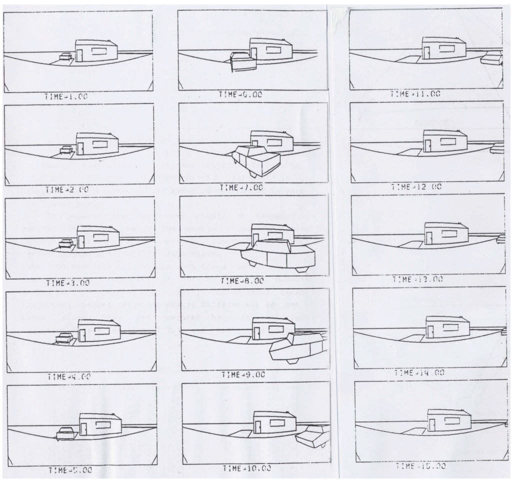
Historical Examples for Scene Interpretation

Early Traffic Scene Interpretation (Badler 75)



Norman I. Badler
Temporal Scene Analysis: Conceptual Descriptions of Object Movements
Dissertation, Report TR 80,
Dep. of Computer Science,
University of Toronto, 1975

Task:
Describe motion in terms of changing spatial relations

Input data:
15 "snapshots" of a car leaving the driveway of a house

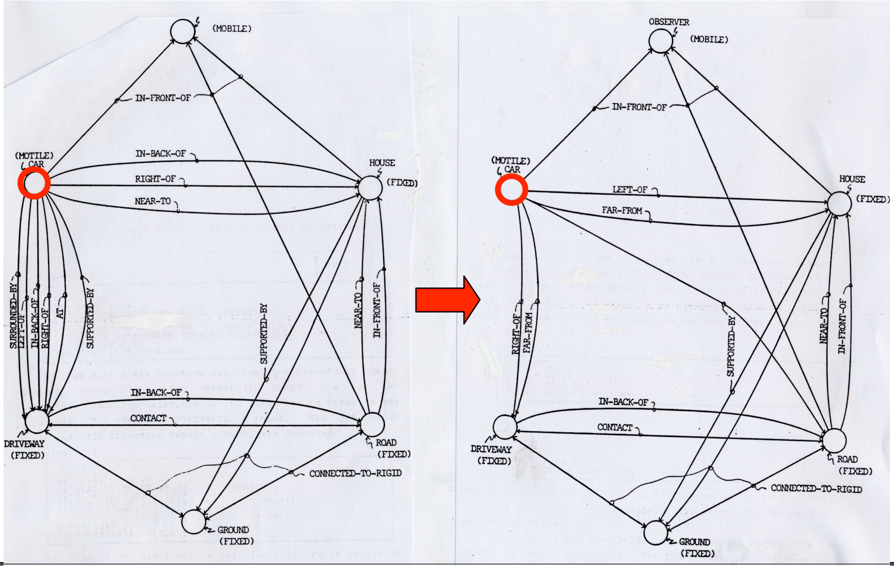
Directional Adverbials for Motion Description (Badler 75)

Scene interpretation is performed by recognising changing spatial relationships between objects and relating the changes to directional adverbials.

Directional adverbials used by Badler:

- **ACROSS**
- **AFTER**
- **AGAINST**
- **AHEAD-OF**
- **ALONG**
- **APART**
- **AROUND**
- **AWAY**
- **AWAY-FROM**
- **BACK**
- **BACK-AND-FORTH**
- **BACKWARD**
- **BEHIND**
- **BY**
- **CLOCKWISE**
- **COUNTERCLOCKWISE**
- **DOWN**
- **FORWARD**
- **FROM**
- **IN**
- **IN-THE-DIRECTION-OF**
- **INTO**
- **INWARD**
- **OFF**
- **OFF-OF**
- **ON**
- **ONTO**
- **ONWARD**
- **OUT**
- **OUT-OF**
- **OUTWARD**
- **OVER**
- **SIDEWAYS**
- **THROUGH**
- **TO**
- **TO-AND-FRO**
- **TOGETHER**
- **TOWARD**
- **UNDER**
- **UP**
- **UP-AND-DOWN**
- **UPWARD**
- **WITH**

Changing Scene Graph for Car Scene (Badler 75)



Demon Representation of "ACROSS" Motion (Badler 75)

A NEAR-TO relation with one side of an object is broken and replaced by a similar relation with the other side. There is an implicit sense of passage ABOVE the object.

Precondition 1
NEAR-TO(X S1).
SUB-PART(Y S1) for some object Y and SUB-PART [chain] to object S1.
FRONT or BACK or LEFT-SIDE or RIGHT-SIDE(Y S1).
ACROSS remains active as long as NEAR-TO(X Y) and ABOVE(X Y) hold.

Precondition 2
NEAR-TO(X S2).
SUB-PART(Y S2) for a SUB-PART [chain] to object S2.
FRONT or BACK or LEFT-SIDE or RIGHT-SIDE(Y S2) where S1 ≠ S2 and at least one of the ORIENTATION relations to S1 (from Precondition 1) no longer holds.

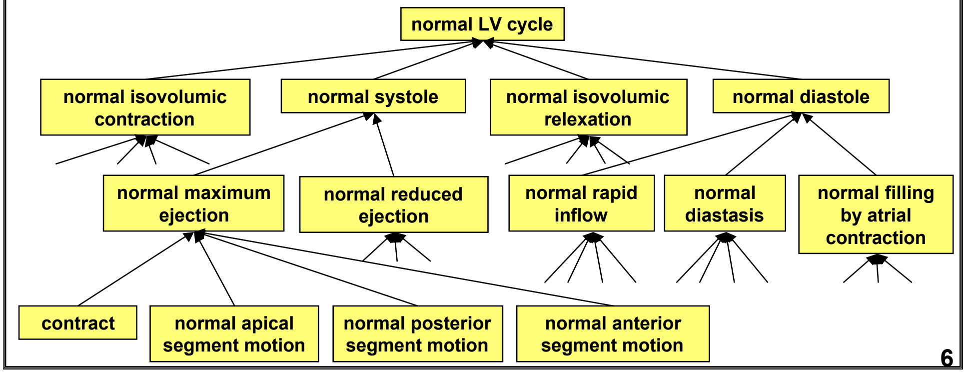
Postcondition
SUBJECT X
DIRECTION PCONS((ACROSS Y), DIRECTION)

Left-ventricular Motion PART-OF Hierarchy (Tsotsos et al. 79)

Tsotsos, J., Mylopoulos, J., Covvey, H.D., Zucker, S.W., **A Framework for Visual Motion Understanding**, Proc. Workshop on Computer Analysis of Time-Varying Imagery, Philadelphia, 1979.

Task: Recognize heart conditions from ultrasound heart images

PART-OF structure supports part-whole reasoning in recognition processes



normal LV cycle

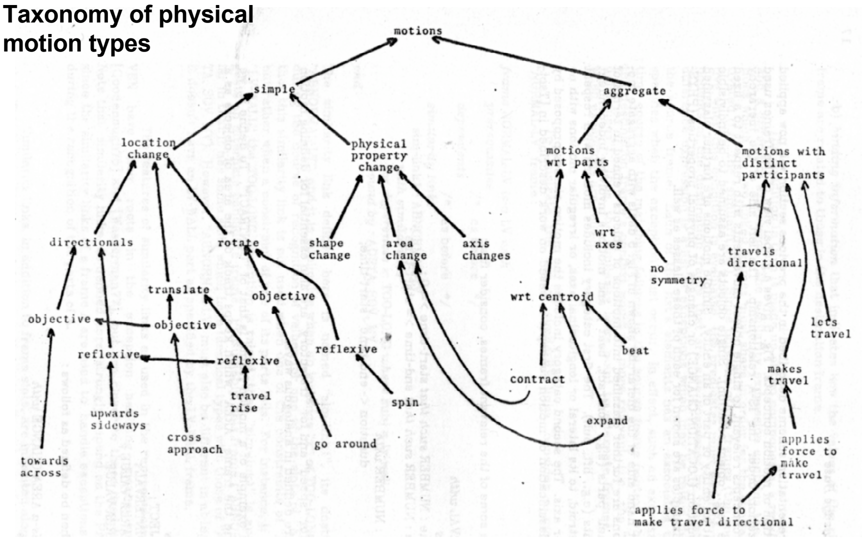
normal isovolumic contraction
normal systole
normal isovolumic relexation
normal diastole

normal maximum ejection
normal reduced ejection
normal rapid inflow
normal diastasis
normal filling by atrial contraction

contract
normal apical segment motion
normal posterior segment motion
normal anterior segment motion

Motion IS-A Hierarchy (Tsotsos et al. 79)

Taxonomy of physical motion types



Model-based Prediction for Tracking a Jointed Moving Object (Hogg 84)

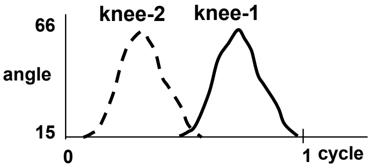
D. Hogg, **Interpreting Images of a Known Moving Object.** PhD thesis, University of Sussex, Brighton, UK, 1984.

Task: Describe highly coordinated motion of parts.

Use of quantitative measures along time axis.

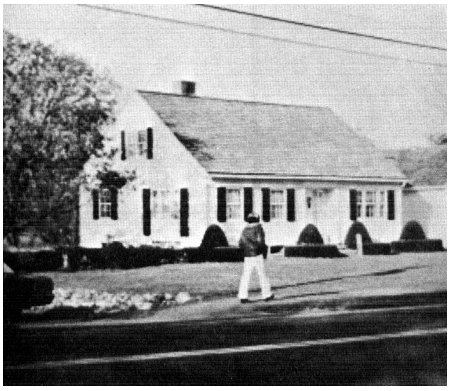
Posture curves + constraints represent coordinated motion of joints of walker.

Example:



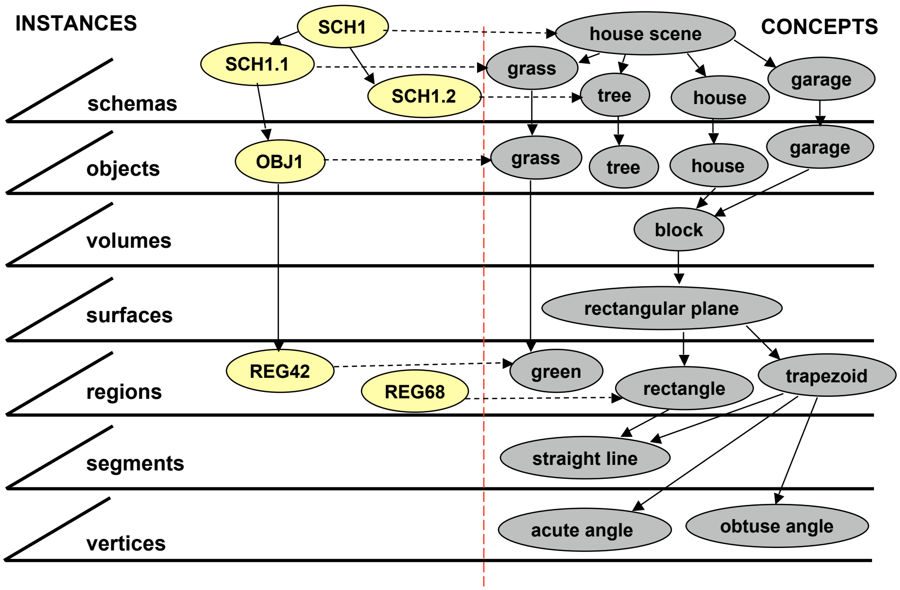
The VISIONS Image Interpretation System (Hanson & Riseman 78)

Long-term research about the interpretation of land-house scenes



(original in colour)

Representation Hierarchy in VISIONS



INSTANCES

CONCEPTS

schemas

objects

volumes

surfaces

regions

segments

vertices

SCH1

SCH1.1

SCH1.2

OBJ1

REG42

REG68

house scene

grass

tree

house

garage

grass

tree

house

garage

block

rectangular plane

green

rectangle

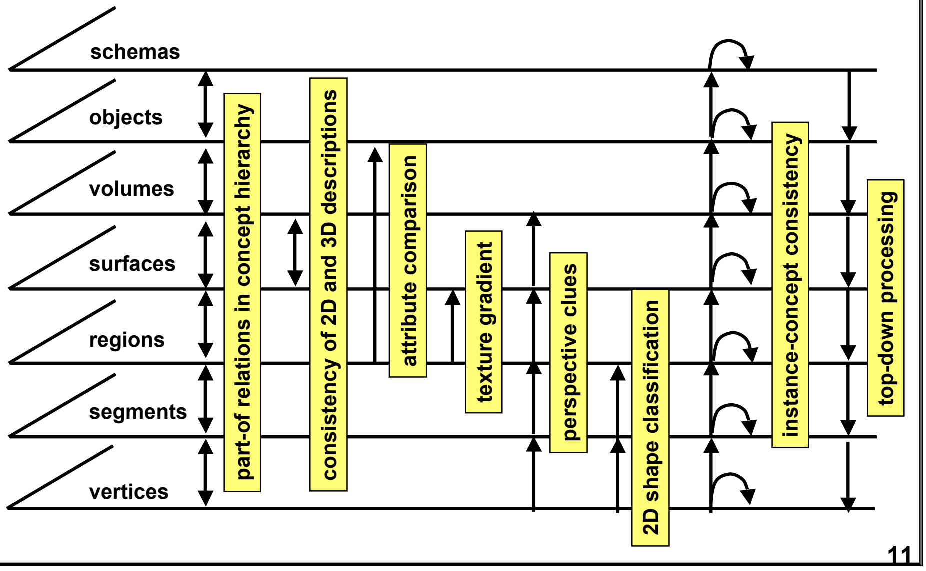
trapezoid

straight line

acute angle

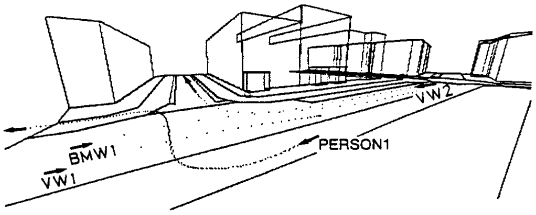
obtuse angle

Knowledge Sources for VISIONS


schemas
objects
volumes
surfaces
regions
segments
vertices
part-of relations in concept hierarchy
consistency of 2D and 3D descriptions
attribute comparison
texture gradient
perspective clues
2D shape classification
instance-concept consistency
top-down processing

NAOS - Natural Language Description of Object Motions in Traffic Scenes

Neumann, B.; Novak, H.-J., **NAOS: Ein System zur natürlichsprachlichen Beschreibung zeitveränderlicher Szenen (NAOS: A System for Natural-language Description of Time-varying Scenes)**, Informatik Forschung und Entwicklung 1, 83 - 92, 1986



English paraphrase of automatically generated description:

The scene contains four moving objects: three cars and a pedestrian.

A VW drives from the Alte-Post to the front of the FBI. It stops.

Another VW drives towards Dammtor. It turns off Schlueterstrasse. It drives on Bieberstrasse towards Grindelhof.

A BMW drives towards Hallerplatz. While doing so, it overtakes the VW which has stopped, before Bieberstrasse. The BMW stops in front of the traffic lights.

The pedestrian walks towards Dammtor. While doing so, he crosses Schlueterstrasse in front of the FBI.

From Scene Data to a Natural-language Scene Description (NAOS)

natural-language scene description

⬆

case frames

⬆

occurrences

⬆

primitive occurrences

⬆

perceptual primitives

⬆

geometrical scene description (GSD)

Geometrical Scene Description (GSD) in NAOS

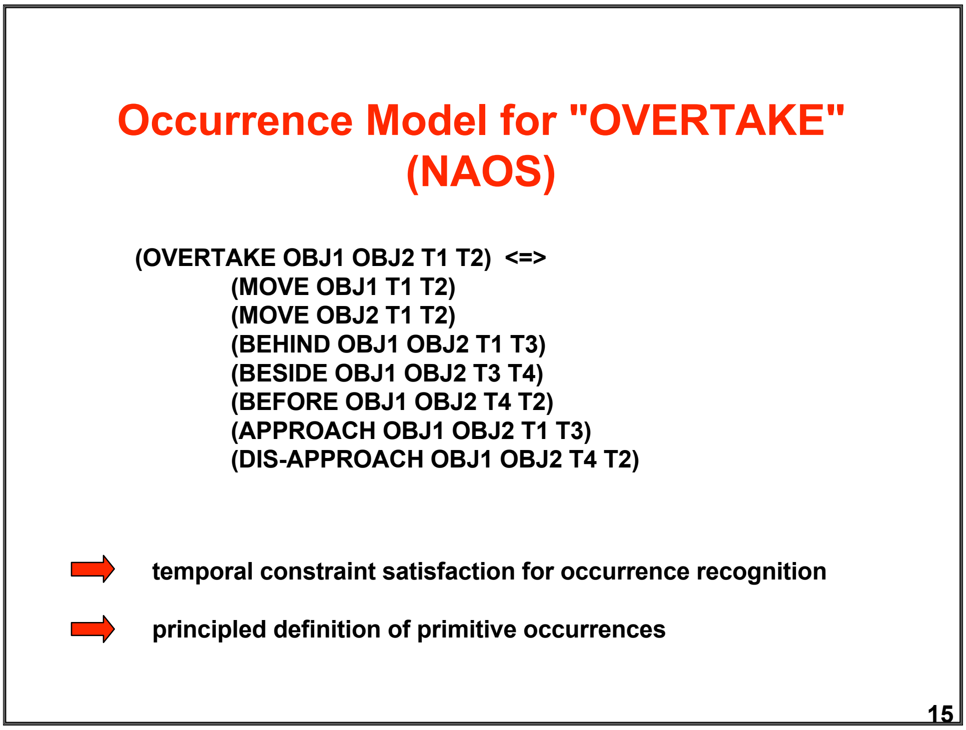
Quantitative description of all objects in a time-varying scene:

- **name of all objects (class or identity)**
- **position of all objects at all times (location and orientation)**
- **illumination (if required for high-level description)**

Example of a synthesized GSD in NAOS:

```
(LAGE VW2 (779. 170. 0.) (-1.0 0.0 0.0) 0)
(LAGE VW2 (753. 170. 0.) (-1.0 0.0 0.0) 1)
(LAGE VW2 (727. 170. 0.) (-1.0 0.0 0.0) 2)
(LAGE VW2 (701. 170. 0.) (-1.0 0.0 0.0) 3)
(LAGE VW2 (675. 170. 0.) (-1.0 0.0 0.0) 4)
(LAGE VW2 (649. 170. 0.) (-1.0 0.0 0.0) 5)
(LAGE VW2 (623. 170. 0.) (-0.999 0.037 0.0) 6)
(LAGE VW2 (596. 171. 0.) (-1.0 0.0 0.0) 7)
(LAGE VW2 (570. 171. 0.) (-1.0 0.0 0.0) 8)
(LAGE VW2 (544. 171. 0.) (-1.0 0.0 0.0) 9)
.
.
.
```

location   orientation   time

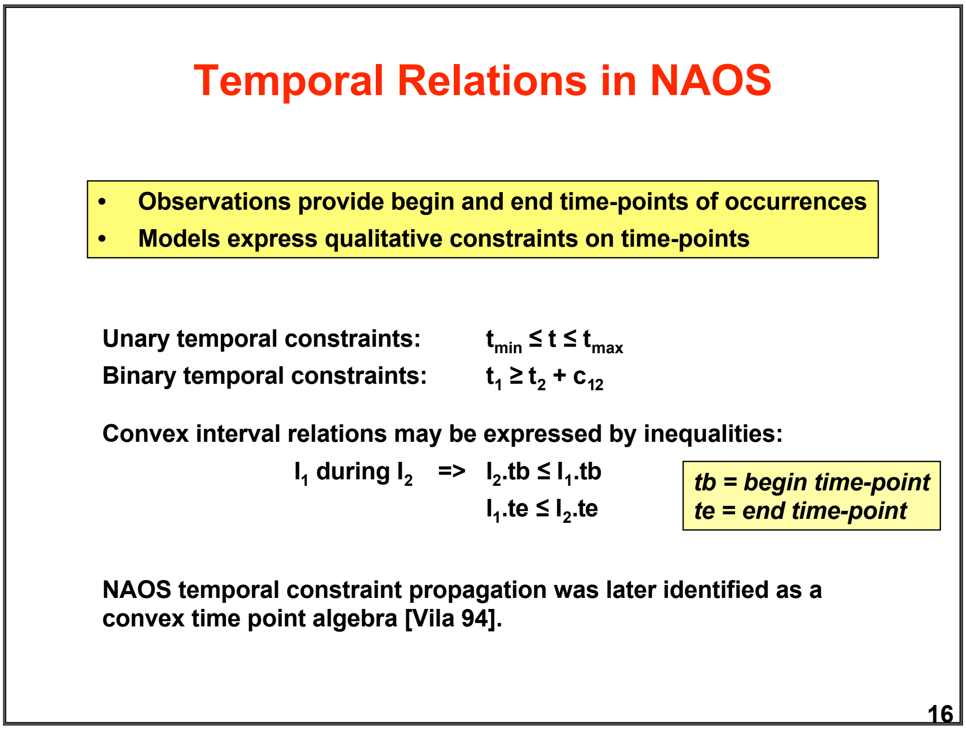


Occurrence Model for "OVERTAKE" (NAOS)

(OVERTAKE OBJ1 OBJ2 T1 T2) <=>
(MOVE OBJ1 T1 T2)
(MOVE OBJ2 T1 T2)
(BEHIND OBJ1 OBJ2 T1 T3)
(BESIDE OBJ1 OBJ2 T3 T4)
(BEFORE OBJ1 OBJ2 T4 T2)
(APPROACH OBJ1 OBJ2 T1 T3)
(DIS-APPROACH OBJ1 OBJ2 T4 T2)

➡ **temporal constraint satisfaction for occurrence recognition**

➡ **principled definition of primitive occurrences**



Temporal Relations in NAOS

- **Observations provide begin and end time-points of occurrences**
- **Models express qualitative constraints on time-points**

Unary temporal constraints: $t_{min} \leq t \leq t_{max}$
Binary temporal constraints: $t_1 \geq t_2 + c_{12}$

Convex interval relations may be expressed by inequalities:

I_1 during I_2 => $I_2.tb \leq I_1.tb$
$I_1.te \leq I_2.te$

tb = begin time-point
te = end time-point

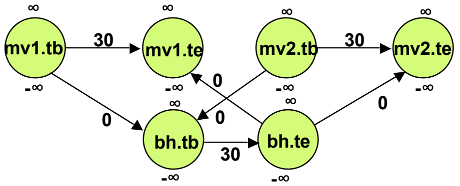
NAOS temporal constraint propagation was later identified as a convex time point algebra [Vila 94].

Constraint Propagation for Occurrence Verification in NAOS (1)

Example:

Verify occurrence "two moving objects, one behind the other"

1. **Initialize constraint net of occurrence model**



- ***mv1 and mv2 must last at least 30 time units***
- ***bh must last at least 30 time units***
- ***bh must occur during mv1 and during mv2***

2. **Compute primitive events for scene**

ID: move1
instance: move
parts: mv-ob = obj1
mv-tr = trj1
times: mv-tb = 13
mv-te = 98

ID: behind1
instance: behind
parts: bh-ob1 = obj1
bh-obj2 = obj2
times: bh-tb = 20
bh-te = 53

(and many more)

Constraint Propagation for Occurrence Verification in NAOS (2)

3. **Instantiate parts in occurrence model**

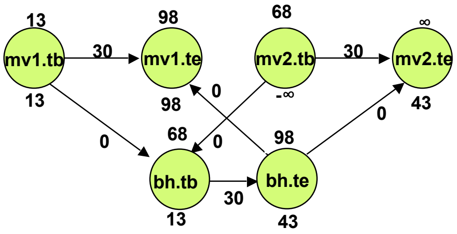
Propagate minima and maxima of time-points through constraint net:

- minima in edge direction $t_{2min} = \max \{t_{2min}, t_{1min} + c_{12}\}$

- maxima against edge direction $t_{1max} = \min \{t_{1max}, t_{2max} - c_{12}\}$

Example: • **move1 in scene instantiates mv1 of model**
• **time point values are propagated**

ID: move1
instance: move
parts: mv-ob = obj1
mv-tr = trj1
times: mv-tb = 13
mv-te = 98



Constraint Propagation for Occurrence Verification in NAOS (3)

4. **Consistency and completeness test**

   A (partially) instantiated model is inconsistent, if for any node T one has: Tmin > Tmax

   => search for alternative instantiations or terminate with failure

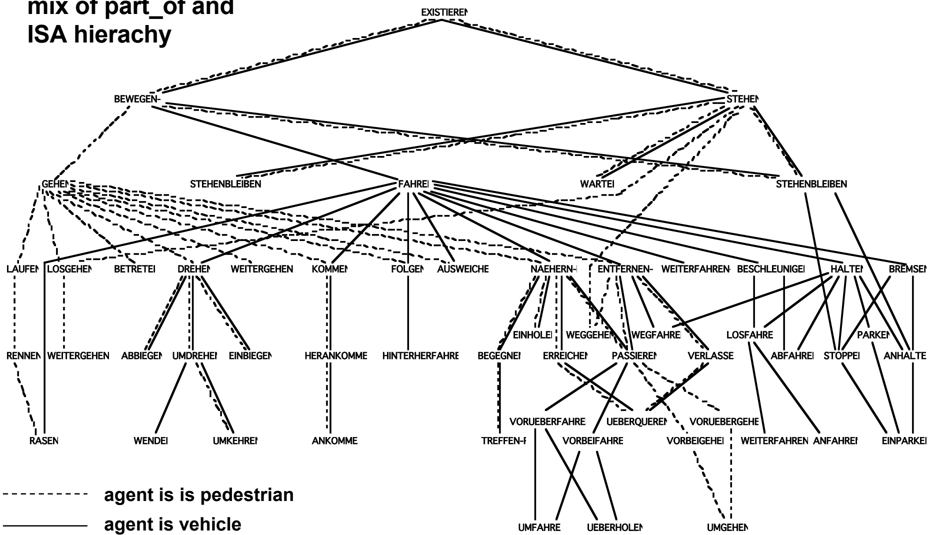
   An occurrence has been recognized if the occurrence model is instantiated with sufficient completeness and the instantiation is consistent.

Note:

- **<u>Incremental</u> occurrence recognition follows an evolving scene**
- **<u>A-posteriori</u> occurrence recognition is carried out after observing a scene (choice of order!)**
- **Partially instantiated models may be used for scene <u>prediction</u>**

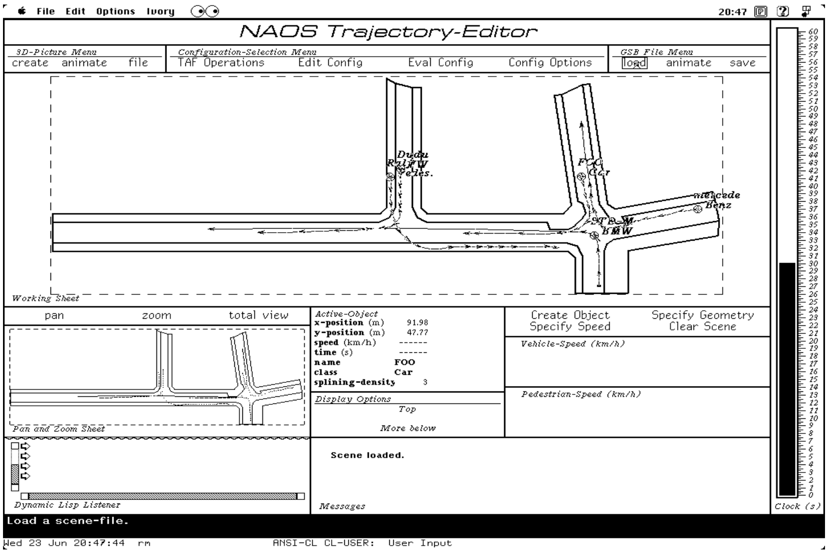
Hierachy for Object Motions in Street Traffic (NAOS)

mix of part_of and ISA hierachy



NAOS System: Editor

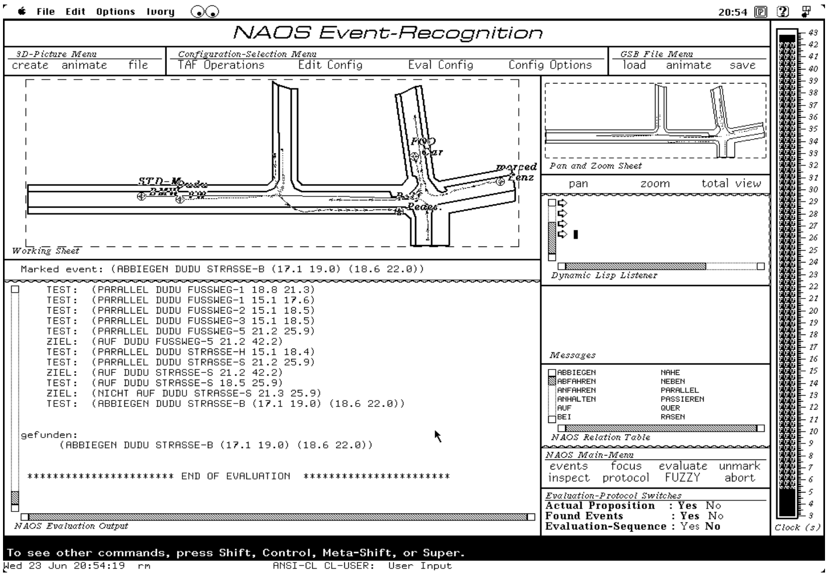
The NAOS system used artificially generated trajectory input data



Active-Object
x-position (m) 91.98
y-position (m) 47.77
speed (km/h) ------
time (s) ------
name FOO
class Car
splining-density 3

```
Scene loaded.
Load a scene-file.
Wed 23 Jun 20:47:44  rm                    ANSI-CL CL-USER:  User Input
```

NAOS System: Recognizing a Turning-off Occurrence



```
 Marked event: (ABBIEGEN DUDU STRASSE-B (17.1 19.0) (18.6 22.0))

    TEST:  (PARALLEL DUDU FUSSWEG-1 18.8 21.3)
    TEST:  (PARALLEL DUDU FUSSWEG-1 15.1 17.6)
    TEST:  (PARALLEL DUDU FUSSWEG-2 15.1 18.5)
    TEST:  (PARALLEL DUDU FUSSWEG-3 15.1 18.5)
    TEST:  (PARALLEL DUDU FUSSWEG-5 21.2 25.9)
    ZIEL:  (AUF DUDU FUSSWEG-5 21.2 42.2)
    TEST:  (PARALLEL DUDU STRASSE-H 15.1 18.4)
    TEST:  (PARALLEL DUDU STRASSE-S 21.2 25.9)
    ZIEL:  (AUF DUDU STRASSE-S 21.2 42.2)
    TEST:  (AUF DUDU STRASSE-S 18.5 25.9)
    ZIEL:  (NICHT AUF DUDU STRASSE-S 21.3 25.9)
    TEST:  (ABBIEGEN DUDU STRASSE-B (17.1 19.0) (18.6 22.0))


gefunden:
     (ABBIEGEN DUDU STRASSE-B (17.1 19.0) (18.6 22.0))


 ********************** END OF EVALUATION  **********************
```

ABBIEGEN	NAHE
ABFAHREN	NEBEN
ANFAHREN	PARALLEL
ANHALTEN	PASSIEREN
AUF	QUER
BEI	RASEN

Evaluation-Protocol Switches
Actual Proposition : [✓ Yes] No
Found Events : [✓ Yes] No
Evaluation-Sequence : Yes [✓ No]

```
To see other commands, press Shift, Control, Meta-Shift, or Super.
Wed 23 Jun 20:54:19  rm                    ANSI-CL CL-USER:  User Input
```

Generating a Natural-language Description in NAOS

Principle:

sentence
⬆
case frame
⬆
occurrence

language-oriented AI techniques

Problems:

- Which occurrences should be selected for verbalization?
- Which deep cases should be filled?
- Which addtitional time or location information is required?
- In which order should the information be presented?

Solution:

Speech planning based on hearer simulation

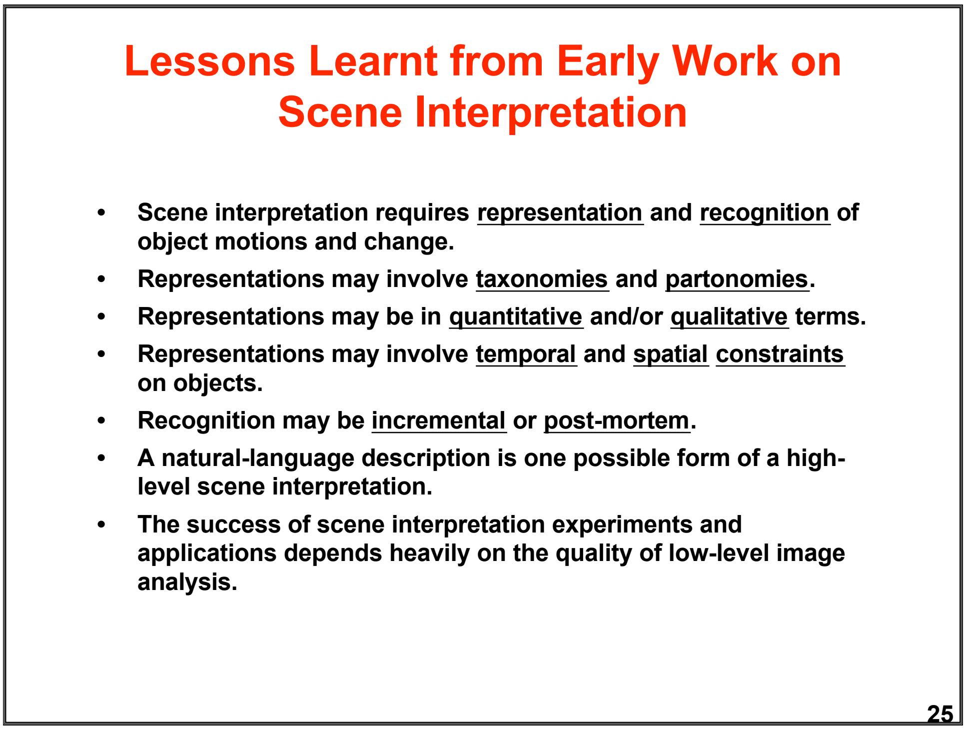
informing a hearer <=> enabling a hearer to imagine the scene

Standard Plan for Generating Natural-language Scene Descriptions in NAOS

- rules which assure that the hearer will be able to imagine the scene
- summary + descriptions of all object trajectories, each in chronological order
- no explicit hearer simulation

Description of an object trajectory

1. Each time interval is described by the most special occurrence
2. The first occurrence begins at the beginning of the scene
3. The next occurrence follows in temporal order
4. Location information is given by prepositional expressions as required
5. Temporal information is given by prepositional expressions or references to other occurrences as required



Lessons Learnt from Early Work on Scene Interpretation

- Scene interpretation requires representation and recognition of object motions and change.
- Representations may involve taxonomies and partonomies.
- Representations may be in quantitative and/or qualitative terms.
- Representations may involve temporal and spatial constraints on objects.
- Recognition may be incremental or post-mortem.
- A natural-language description is one possible form of a high-level scene interpretation.
- The success of scene interpretation experiments and applications depends heavily on the quality of low-level image analysis.