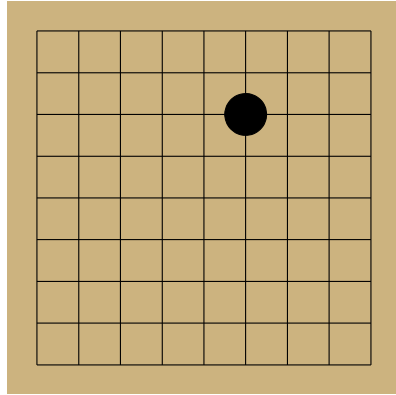
Go81 (my program)

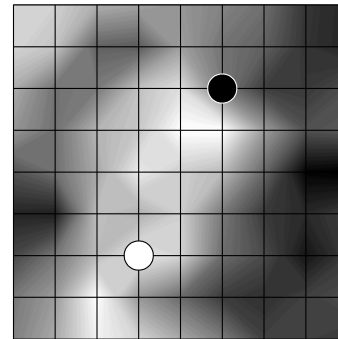
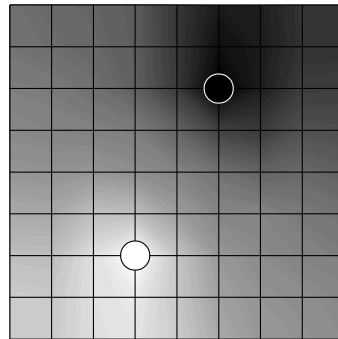
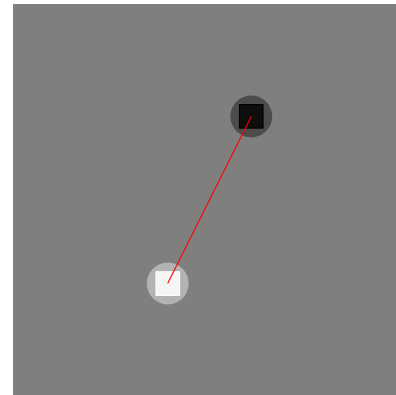
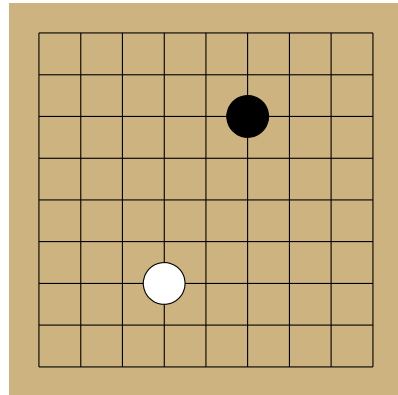
- Go-playing program for Palm handheld computers
- Done in spare time 2002–2004
- Tiny and fast, available with source codes
- AI based on swarm intelligence:
The game is played several times to the end from the current position
- The simple agents use only local information to score moves

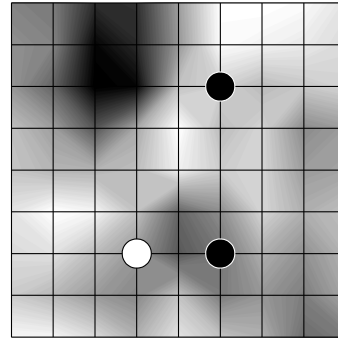
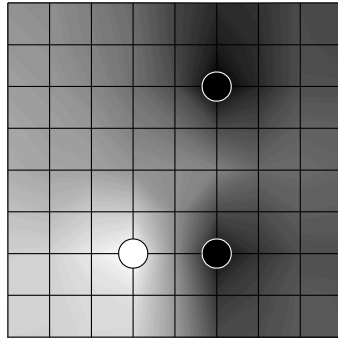
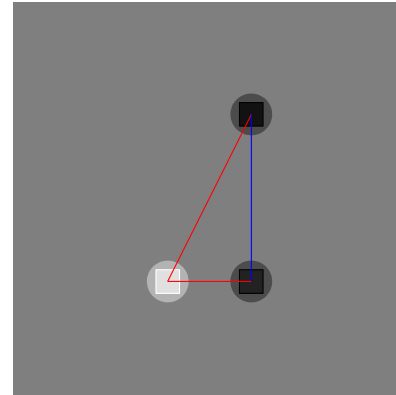
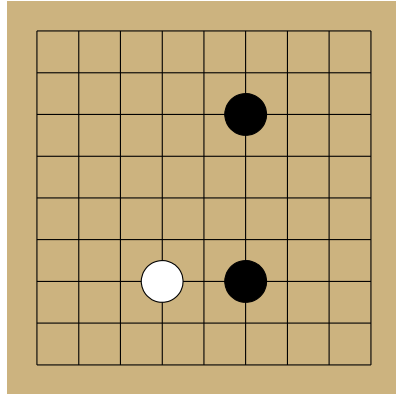


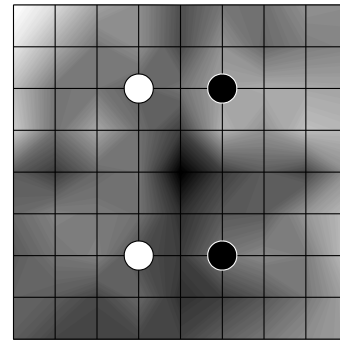
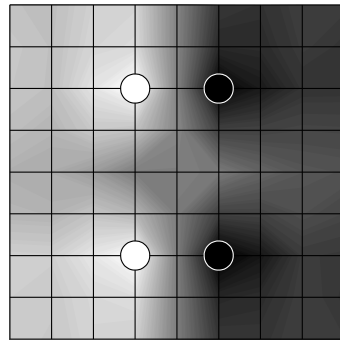
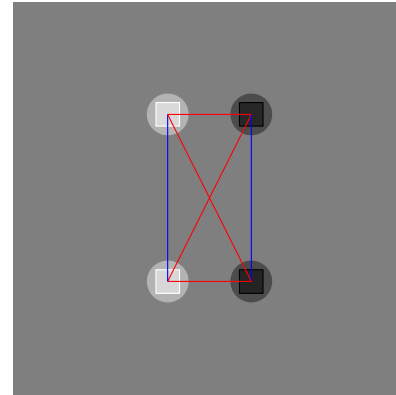
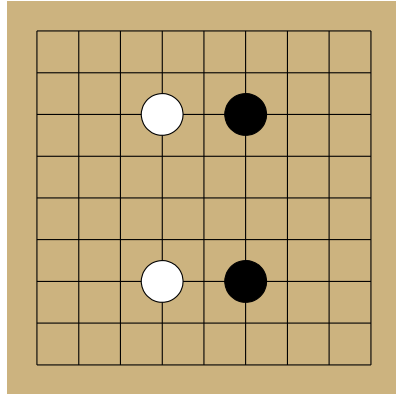
Experiments

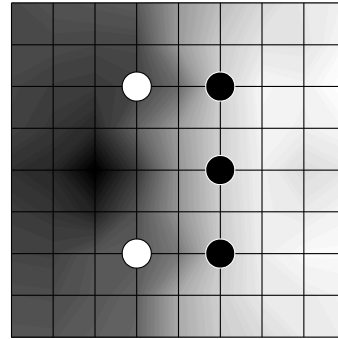
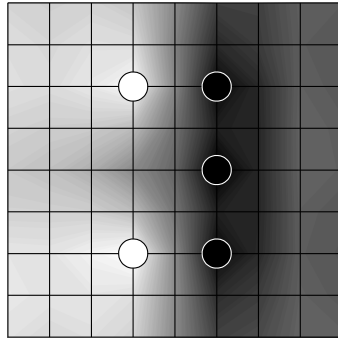
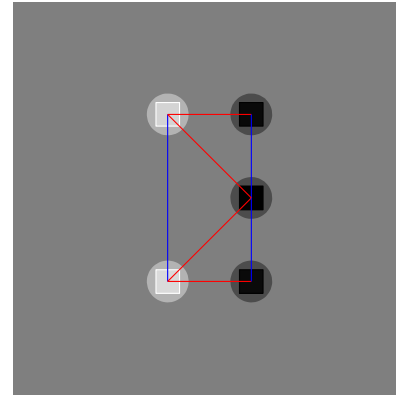
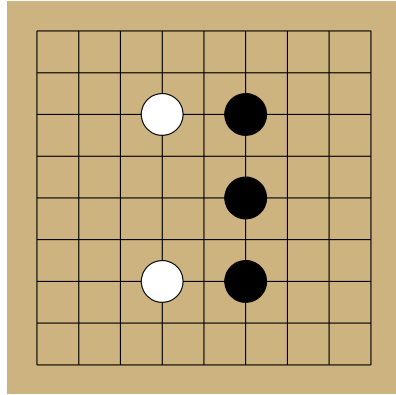
- **Goal:** determine the status of the stones without lookahead
- **Input:** 13 features for each block, pairwise relations with 1 feature
- **Output:** How many times the block survives in the 1000 possible futures (self-play)
- **Templates:** $(\text{block}(X), \text{ally}(X, Y), \text{block}(Y))$ and $(\text{block}(X), \text{enemy}(X, Y), \text{block}(Y))$
- Collective regression for all the blocks

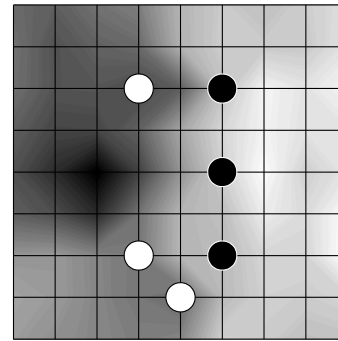
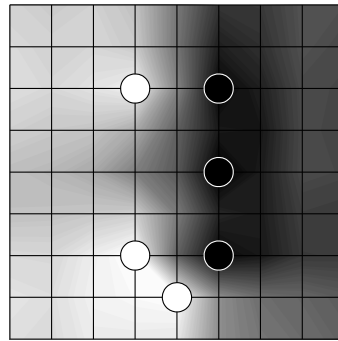
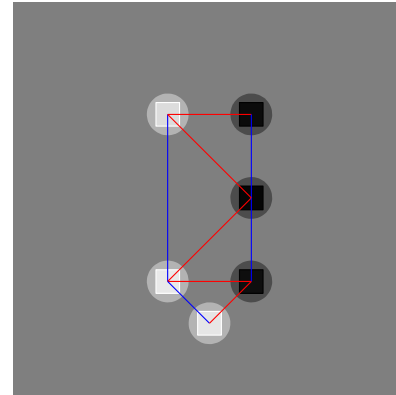
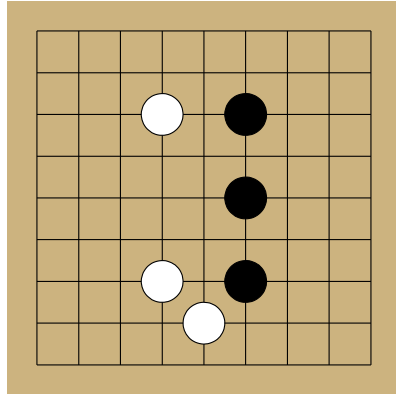


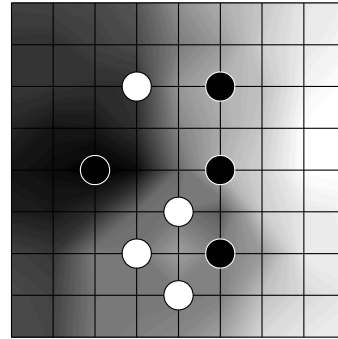
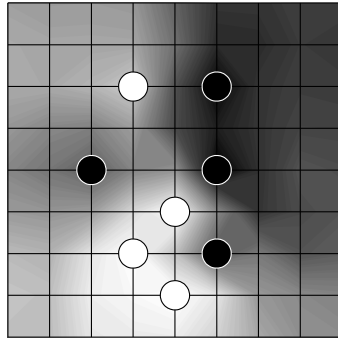
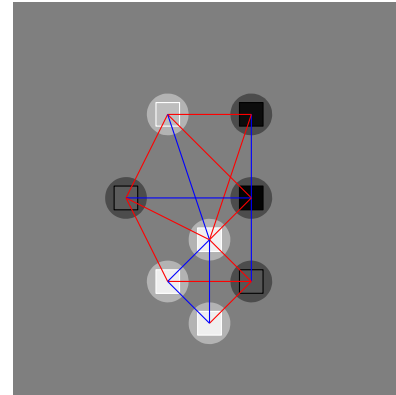
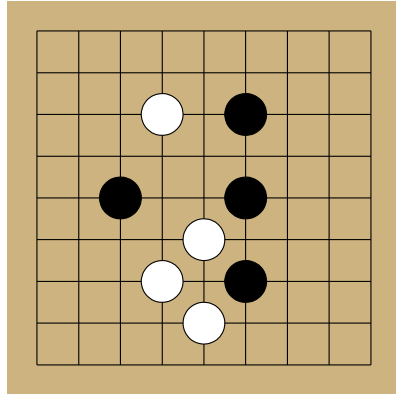


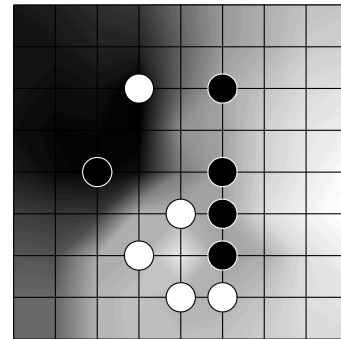
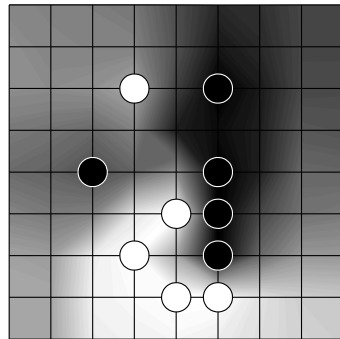
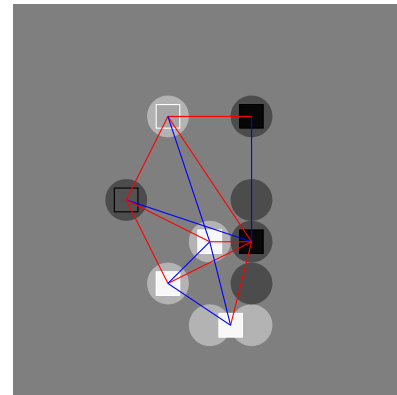
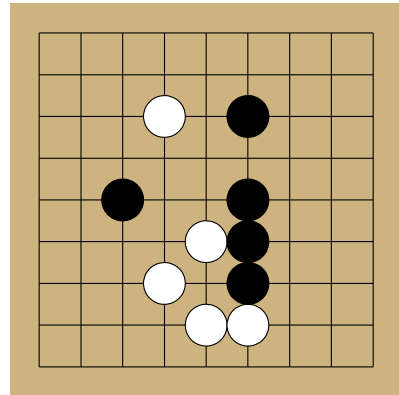


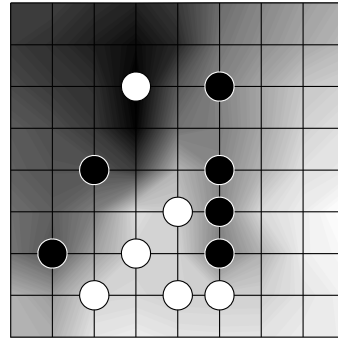
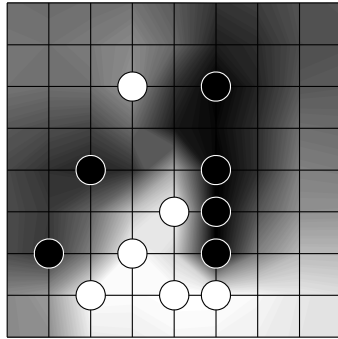
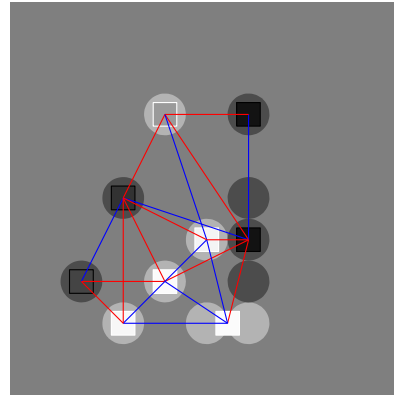
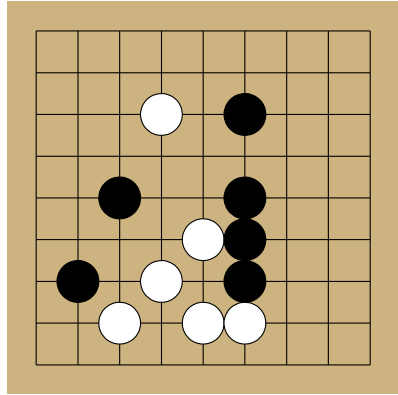


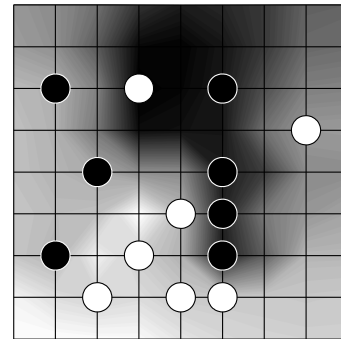
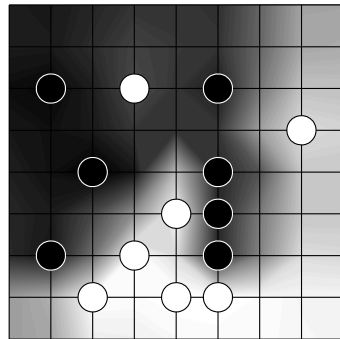
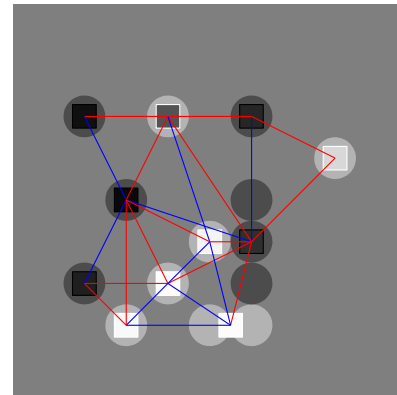
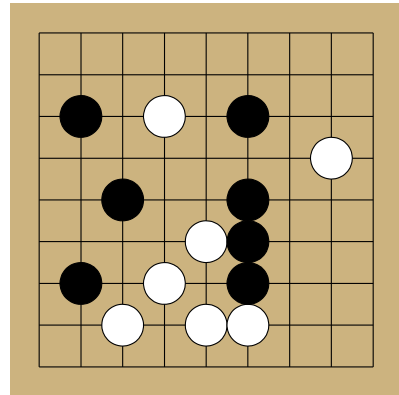


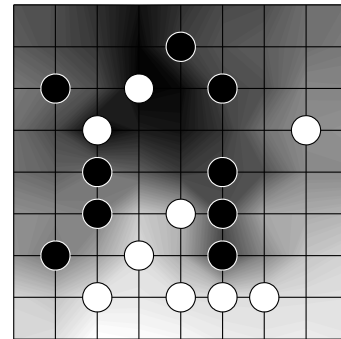
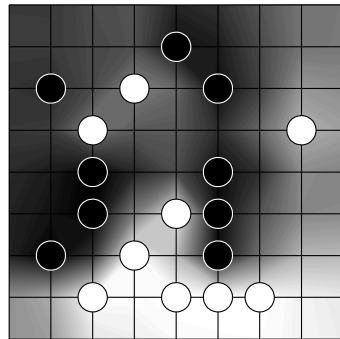
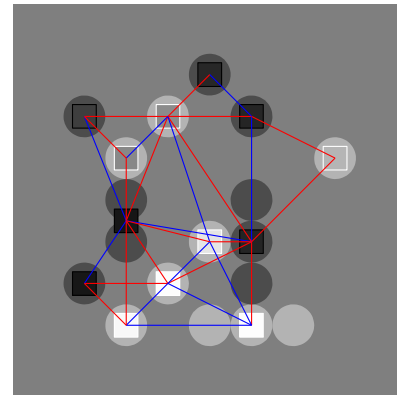
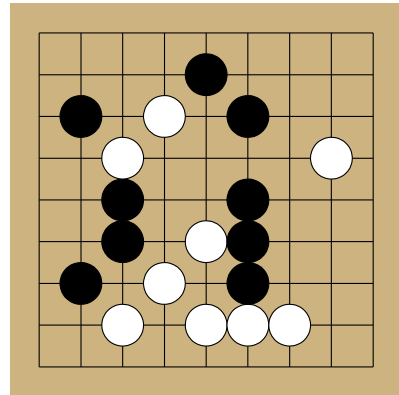


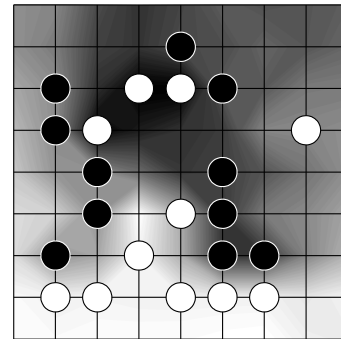
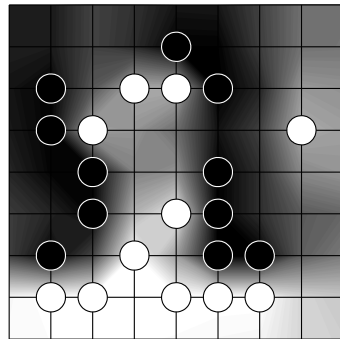
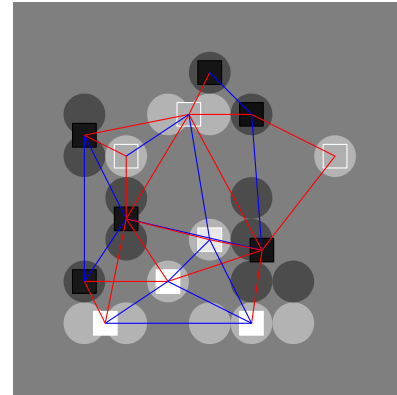
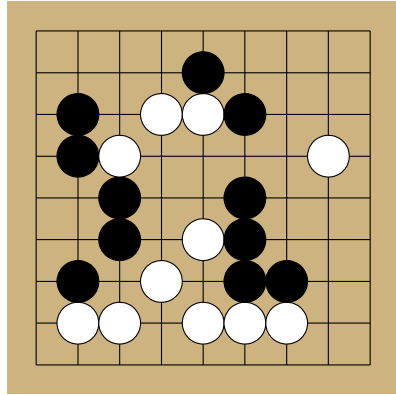


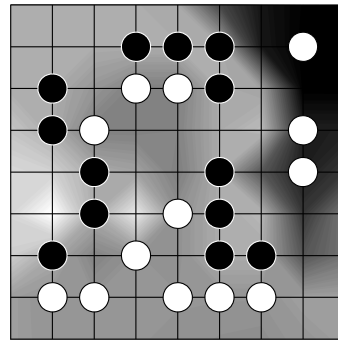
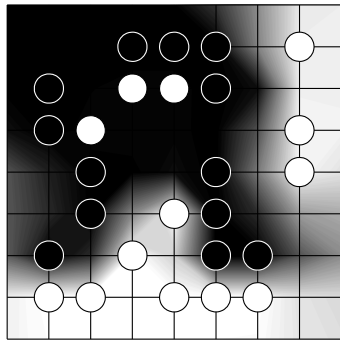
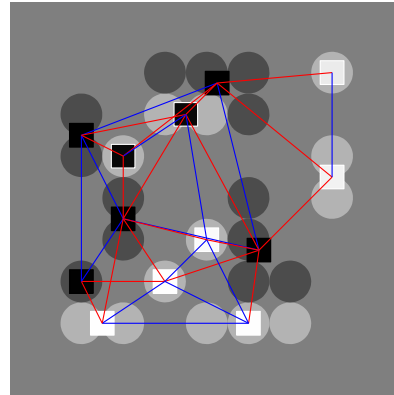
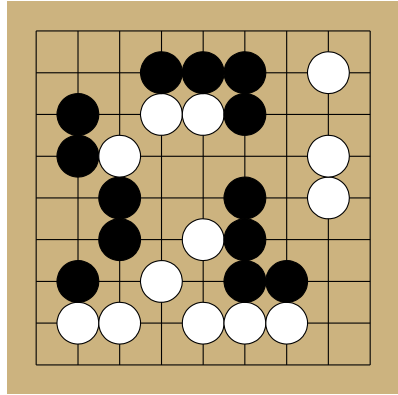


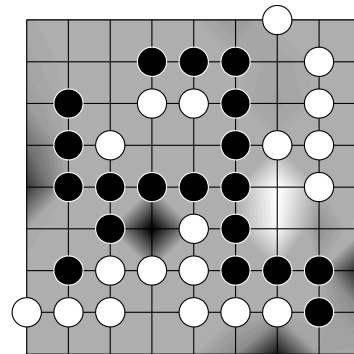
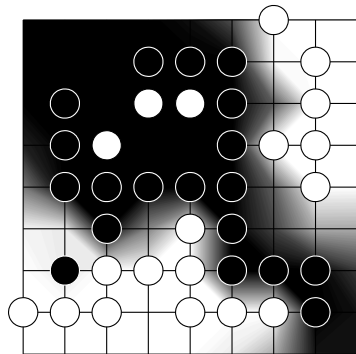
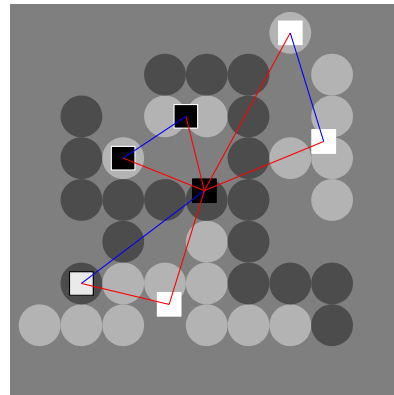
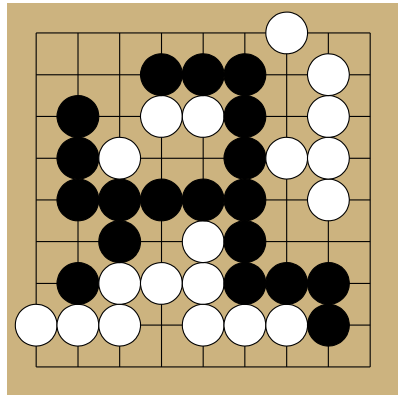


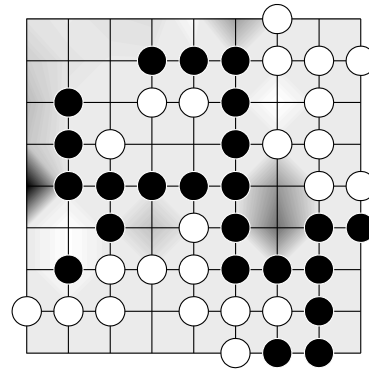
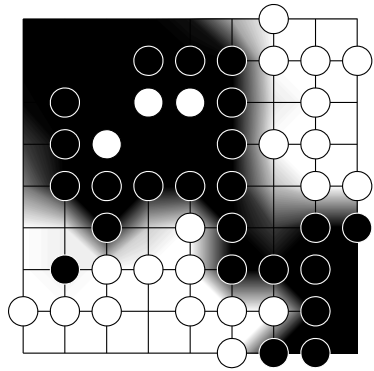
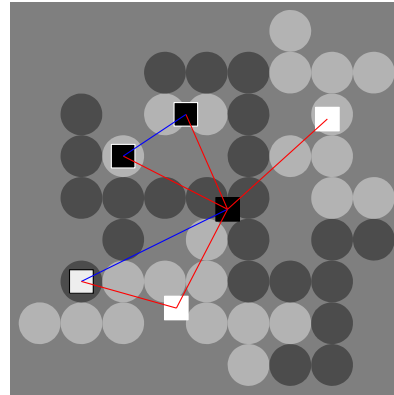
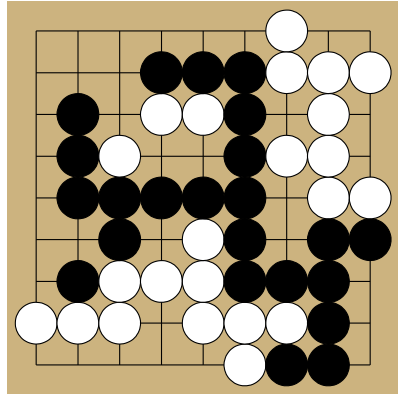


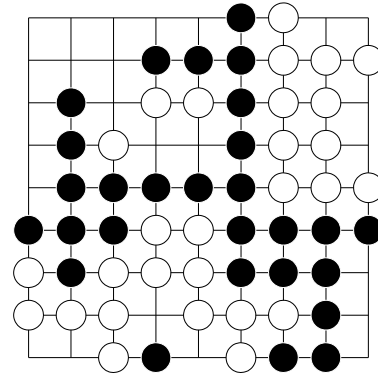
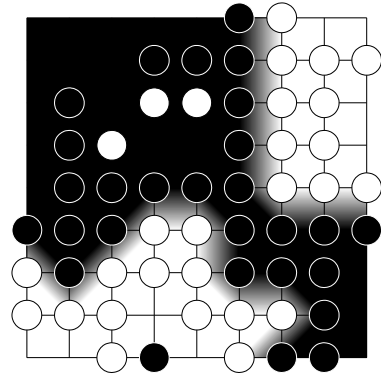
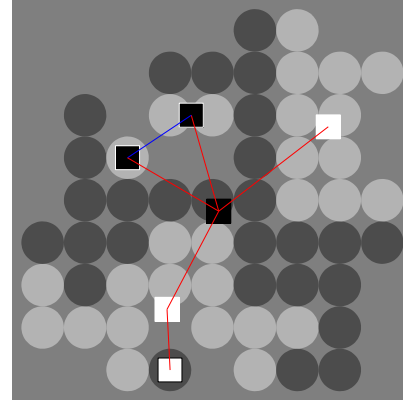
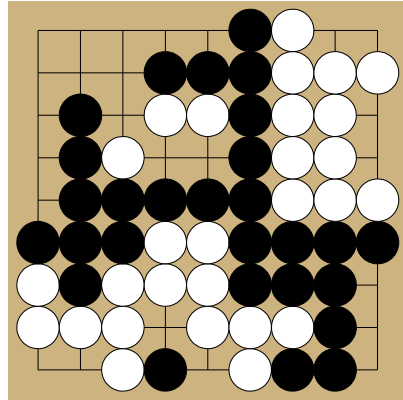












Results

- RMS errors for inferring the survival probabilities of the blocks

	Linear	Nonlinear
Separate regression	0.2172	0.2052
Collective regression	0.2171	0.2037

- Nonlinear models better than linear ones
- Collective regression better than separate regression
- Results still unsatisfactory — static board evaluation is difficult!

Conclusions

- **Nonlinear Relational Markov Networks** extend graphical modelling to both **nonlinear** and **relational** directions for the first time
- As a testbed, the game of **Go** is a difficult enough but still clearly bounded and results measurable