A Visual Logic for the Description of Highway Traffic Scenarios

Verkehr
Transportation

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1 Motivation

- Logic developed in context of advanced driver assistance system (ADAS) development
- Specify driving manoeuvres as (sequences of) traffic situations on the highway
  $\Rightarrow$ Relations and interactions between vehicles/vehicle components
- Interface between developers and scientists
  - Simple and intuitive, easy to learn and use
  - Formal foundation and semantics for further analysis

  $\Rightarrow$ Bridge terminology gap between different domain experts

2 The Visual Logic (VL)

Atoms

- Basic building blocks of the VL
- Single atom: traffic “snapshot”
- Sequence of atoms: traffic scenario (with evolution)
- Two parts
  - Traffic View: spatial relations of vehicles
  - Communication Description: communications/synchronisations during situation sketched in Traffic View
- Compositionality of Atoms: if both Traffic View and Communication Description are composable (later)

3 The Visual Logic (VL)

Traffic View: Basics

- Describe spatial relations of vehicles
- Set of lane separators spans “canvas”
- Traffic flow from left to right, orientational notions accordingly
- Position defined via vehicle sides
- Separate position relations for two dimensions

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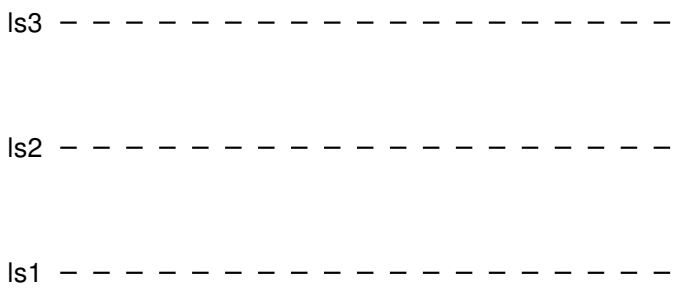

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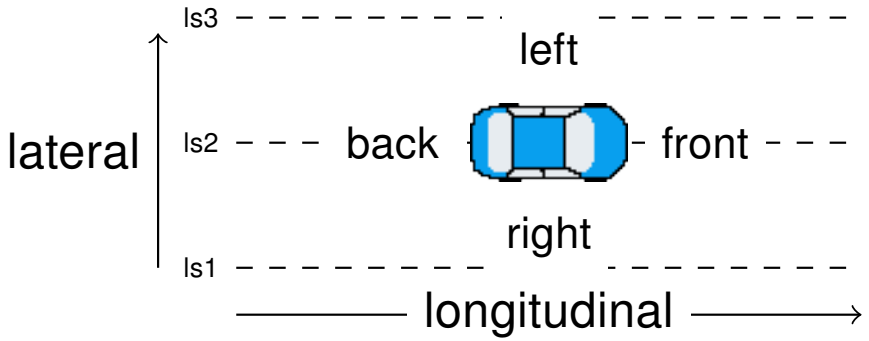

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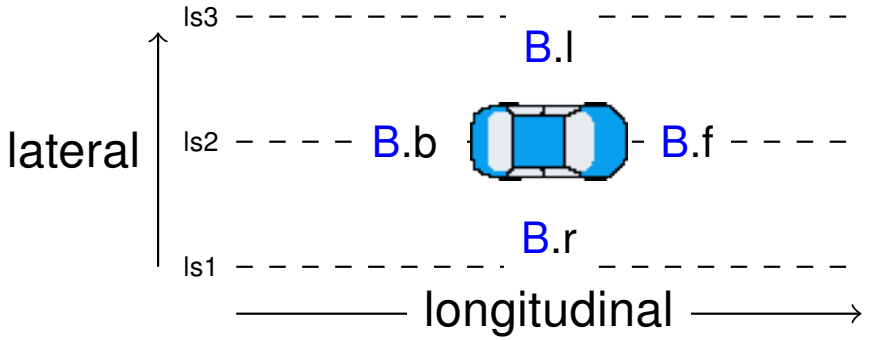
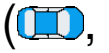
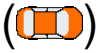
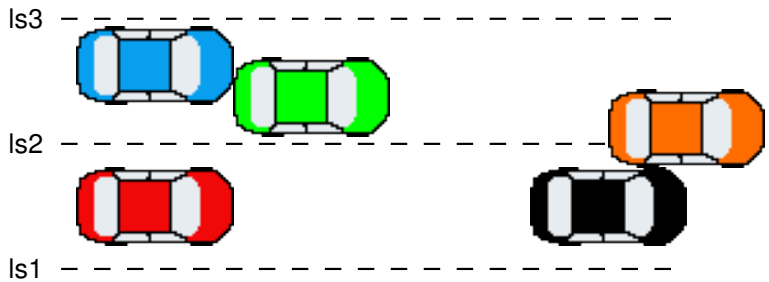


4 The Visual Logic (VL)

Traffic View: Relations

- Longitudinal relations (binary): *before* (e.g.  , ), *meets* ( , ), *overlaps* ( , ) (or respective inverse) or *equals* ( , ) for each pair of vehicles
  $\Rightarrow$ induces total order on front/back vehicle sides
- Lateral relations: binary as before, plus unary (high-level) *on_lane* (e.g. ) or *between_lanes* () for each vehicle
  $\Rightarrow$ induces total order on left/right vehicle sides and lane separators
- Distance arrows to further restrict relative positions (default: arrow with label $[0, \infty[$ to next element—not shown in pictures)



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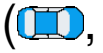
- Longitudinal relations (binary): *before* (e.g.  , ), *meets* ( , ), *overlaps* ( , ) (or respective inverse) or *equals* ( , ) for each pair of vehicles
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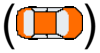
- Lateral relations: binary as before, plus unary (high-level) *on_lane* (e.g. ) or *between_lanes* () for each vehicle
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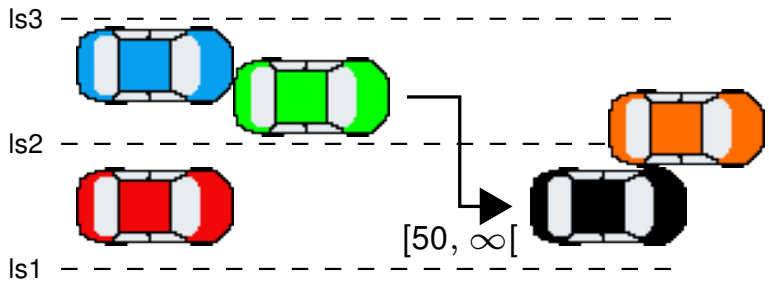
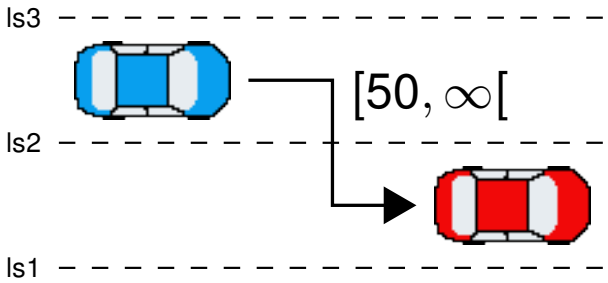


5 The Visual Logic (VL)

Traffic View: Constraints

- Each Traffic View translated into *spatial constraint*



sc1: $(ls3 > B.l) \wedge (B.r > ls2) \wedge (ls2 > R.l) \wedge (R.r > ls1) \wedge (R.b - B.f > 50)$

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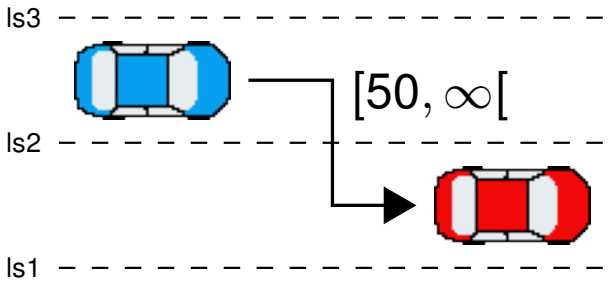

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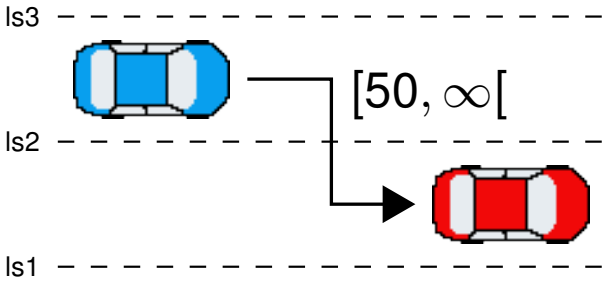
- Implicit assumptions
  - $(B.l > B.r) \wedge (B.f > B.b) \wedge (R.l > R.r) \wedge ...$
  - No other vehicles/lanes apart from those depicted
- Compositionality of Traffic Views: if position changes (spatial constraints) adhere to “physically reasonable” behaviour (details in paper)

6 The Visual Logic (VL)

Traffic View: Composition (Lane Change Example)



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6 The Visual Logic (VL)

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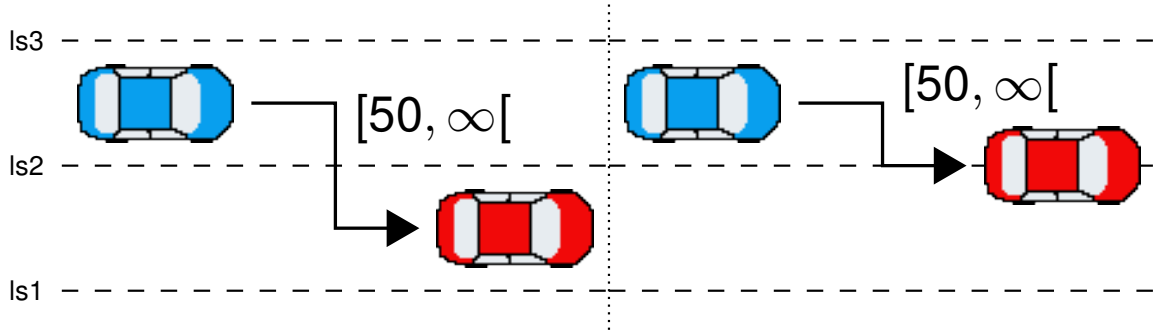

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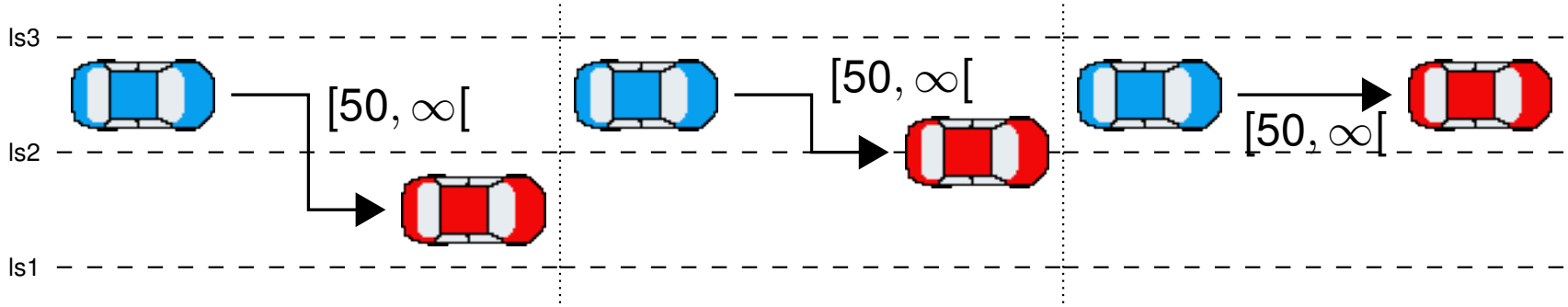

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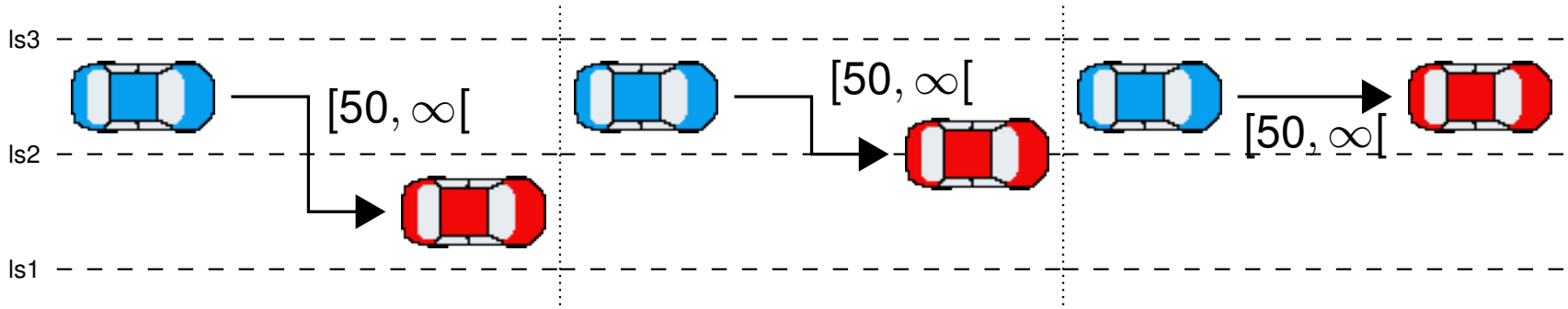

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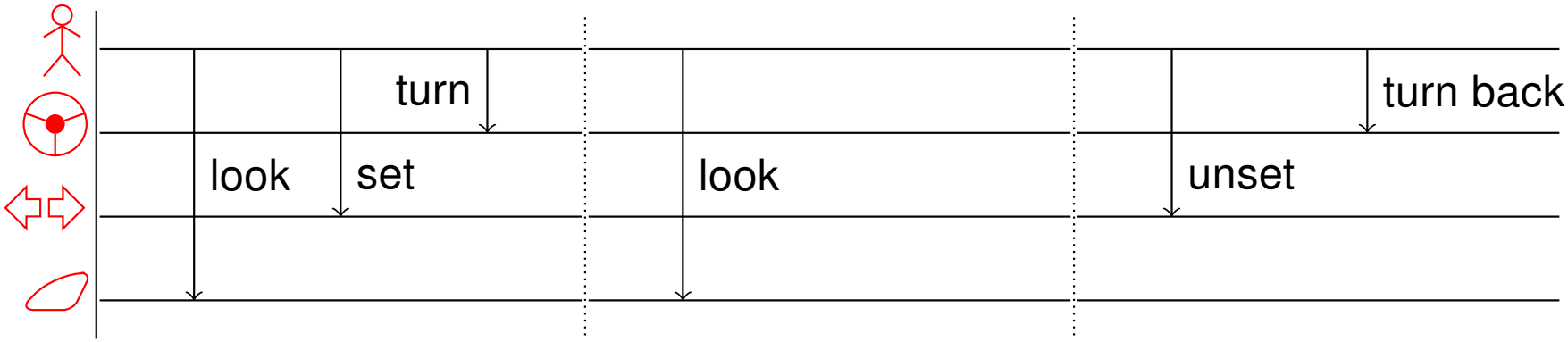
- Spatial constraints must be disjoint to find “transition point”

7 The Visual Logic (VL)

Communication Description

- Specify communications/synchronisations during situation sketched in Traffic View
- Feature subset of Live Sequence Charts (extension of Message Sequence Charts) $\Rightarrow$ translation into automaton representation
- Communicating instances: communicating parts of vehicles in Traffic View

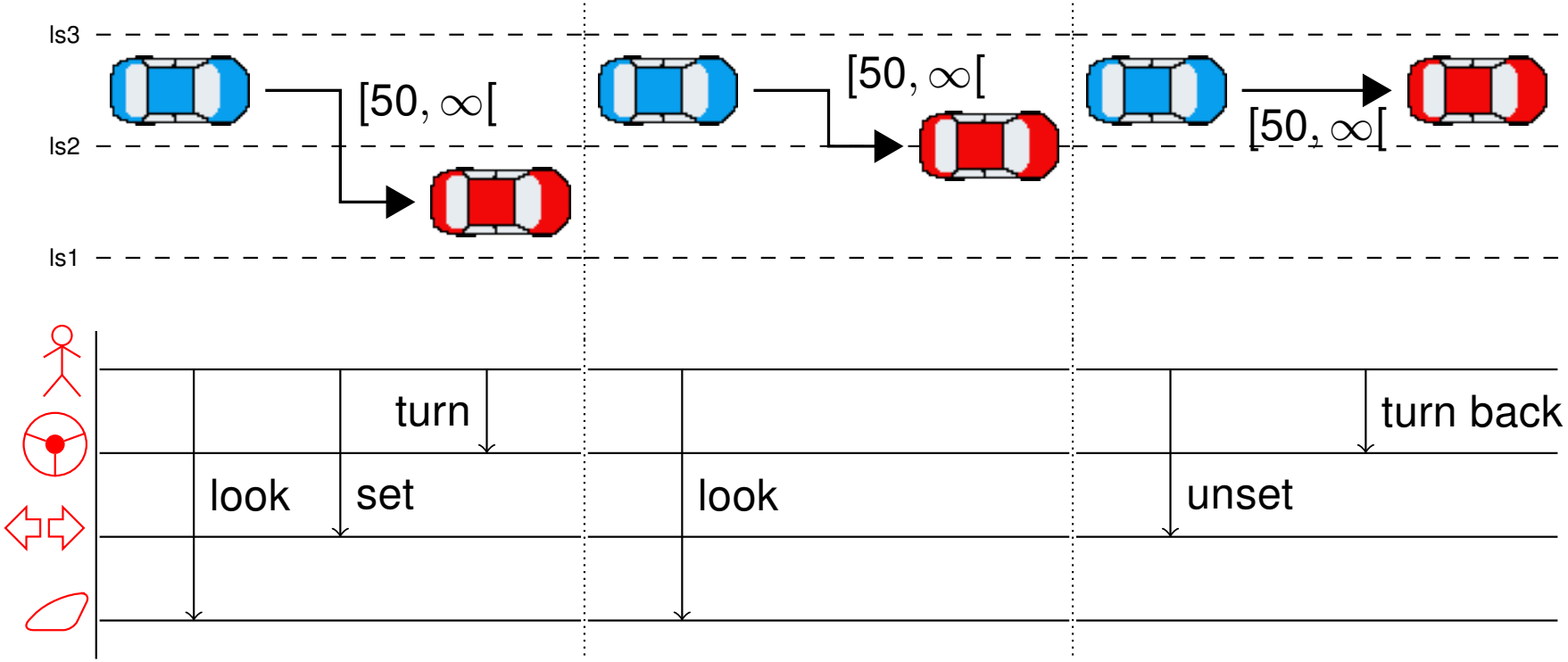


- Compositionality of Communication Descriptions: if set of communicating instances is identical

8 The Visual Logic (VL)

Semantics

- For each Atom: annotate Communication Description with spatial constraint



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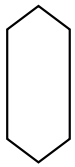
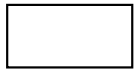
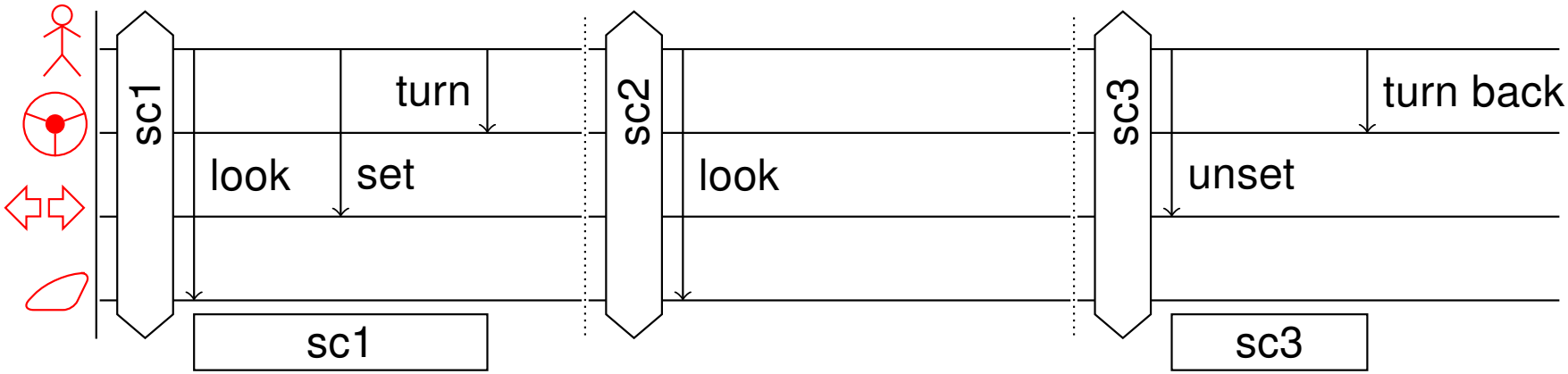

Condition (“barrier synchronisation”)


Invariant



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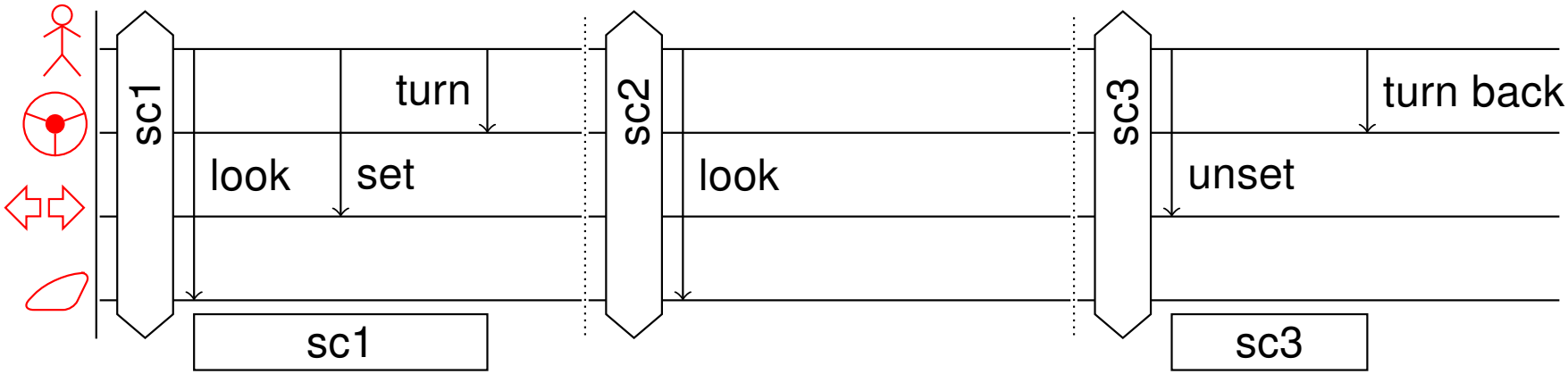
- Translate “single” Communication Description into automaton representation



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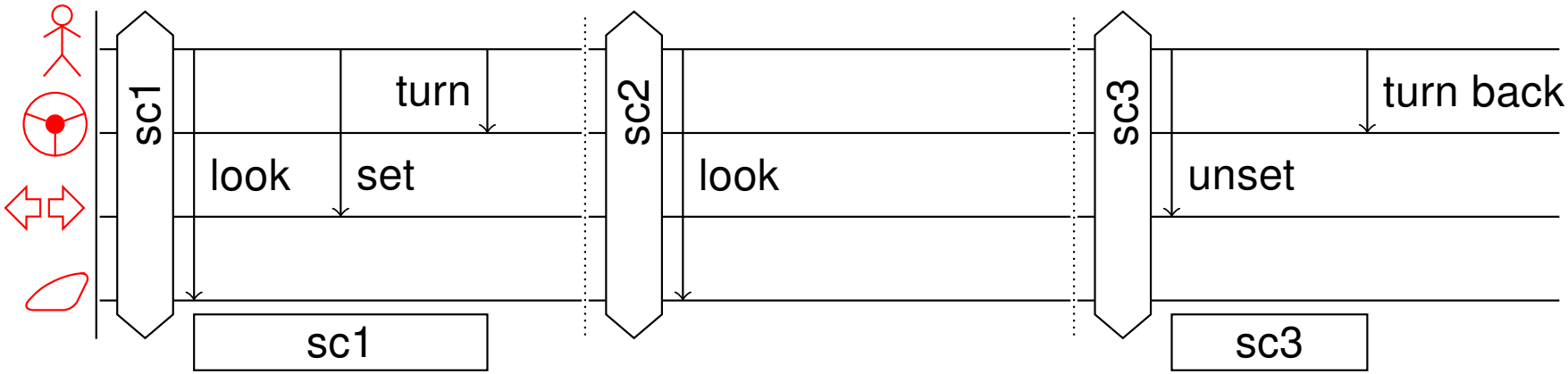

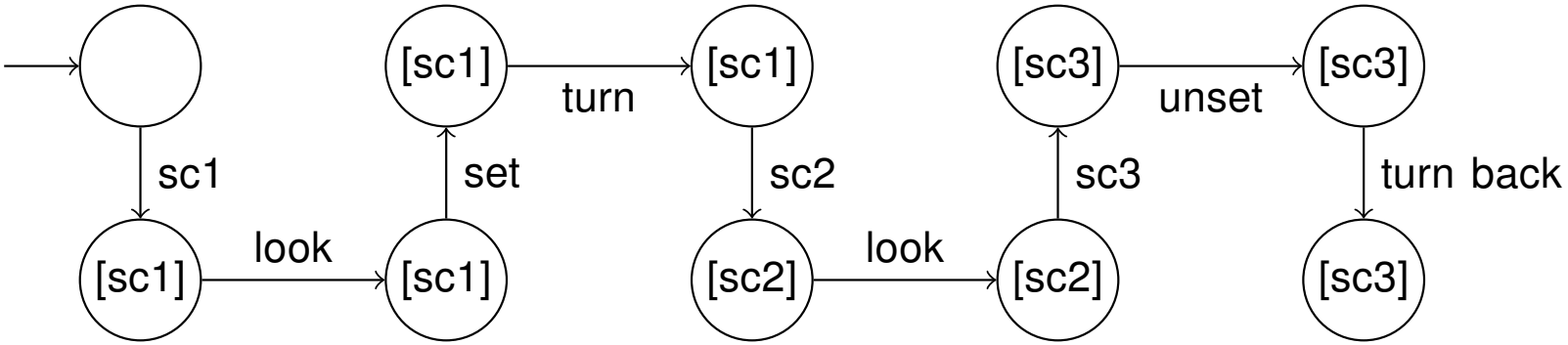

9 Application

Observer-based Verification

- Use automaton as observer to observe occurence of specified behaviour during nomal system behaviour
- Example
  - Goal: Check usability of ADAS interface
  - VL specification to describe driver-ADAS interaction during driving manoeuvres
  - System behaviour given as set of sample trajectories (driving simulator, human test driver with prototypical implementation of ADAS)
  - Test driver behaviour compliant with VL specification?
    - Yes: Final implementation of prototype
    - No: Find out why not (non-straightforward!), adapt either VL specification or prototype, check again

10 Conclusion

- VL to describe highway traffic scenarios with communications
- Purely graphical specification of scenarios and manoeuvres
  - Intuitive and easy to understand
  - Yet with formal semantics
- VL as interface between different domain experts
  - System engineers and traffic psychologists developing ADASs
  - Scientists modelling, analysing and verifying behaviour of ADASs

11 Future Work

- Extend VL with
  - Full set of LSC features (for Communication Descriptions), e.g.
    - Desired or forbidden behaviour?
    - Behaviour to be observed once or repeatedly?
    - Partial observation: non-occurence or major system failure?
  - Vehicle-specific properties like speed or acceleration
  - Appearance and disappearance of lanes
- Parallel work on generalisation of VL
  - General 2D plane,
  - User-defined (spatial) relations,
  - Straight or arched trajectories, ...

Thank You!