# Knowledge Representation and Reasoning
## Second Project

– Predator and Prey –

Consider a (overly simplified) model that uses directed graphs to represent systems of animal species and their predators/prey relationships, according to which a (predation) graph (A, E) represents a system where A is the set of existing species and $E = A \times A$ the predation relation, such that $(\alpha, \beta) \in E$ if species α preys on species β.

The following predation graph exemplifies the model, encoding a system containing five species (a, b, c, d and e) where species a preys on species b, species d preys both on species c and e, species e only preys on itself (an autophagic species), etc...
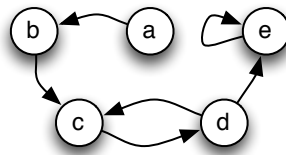

Using this model, scientists have determined that, for a given system represented by graph (A, E), certain subsets of species are interesting and worth studying. They defined the interesting subsets as follows:
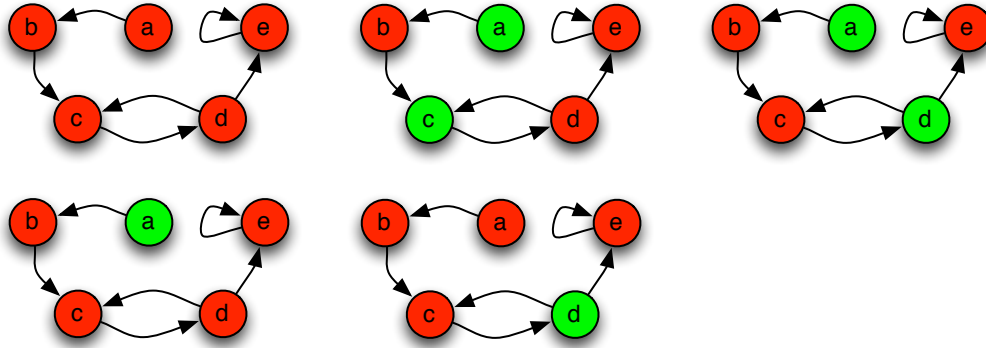
- **Predation-Free** A set of species $S \subseteq A$ is *predation-free* if there are no $\alpha, \beta \in S$ such that $(\alpha, \beta) \in E$. With respect to the running example, the following figure depicts *some* predation-free sets of species (in green).
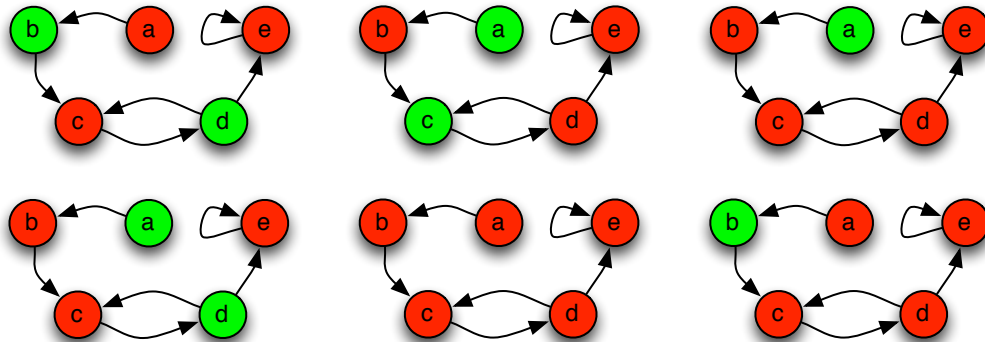
- **Stable** A set of species $S \subseteq A$ is *stable* if it is predation-free and every species not in S is preyed on by a species in S. With respect to the running example, the following figure depicts the single stable set of species (in green).
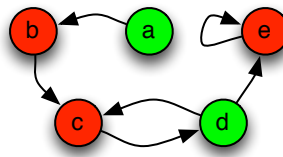
- **Communal** A set of species $S \subseteq A$ is *communal* if it is predation-free and every species not in S that preys on a species in S is preyed on by a species in S. With respect to the running example, the following figure depicts the five communal sets of species (in green).

Group 1

Write Answer Set Programs that, when combined with a representation of a predation graph, have their Answer Sets correspond to the sets of *Predation-Free*, *Stable*, and *Communal* subsets of species. Predation graphs are represented by facts of the form `species/1` and `pred/2`, where a fact `species(a)` represents that a is a species and a fact `pred(a,b)` represents that species a preys on species b.

Group 2

While studying the notes of the late Dr. Khalal on an alien planet, we came to realise that he had been recording information about several species and their relations. According to his notes, we know that there are thirteen species that he named *aendius*, *bionius*, *calipius*, *dormendius*, *eptondius*, *focacius*, *gerontius*, *halacius*, *isodius*, *jacacius*, *kaladius*, *lamelius* and *marmelius*. He never discovered the predation graph, but included the following discoveries which will help us understanding their relationships:

- every species is preyed on by at least one other species.

- every species prey on exactly two species.

- there are two autophagic species.

- *eptondius* prey on either *focacius* or *gerontius*.

- *kaladius*, *lamelius* and *marmelius* all prey on each other.

- either *jacacius* prey on *kaladius*, or *kaladius* prey on *jacacius*.

- if *jacacius* prey on *kaladius*, then *aendius* and *bionius* prey on each other.

- *aendius* prey on *calipius* who prey on *dormendius* who prey on *aendius*.

- *halacius* prey on two of *isodius*, *jacacius* and *dormendius*.

- *jacacius* is preyed by three species.

- either *aendius* and *bionius* or *eptondius* and *jacacius* are autophagic.

- *bionius* prey on *eptondius*.

- *focacius* and *gerontius* prey on each other.

- *focacius* and *gerontius* prey on every species that is preyed by both *kaladius* and *marmelius*.

- *calipius* and *dormendius* are predators of *halacius*.

- *isodius* prey on *dormendius* and *jacacius*.

Write an Answer Set Program whose answer sets correspond to the predation graphs that are consistent with Dr. Khalal's notes. How many are there?

Group 3

Use the Answer Set Programs of the previous two groups to answer the following questions, for each of the species graphs consistent with Dr. Khalal's notes:

1. How many predation-free species sets are there?

2. How many stable species sets are there?

3. Which species belong to all stable species sets?

4. How many communal species sets are there?

– Gerry-mander –

The term Gerry-mander appeared first in the Boston Gazette (in 1812) in reference to the redrawing of the Massachusetts state senate election districts under Governor Elbridge Gerry that was claimed to make one district appear to have the shape of a mythological salamander.

The objective of Gerrymandering is to obtain an advantage in the next elections for a particular political party or group by changing the district boundaries (based on previous voting results). Many articles can be found on the Web on the topic including examples of court debates and rulings. The principal idea is illustrated in the following figure.

HOW TO STEAL AN ELECTION
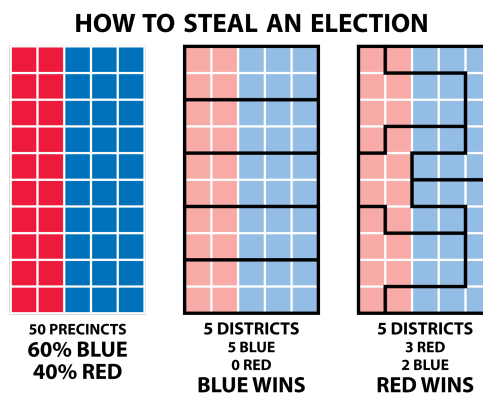
You can also try out the following to get a better idea:
http://polytrope.com/district/sandbox.html

Consider the following (simplified) situation. You are a member of the Circle Party and you get the opportunity to redraw the map of districts in your state. Your objective is to find a layout of districts that, based on the voting results from the previous election, minimizes the success of the Diamond Party, the other contender in the upcoming elections, where the winner in each district is determined by simple majority. While thinking about the problem, you realize that maybe you can come up with a solution that is also useful to your fellow party members in other states of the country.

The map of a state is represented by a rectangular grid of precincts, which can be joined into districts. You know that each precinct has the same number of voters and that the size of districts may vary by one precinct. You also know that the commission deciding about any proposal will dismiss any layout in which a precinct of some district is not connected to the other precincts or only connected via a diagonal.

The data of your state can be summarized as follows.

```
          rows(2).  columns(2).  districts(2).  party(c).  party(d).
    votes(1,1,c,47).  votes(1,1,d,53).  votes(1,2,c,59).  votes(1,2,d,41).
    votes(2,1,c,54).  votes(2,1,d,46).  votes(2,2,c,42).  votes(2,2,d,58).
```

Facts over `rows/1` and `columns/1` determine the size of the state, while `districts/1` indicates the number of districts. Facts over `party/1` represent the two parties and facts over `votes/4` represent the results of the previous election for these parties (in percent).

Group 4

Write an Answer Set Program that, for any state in the country, allows you to determine the optimal district layout from the point of view of the Circle Party, i.e., the layout that includes the least number of districts won by the Diamond Party.

A correct solution in file 4_gerryMander.lp should output something similar to the following:

```
clingo 4_gerryMander.lp gerryInst01.lp
clingo version 5.3.0
Reading from 4_gerryMander.lp ...
Solving...
Answer:  1
district(1,1,1) district(2,1,2) district(1,2,1) district(2,2,2) won(c,1) won(d,1)
Optimization:  1
Answer:  2
district(1,1,1) district(2,1,1) district(1,2,2) district(2,2,2) won(c,2) won(d,0)
Optimization:  0
OPTIMUM FOUND
```

Further Hints

Please consult the manual for advanced modelling features of clingo. Also, note that there is an archive `gerryMander.zip` available for download from CLIP containing several proplem instances you can use for testing. For instances with a larger amount of possible district layouts (in particular instances 8, 9, and 10 with up to millions of possible layouts), you need to encode the problem in an efficient manner. For this, consider reducing the number of predicates, the arity of predicates, and the number of grounded rules, and try to reduce symmetries in between the possible district layouts.

Deliverables

You should send a single zip file labelled with your student numbers (individually or in groups of two students) to mkn@fct.unl.pt. The file should contain:

- One file for each ASP program developed, labelled appropriately (e.g. 1_predation_free.lp, 1_stable.lp, 1_communal.lp, 2.lp and 4_gerryMander.lp).

- Any test files you may have used, labelled appropriately.

- A report (single PDF file) which should include the commented code of all ASP programs used (with references to the corresponding files), and the answers, with justification, to the questions in this document.

- If you wish, you can add a section to the report with comments and suggestions about this project, and how to improve it.

Finally, note that different groups have to submit different solutions; in case of plagiarism all groups involved will fail the project.