Constructive Artificial Intelligence

Search

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Search

In a search, one begins with a known configuration and attempts to find the path towards a desired target configuration according to allowed transitions. More precisely:

Definition (Search Problem)

A **search problem** is defined by its

State/Node Set: a set $\mathcal{N}$ of **nodes** (also called **states**), each of which describes a particular situation that could (theoretically) occur in the given scenario;

Successor Rule: for each node $n \in \mathcal{N}$, the function S generating the set $S(n) \subseteq \mathcal{N}$ of successors of n;

Start Node: one node s, at which the search starts;

Goal State Set: a set $\mathcal{G} \subseteq \mathcal{N}$ of one or more goal nodes of the search.

Goal

Find a **path** from $n_0 := s$ to some $n_k := g \in \mathcal{G}$, i.e. a sequence $n_0, n_1, n_2, \ldots, n_k$ such that n_{i+1} is a successor of n_i.

Search Interface

Example (search.py — Interface Construction in Python)

```
####################################################
#
# this is just an interface, do not use on its own
#
####################################################

class Nodes:
    def succ(self, n):
        raise Exception, "Successor undefined"
    def start(self):
        raise Exception, "Start undefined"
    def goal(self, n):
        raise Exception, "Goal undefined"
```

Exercise 1 (Wolf/Cabbage/Goat Problem)

Exercise

Formulate the Wolf/Cabbage/Goat Problem in terms of state variables, start node, goal node and transitions and write a class that represents it.

Wolf/Cabbage/Goat I

```
##########################################################################
# wolf_cabbage_goat.py
##########################################################################

import search                           # get the interface

def other_side(left_right):
    if left_right == 'left': return 'right'
    elif left_right == 'right': return 'left'

def safe(node):
    # the side without the farmer needs check,
    # the other is safe
    side_without_farmer = other_side(node['farmer'])

    lone_travelers = set(traveler for traveler in node
                         if node[traveler] == side_without_farmer)

    # dangeroos animals
    unsafe = set(['wolf', 'goat']).issubset(lone_travelers) or\
             set(['goat', 'cabbage']).issubset(lone_travelers)
    return not unsafe

class Wolf_Cabbage_Goat(search.Nodes):
    def start(self):
        # farmer, wolf, cabbage, goat on one side
        return { 'farmer': 'left',
                 'wolf': 'left',
                 'goat': 'left',
                 'cabbage': 'left' }
```

Wolf/Cabbage/Goat II

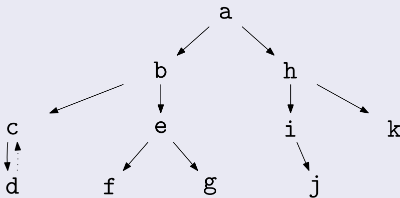
```
def goal(self, node):
    # true if all moved to right
    return set(node[i] for i in node) == set(['right'])

def succ(self, node):
    for traveler in node.keys() + ['']:
        # for all possible travelers, including none

        if traveler == 'farmer':
            continue
        # ignore, we'll deal separately with him

        new_node = node.copy()
        # create a safety copy

        # if somebody wants to travel, and the farmer is on the
        # same side, do it

        if traveler and new_node[traveler] == new_node['farmer']:
            new_node[traveler] = other_side(new_node[traveler])

        # the farmer always travels
        new_node['farmer'] = other_side(new_node['farmer'])

        # after a trip, the new state is ok if no one gets eaten
        if safe(new_node):
            yield new_node
```

Depth-First Search

For a given node n, search solution path $\mathrm{Sol}(n)$ to some goal node, by considering

Base Case: if $n \in \mathcal{G}$, define the solution path $\mathrm{Sol}(n)$ by $[n]$;

Recursion Step: else if n has a successor n' with a solution path $\mathrm{Sol}(n') = [n', \ldots, g]$ (reduced problem), then define solution path $\mathrm{Sol}(n) := [n] + \mathrm{Sol}(n') = [n, n', \ldots, g]$



Depth-First Search

Example (depth_first_search.py — DFS-Algorithm)

```
def depth_first_search(problem, node):
    if problem.goal(node): return [node]
    # base case

    for n_succ in problem.succ(node):
        sol = depth_first_search(problem, n_succ)
        if sol:
            # first path is returned
            return [node] + sol
```

Example (wcg_run.py — Running Code)

```
import wolf_cabbage_goat
from depth_first_search import *

wcg = wolf_cabbage_goat.Wolf_Cabbage_Goat()
print depth_first_search(wcg, wcg.start())
```

Problems of Depth-First Search

Observations

- parsimonious storage of candidate solution paths
- if the goals happen to be in the wrong branch, the search can take long

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- naive Depth-First can fail if the search tree is infinitely deep at places or contains repeats (loops)

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- parsimonious storage of candidate solution paths
- if the goals happen to be in the wrong branch, the search can take long
- naive Depth-First can fail if the search tree is infinitely deep at places or contains repeats (loops)
- Protection against repeats: record all past positions

Depth-First Search with State Records I

Example (wcg_token.py — Modified Problem)

```
import wolf_cabbage_goat

class WCG_Token(wolf_cabbage_goat.Wolf_Cabbage_Goat):
    def token(self, node):
        # get the list of pairings of traveler and location
        # each of them e.g. ('goat', 'right')
        pairs = list(node.iteritems())

        # sort them (arbitrarily, but fixed), so that
        # the token does not depend on arbitrary
        # dictionary order
        pairs.sort()

        # make it immutable, turn it into tuple
        return tuple(pairs)
```

Depth-First Search with State Records II

Example (depth_first_search_hash.py — Modified DFS-Search)

```
def depth_first_search(problem, node, visited = set()):
    token = problem.token(node)
    if token in visited: return
    # we have tried this node already

    visited = visited.union(set([token]))
    # create new set that contains the node

    if problem.goal(node): return [node]
    # base case

    for n_succ in problem.succ(node):
        sol = depth_first_search(problem, n_succ, visited)
        if sol:
            # first path is returned
            return [node] + sol
```

Example (wcg_run_token.py — Modified Running Code)

```
import wcg_token
import depth_first_search_hash

wcg = wcg_token.WCG_Token()

print depth_first_search_hash.depth_first_search(wcg, wcg.start())
```