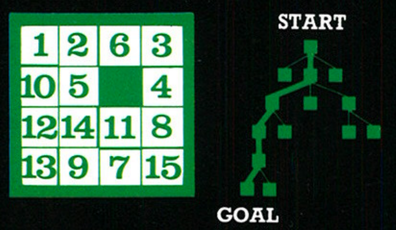
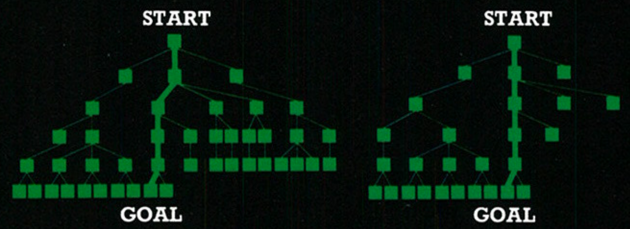
EARLY EDINBURGH WORK ON PLANNING

* From the mid 1960s Edinburgh scientists were experimenting with Heuristic Problem Solvers. These used problem specific information to help to choose between alternatives.
* An early example is the Graph Traverser (Doran & Michie, 1966).
* A problem domain is described by
  - A snapshot of a particular state.
  - A set of operators which can change the state.
* A particular problem is given by
  - The initial state.
  - The final or goal state.
* An evaluation function is provided to give a heuristic ("rule of thumb") estimate of the closeness of any given state to the goal state.
* The graph traverser then starts working on the initial state by
  - Applying the operators to produce new states.
  - Evaluating the closeness of each of these to the goal state.
  - Choosing the current 'best' state.
  - If it is not the goal state then repeat the whole sequence.
* The 8-puzzle – sliding block puzzle.



Value produced by evaluation function. Current 'best' chosen at each iteration.

* Alternative 'dumb' selections search a larger space.



Breadth-First Search — Depth-First Search

* Variations of the state-space search problem solvers were studied, e.g.,
  - Bidirectional Search (from the Initial and Goal States simultaneously)

Problem Reduction – Sub-goaling

* Other approaches to problem solving were also studied – one was sub-goaling.
* Given a complex problem, the idea was to split it into smaller sub-problems and solve these separately.
* Early work was on simple domains where the full problem could be solved by a simple linear sequence of actions which solved each sub-problem.

LINEAR PLANNING WITH INTERACTIONS BETWEEN SUB-PROBLEMS

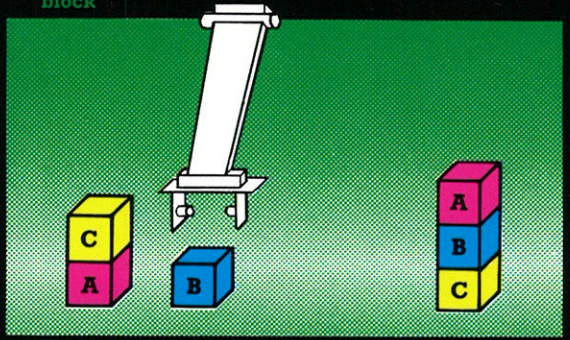
* There were a series of experimental planners in 1973-5 aimed at exploring strategies for planning when solutions to sub-goals interacted.
* Some involved global optimisation of the emerging plan by being more flexible in allowing actions to achieve some particular sub-goal to be interleaved with actions to achieve other sub-goals.

For example, WARPLAN (Warren, 1975)
  - Built a plan for one sub-goal
  - It then chose places in this plan for subsequent actions which avoides interactions.

* Another approach taken in the INTERPLAN system (Tate, 1975) was to use the "Goal Structure" implied by sub-goaling to describe "Holding Periods" for which sub-goals had to be maintained after being achieved. On the basis of the Goal Structure, INTERPLAN recorded sub-goals and recognised a set of interacting conditions requiring interleaving of the action sequences to achieve several sub-goals.
* These Linear Planners explored difficult technical problems on rather trivial applications (to ease explanation of the mechanisms involved).
* For example, Block Stacking problems were used to describe the techniques.

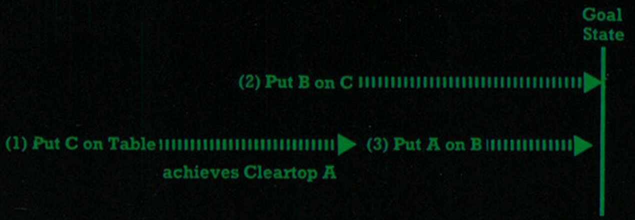
* Interacting Sub-goals in the Block World

  - Given a hand which can only pick up or put down a single block



Initial state ON(C,A) & ON(A,Table) & ON(B,Table) — Goal state ON(A,B) & ON(B,C)

- Achieving either ON(A,B) or ON(B,C) first leaves a sub-problem which cannot be solved without affecting the first sub-goal.
- Solution requires interleaving of sub-goal solutions



NON-LINEAR PLANNING WITH INTERACTIONS BEWEEN SUB-PROBLEMS

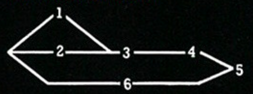
* Following work at Stanford Research Institute on the generation of plans which only contained the order of actions when these actions interfered (so called non-linear planners), further work was performed at Edinburgh.
* The NONLIN Planner (Tate, 1976) used "Goal Structure" as a meta-planning aid to resolving conflicting parallel actions in non-linear plans. It also planned at various levels of detail (hierarchically).
* This system was designed to generate PERT-type Project Networks, but in its early trials was again used on technically difficult problems in simple domains (e.g. Block Stacking).
* The NONLIN System also introduced a Task Formalism (TF) used to describe a problem domain to the planner. For any action it shows –
  - Expansion & Orderings
    The sub-goals and actions needed to achieve the action at a greater level of detail.
  - Conditions
    The Goal Structure for the expansion.
  - Effects
    The state changes to the world model brought about as a result of using this action.

HOUSE BUILDING (1976)

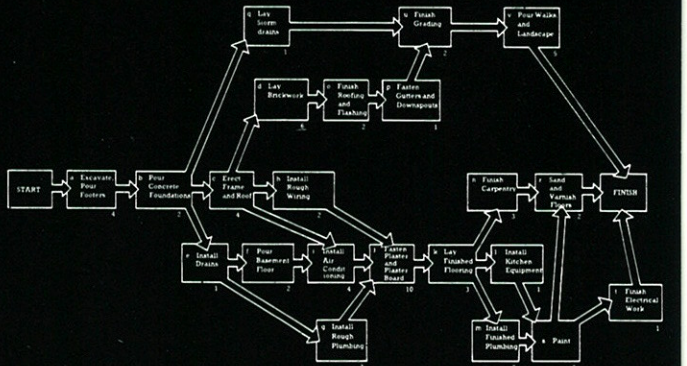
* NONLIN was used to generate project networks for house building tasks comprising 20 - 60 jobs.
* A fragment of the problem description is shown for a DECORATION action.

```
ACTSCHEMA DECOR
   PATTERN <<DECORATE>>
   EXPANSION 1 ACTION <<FASTEN PLASTER AND PLASTER BOARD>>
             2 ACTION <<POUR BASEMENT FLOOR>>
             3 ACTION <<LAY FINISHED FLOORING>>
             4 ACTION <<FINISH CARPENTRY>>
             5 ACTION <<SAND AND VARNISH FLOORS>>
             6 ACTION <<PAINT>>
   ORDERINGS SEQUENCE 2 TO 5  1 --->3   6 --->5
  CONDITIONS UNSUPERVISED <<ROUGH PLUMBING INSTALLED>> AT 1
             UNSUPERVISED <<ROUGH WIRING INSTALLED>> AT 1
             UNSUPERVISED <<AIR CONDITIONING INSTALLED>> AT 1
             UNSUPERVISED <<DRAINS INSTALLED>> AT 2
             UNSUPERVISED <<PLUMBING FINISHED>> AT 6
             SUPERVISED <<PLASTERING FINISHED>> AT 3 FROM 1
             SUPERVISED <<BASEMENT FLOOR LAYED>> AT 3 FROM 2
             SUPERVISED <<FLOORING FINISHED>> AT 4 FROM 3
             SUPERVISED <<CARPENTRY FINISHED>> AT 5 FROM 4
             SUPERVISED <<PAINTED>> AT 5 FROM 6
      END;
```

The partial ordering on the actions is:-



* A sample project network generated for house building



CEGB ELECTRICITY TURBINE OVERALL (1978)

* The Edinburgh Planning Team used AI and Operational Research techniques developed for the NONLIN Planner, Task Formalism and House Building examples to tackle a large scale project planning task.
* Working with the SSEB O.R. Group they developed the TF for describing turbine overall procedures. This had a hierarchical description of the domain at 3 levels with 70, 300 and 750 activity descriptions at the three levels.
* The system was used to interactively generate project networks having around 400 jobs.

FACTORY AUTOMATION

* Work is now underway to apply the NONLIN Planning System (extended to cope with Time Constraints) to the planning and sequencing of a collection of robotic devices, perhaps co-operating with skilled manpower in a flexible manufacturing facility.

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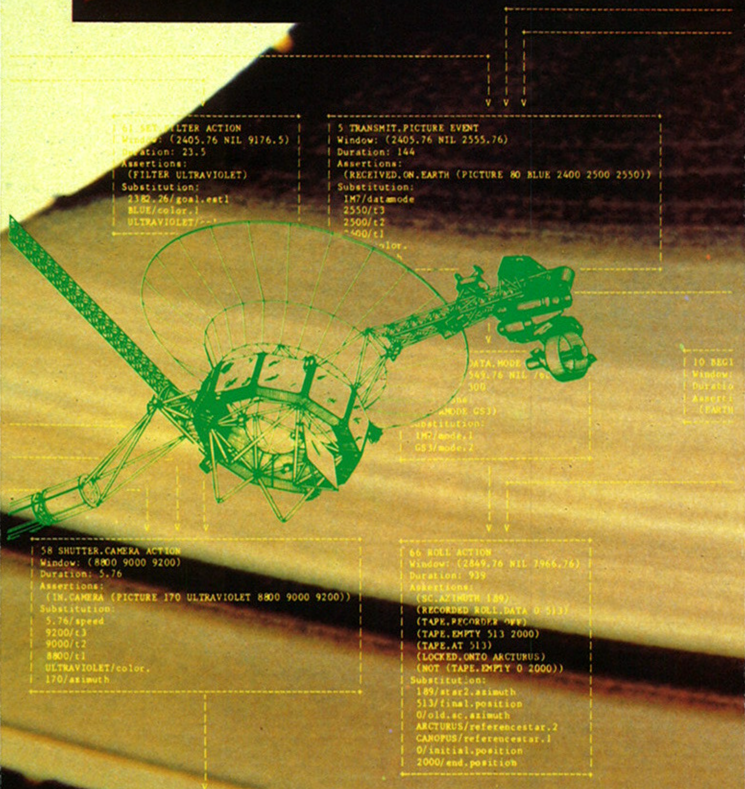
Vere, S. (1981)	Planning in Time: Windows and durations for activities and goals NASA, JPL Report.

NASA Voyager World WORK (1981-2)

* NASA have re-implemented and extended the NONLIN Planner, adding facilities to handle Time Constraints on activities.
* Their planner is called DEVISER (Vere, 1981)
* The system is used for sequencing spacecraft actions necessary to achieve stated scientific objectives.



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