The Horse Raced Past: Gardenpath Processing in Dynamical Systems

28.09.2011

Ninth International Tbilisi Symposium on Language, Logic and Computation
Kutaisi, Georgia

Peter beim Graben
Dept. of German Language and Linguistics
Humboldt-Universität zu Berlin
peter.beim.graben@hu-berlin.de

the

horse

raced

past

the

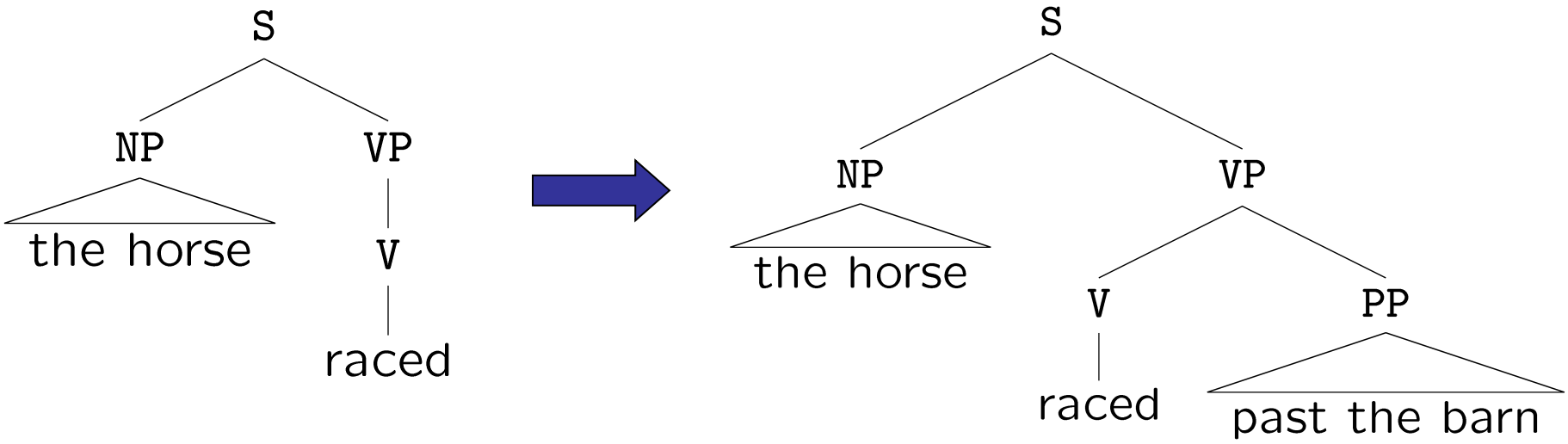
barn

fell.

Gardenpath Sentences

Bever (1970)

Gardenpath Theory

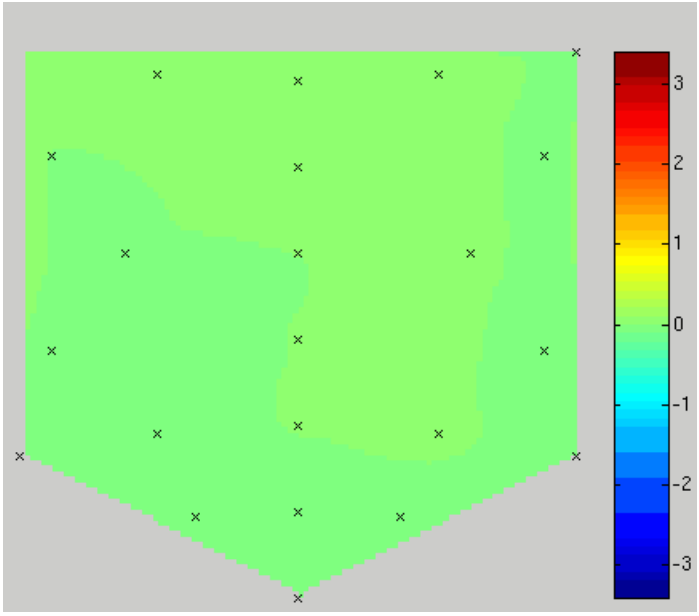


late closure

Frazier (1987)

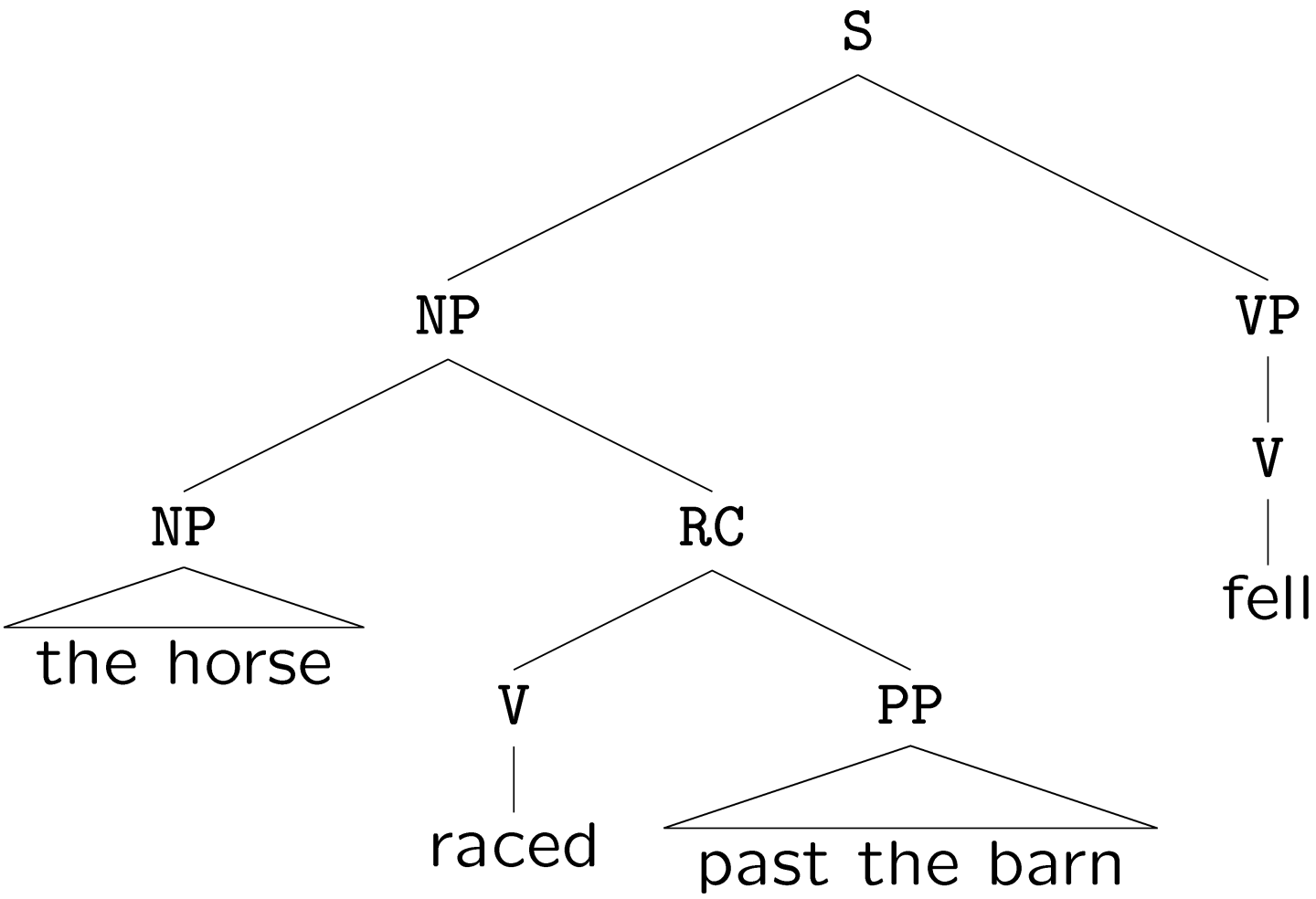
Experimental Findings

- Self-paced reading: slowing down
- Eye-tracking: regressions, longer fixations
- Event-related brain potentials: P600



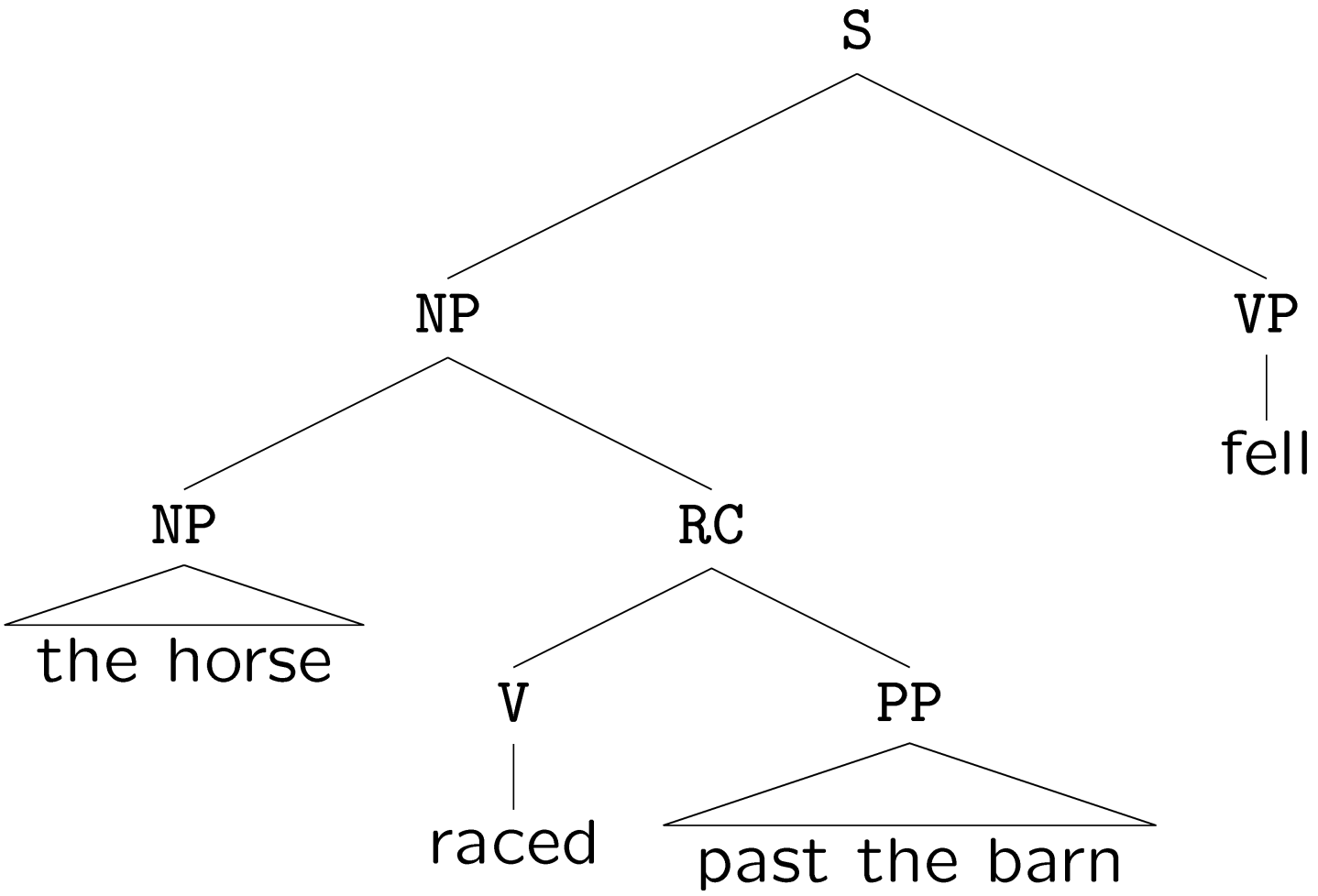
beim Graben et al. (2008)

Reduced Relative

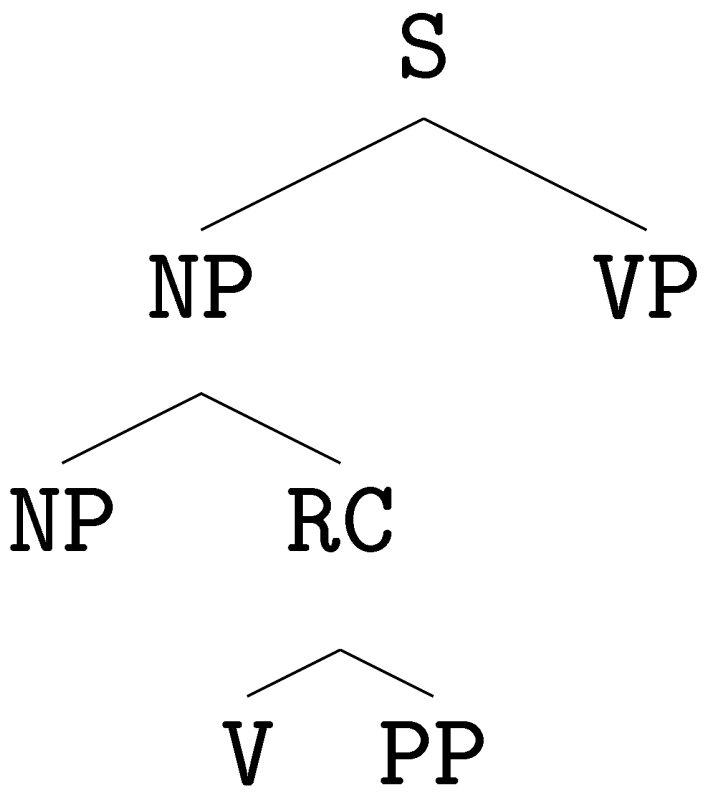


Hale (2003)

Simplified



Context-Free Grammars



$$S \rightarrow NP\ VP.$$

$$NP \rightarrow NP\ RC.$$

$$RC \rightarrow V\ .\ PP$$

$$S \rightarrow NP\ .\ VP$$

$$VP \rightarrow V\ .\ PP$$

Generalized Left-Corner Parser

The horse raced past the barn fell.

1

stack				
input	the horse	raced	past the barn	fell

Generalized Left-Corner Parser

The horse raced past the barn fell.

1

stack				
input	the horse	raced	past the barn	fell

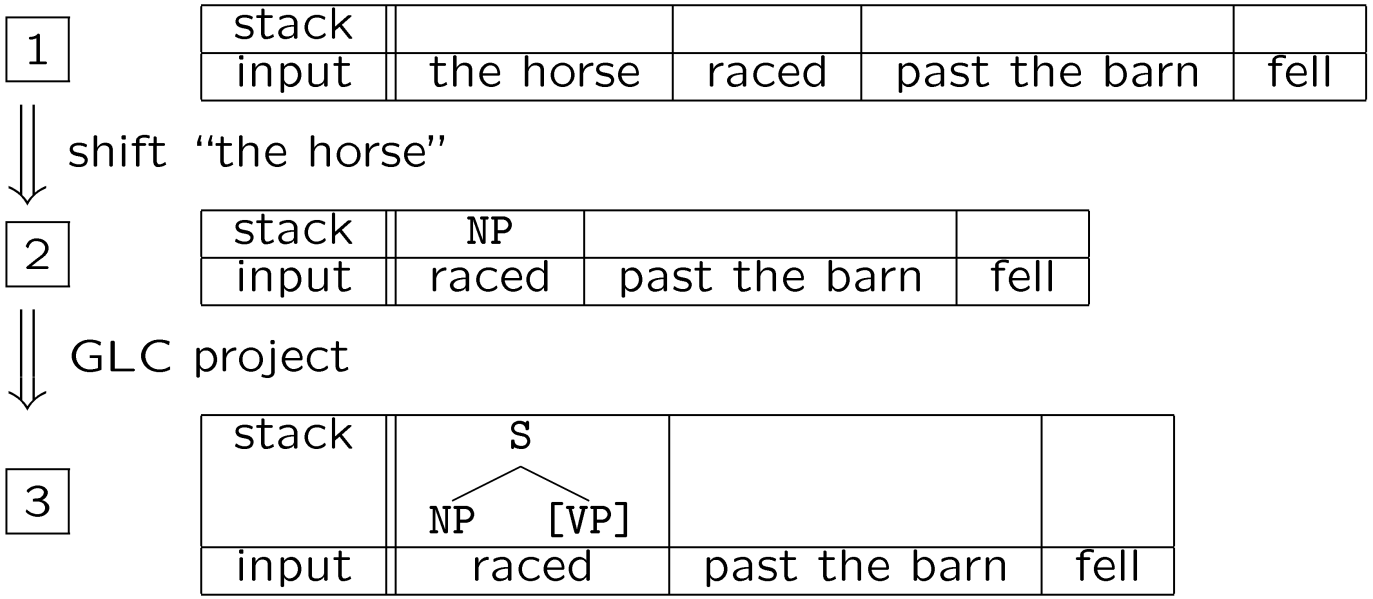
⇓ shift "the horse"

2

stack	NP		
input	raced	past the barn	fell

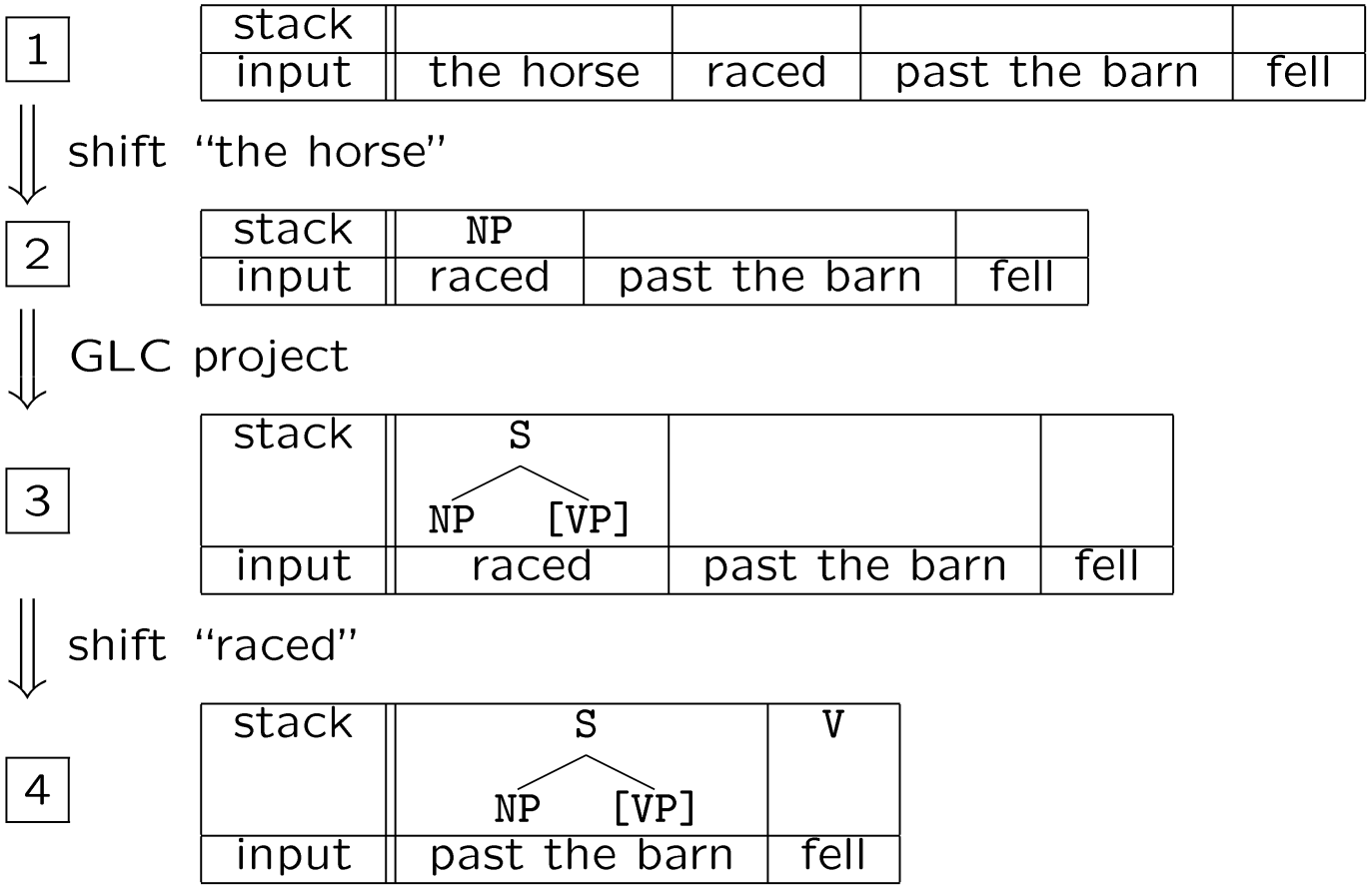
Generalized Left-Corner Parser

The horse raced past the barn fell.



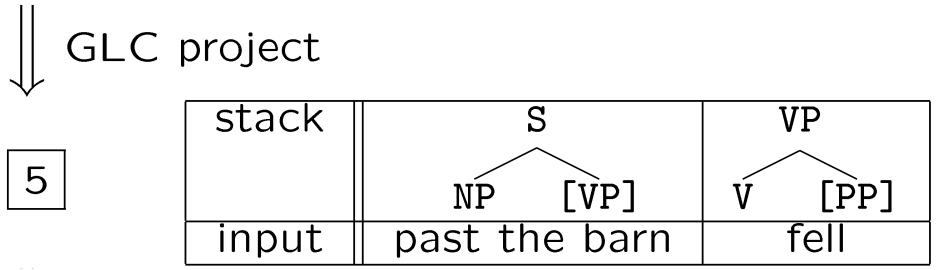
Generalized Left-Corner Parser

The horse raced past the barn fell.



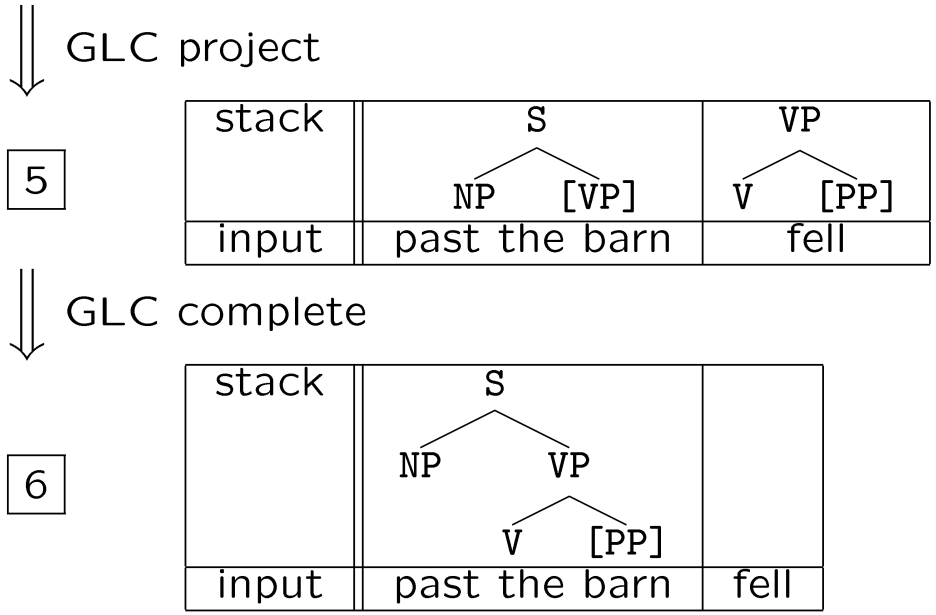
Generalized Left-Corner Parser

The horse raced past the barn fell.



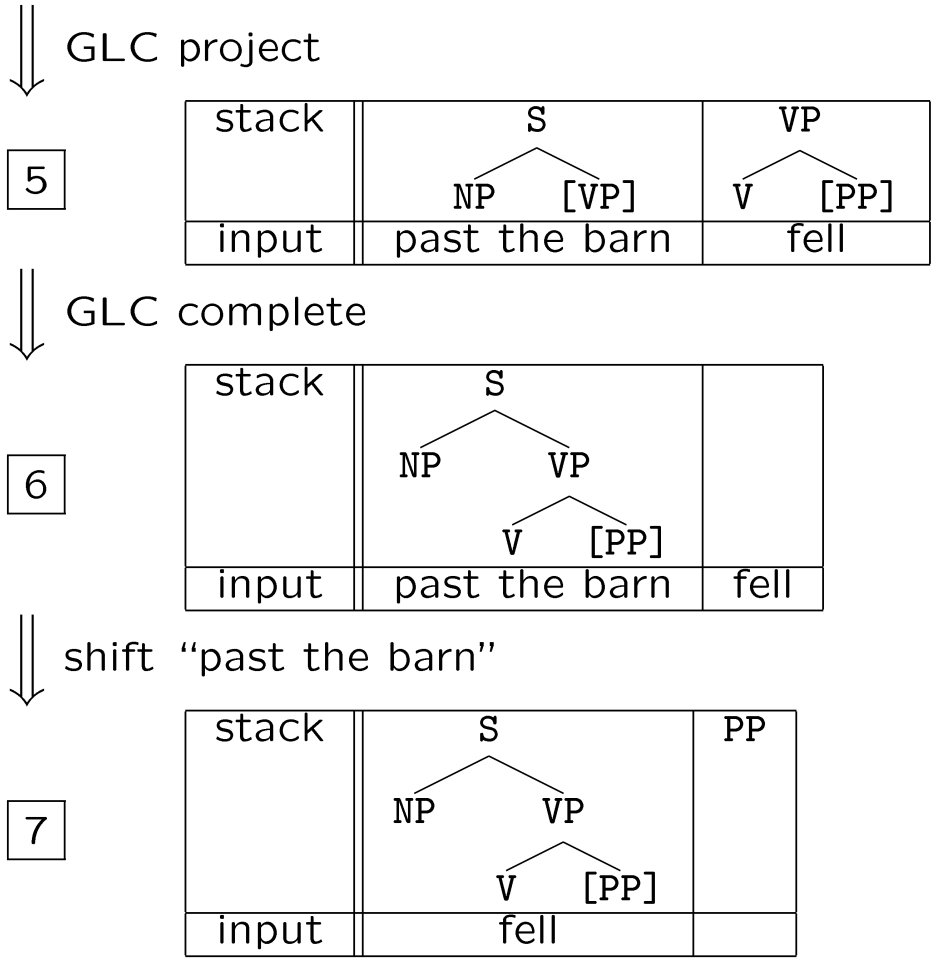
Generalized Left-Corner Parser

The horse raced past the barn fell.



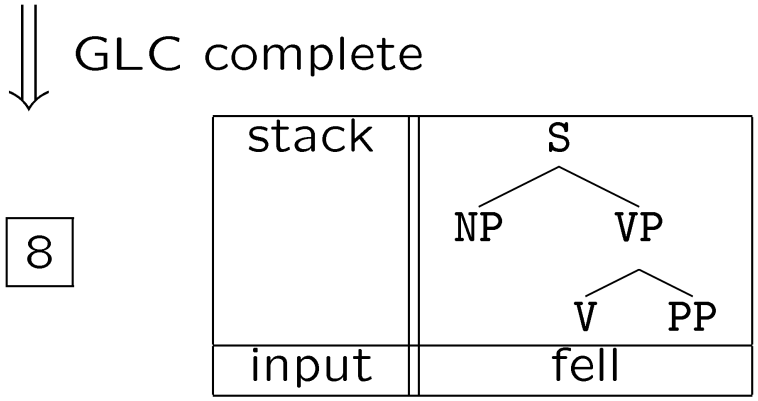
Generalized Left-Corner Parser

The horse raced past the barn fell.



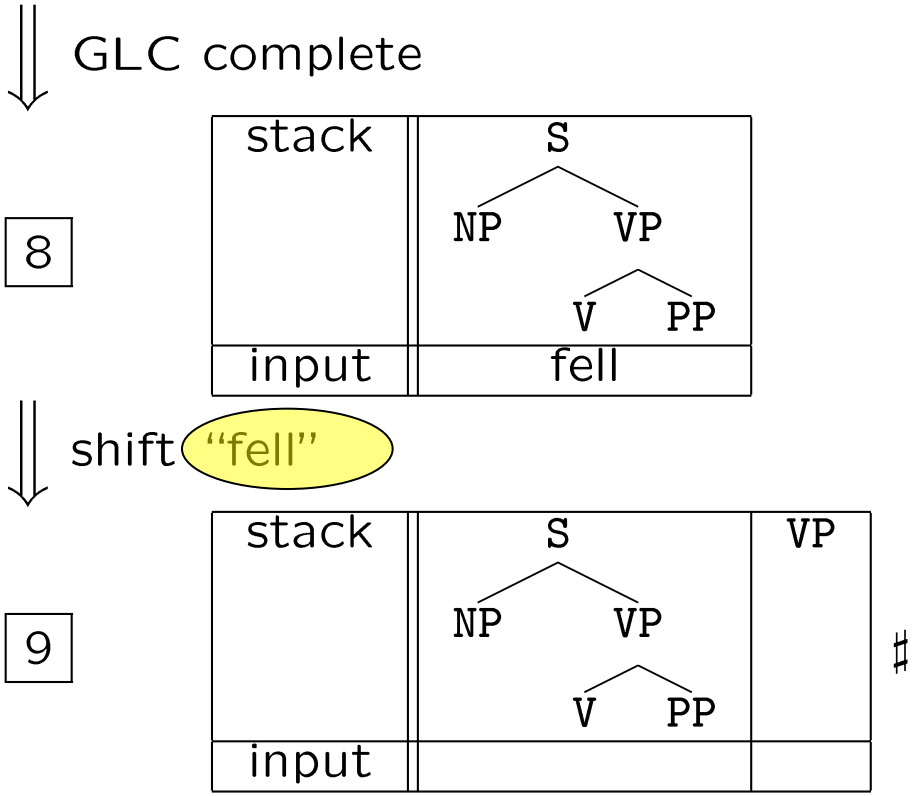
Generalized Left-Corner Parser

The horse raced past the barn fell.



Generalized Left-Corner Parser

The horse raced past the barn fell.



symptom

Fodor & Inoue (1994)

Diagnosis

The horse raced past the barn fell.

The horse raced past. The barn fell. ?

Lexicon:

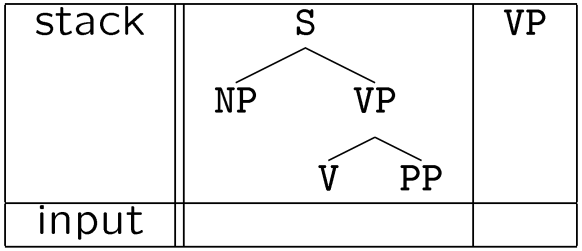
raced = (1) finite verb, past tense
raced = (2) non-finite verb, participle past perfect

Fodor & Inoue (1994)

Repair

The horse raced past the barn fell.

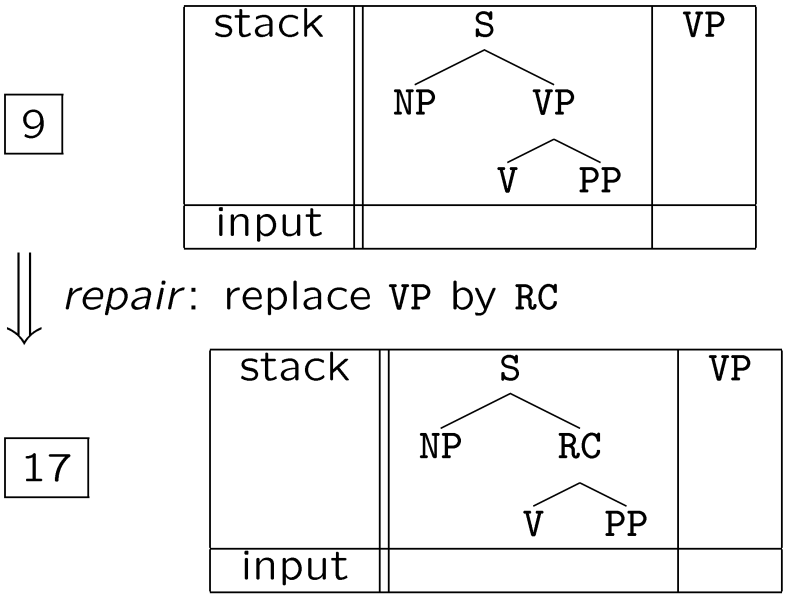
9



Fodor & Inoue (1994)
Lewis (1998)

Repair

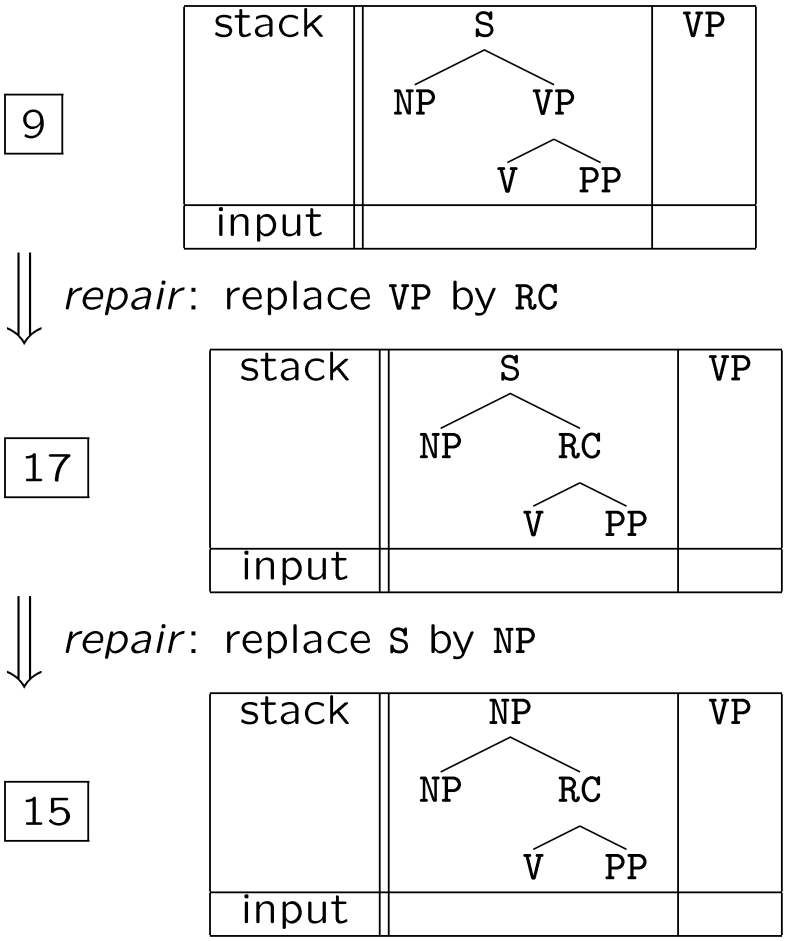
The horse raced past the barn fell.



Fodor & Inoue (1994)
Lewis (1998)

Repair

The horse raced past the barn fell.

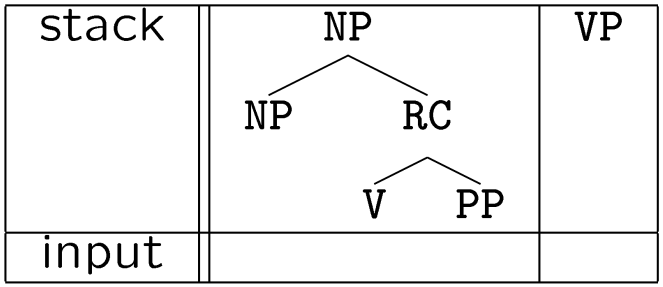


Fodor & Inoue (1994)
Lewis (1998)

Reanalysis

The horse raced past the barn fell.

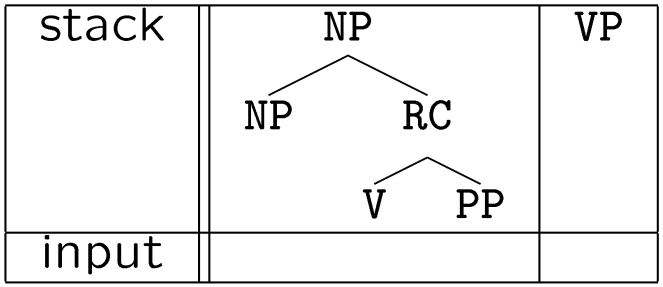
15



Reanalysis

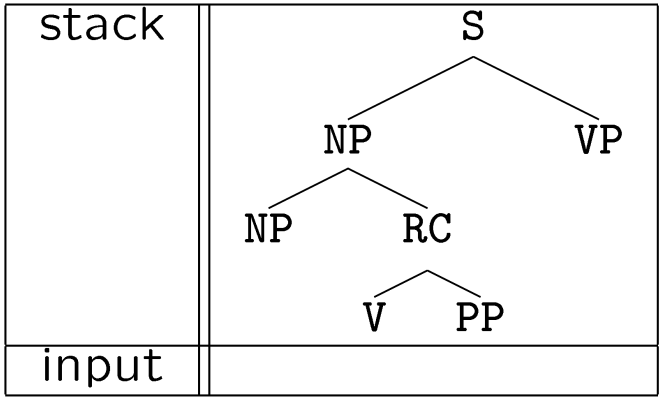
The horse raced past the barn fell.

15



GLC project

16

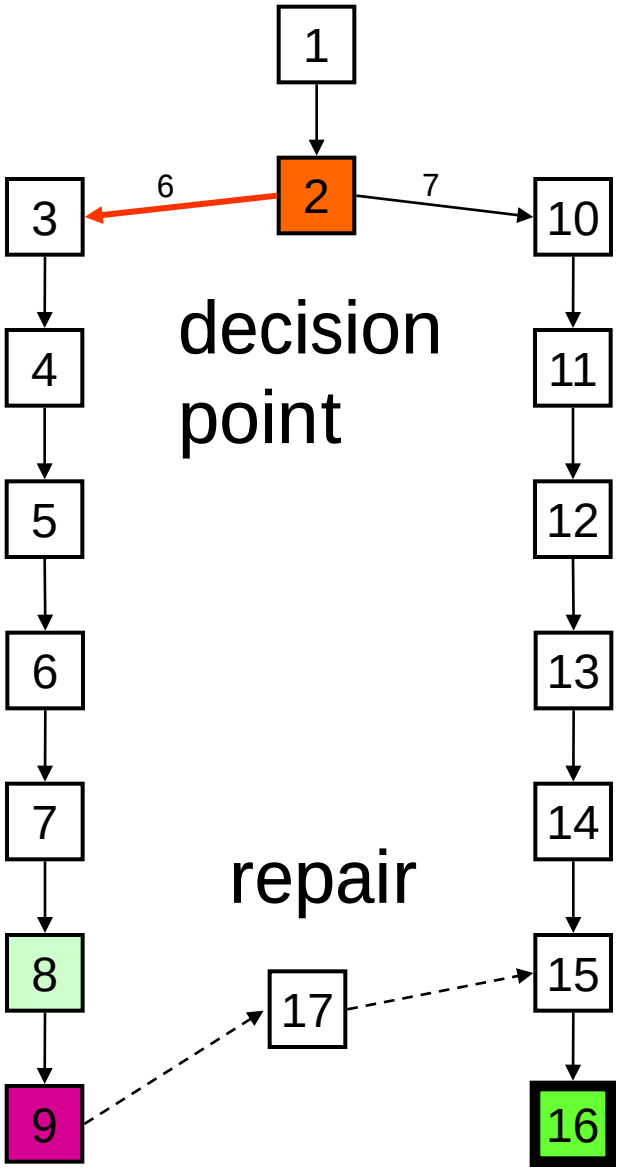


✓

Search Space

weighted directed graph

default path



A* search:
arrive rapidly!

Hale (2011)

Geometric Representation

embedding into Euclidian space

Weights

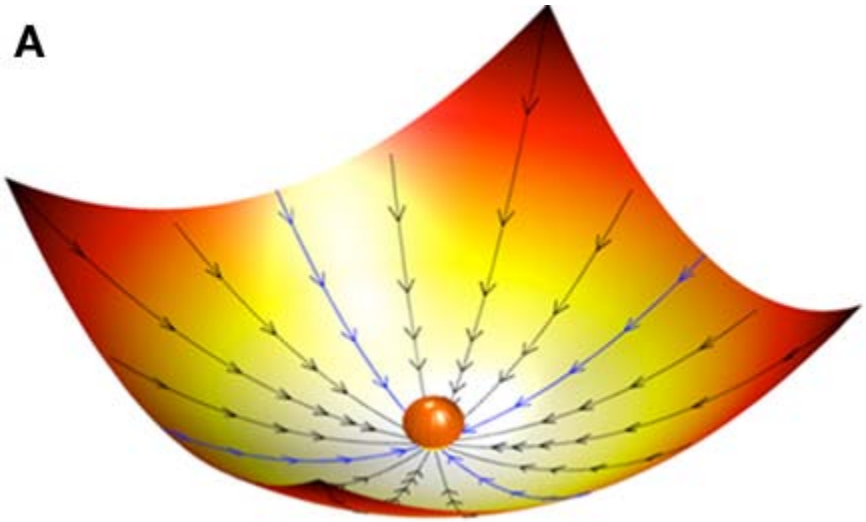
in Euclidian geometry, arc weights could become

1. distances
2. transition times

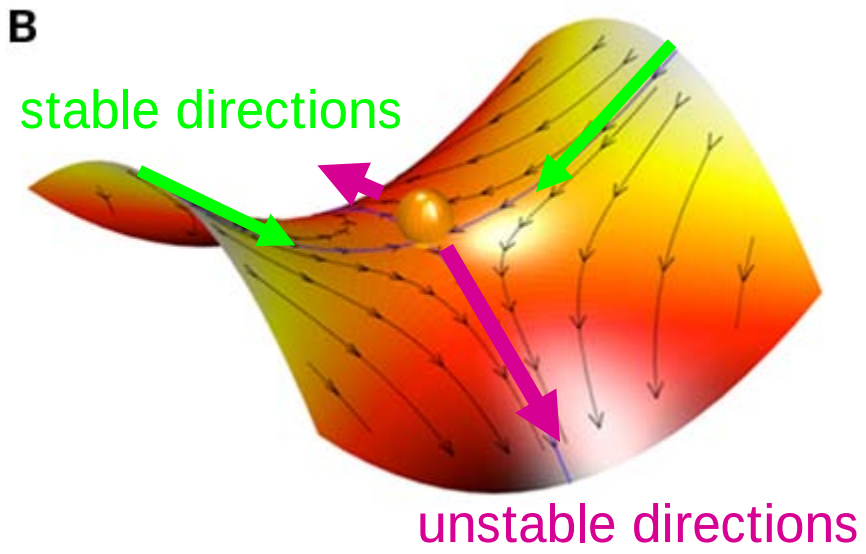
only for constant velocity, 1. and 2. are equivalent

Dynamics

identify parser states with equilibrium points in geometric space



fixed point attractor

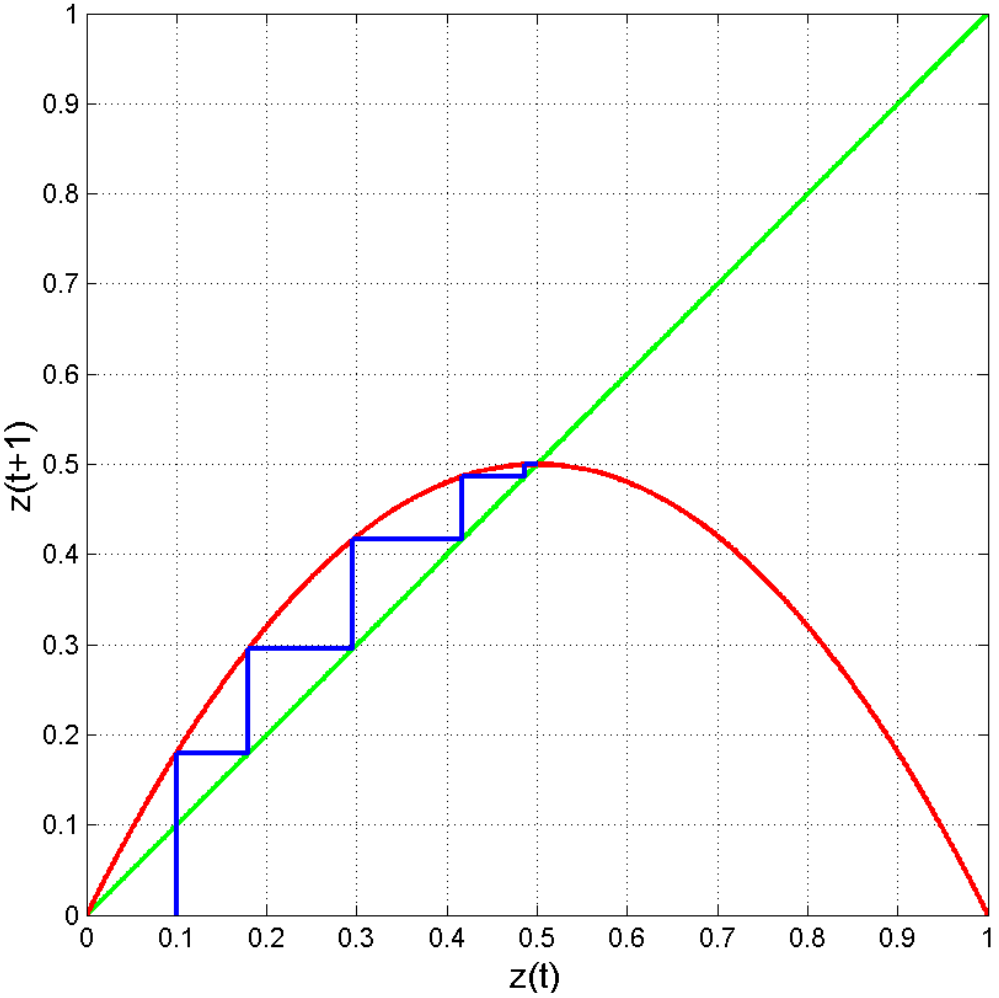


saddle node

Example

logistic map

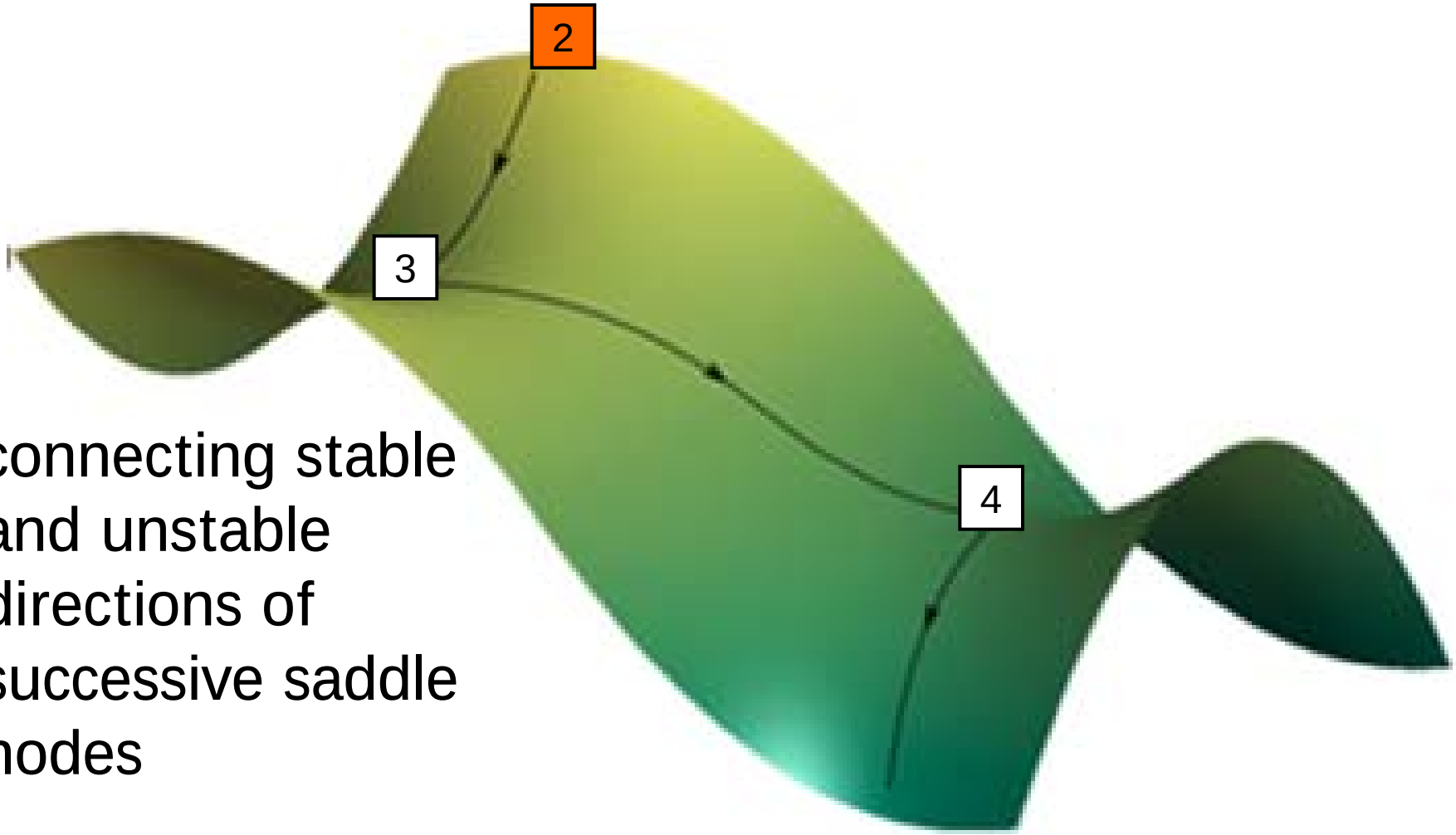
fixed point attractor



control parameter r

$$z(t+1) = rz(t)(1 - z(t))$$

Sequential Dynamics

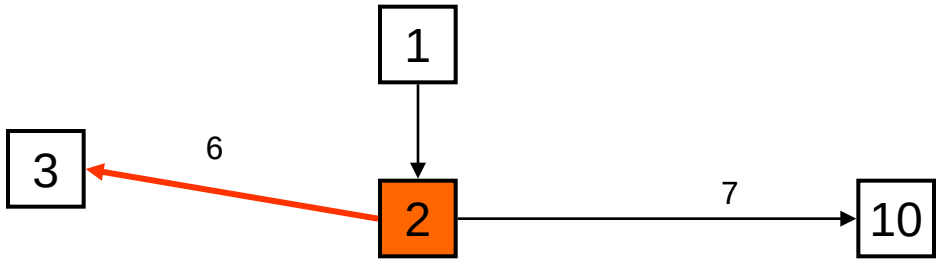


connecting stable and unstable directions of successive saddle nodes

stable heteroclinic sequence (SHS)

Afraimovich et al. (2004)
Rabinovich et al. (2008)

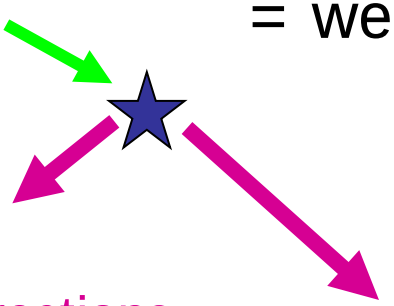
Sequential Decision Problems



stable direction

arrow lengths = escape velocities = weights

saddle node with more than one unstable direction ($d > 2$)

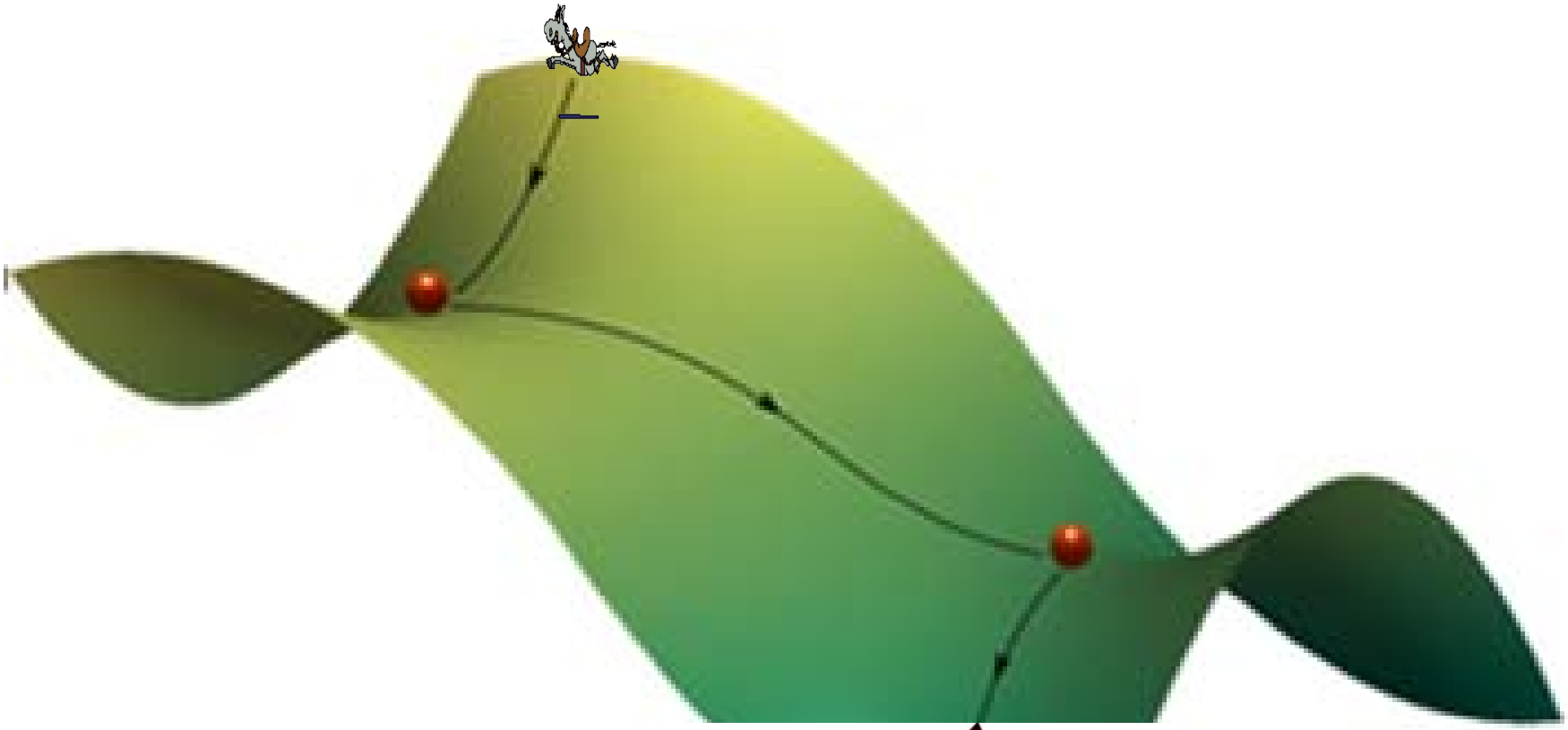


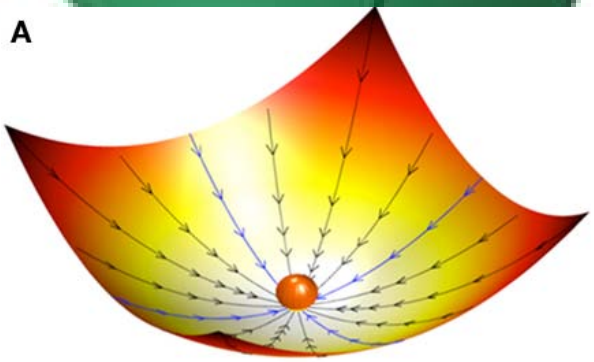
unstable directions

A* search = high risk decision for large velocities

Rabinovich et al. (2006)

Gardenpath States



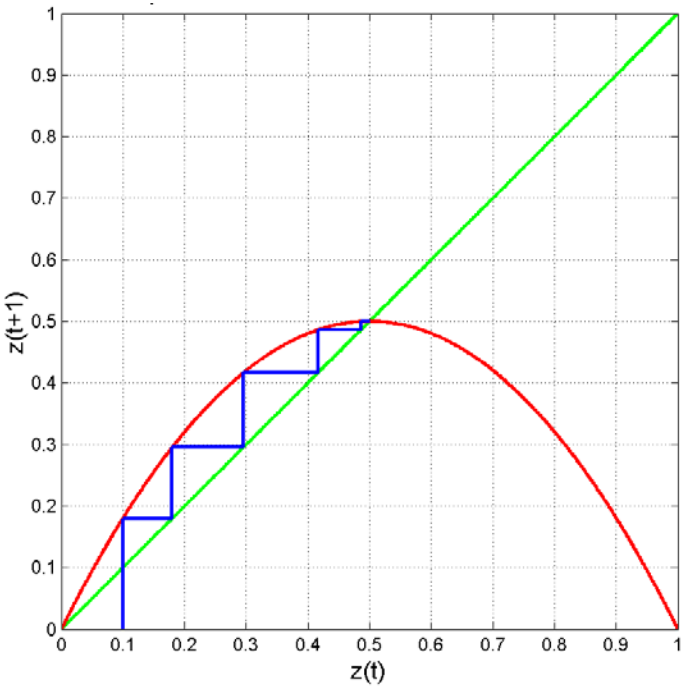


unwanted attractor

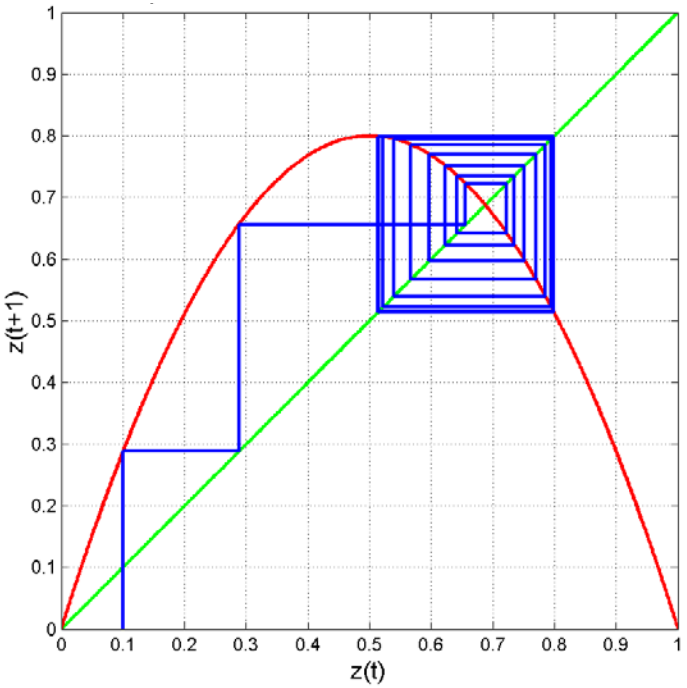
Bifurcations

fixed point attractor

unstable fixed point



increasing r

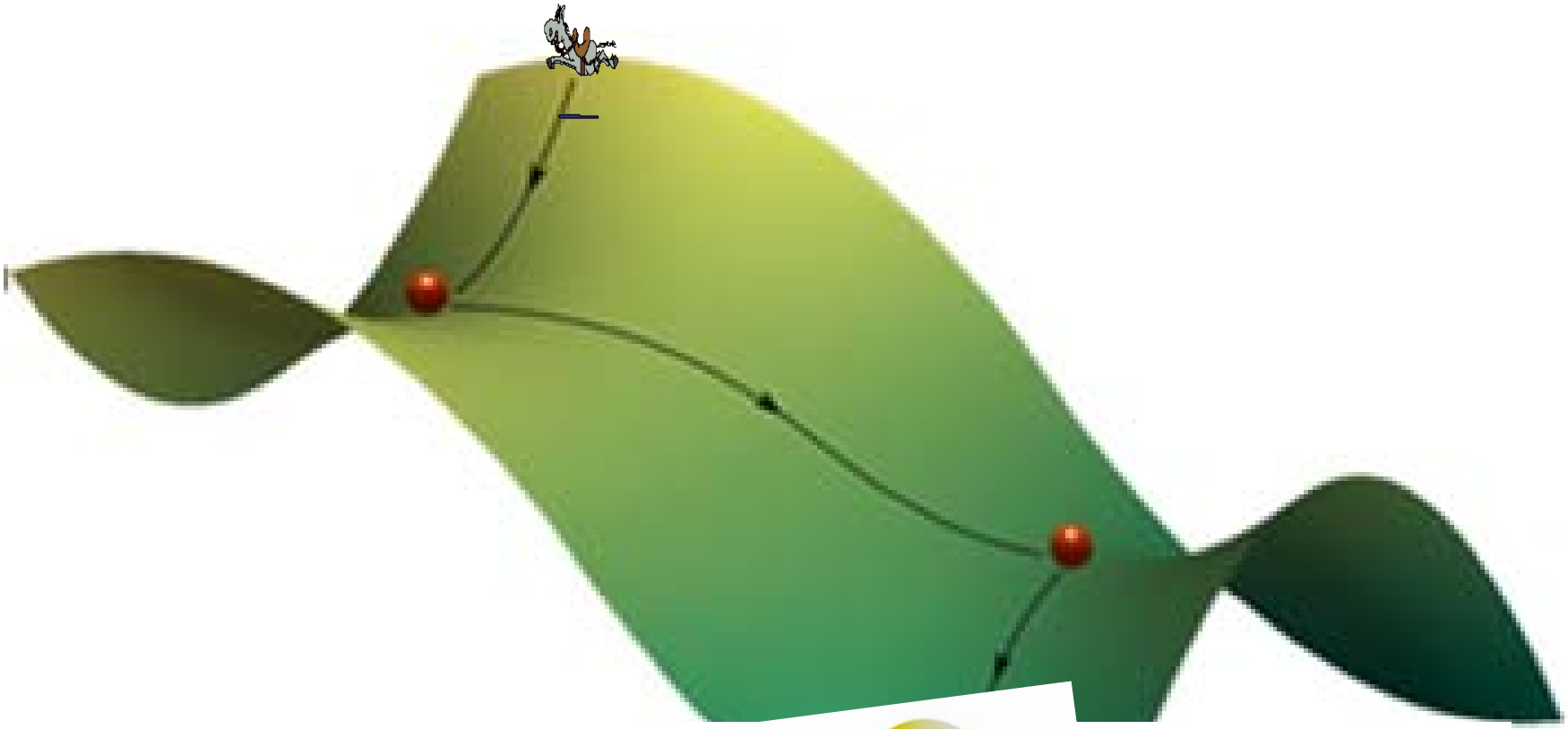


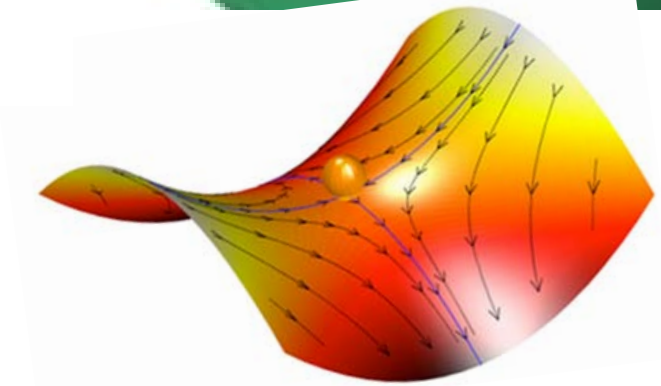
$|F'(z^*)| < 1$

$|F'(z^*)| > 1$

$$z(t+1) = rz(t)(1 - z(t))$$

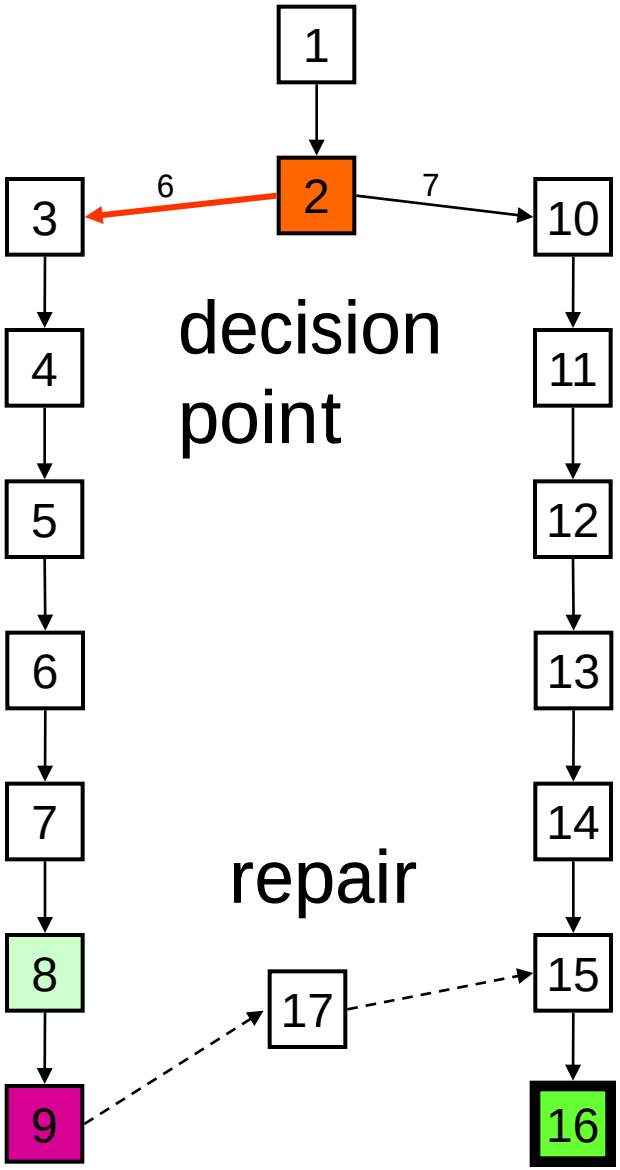
Repair by Bifurcation





beim Graben et al. (2004)

Search Space

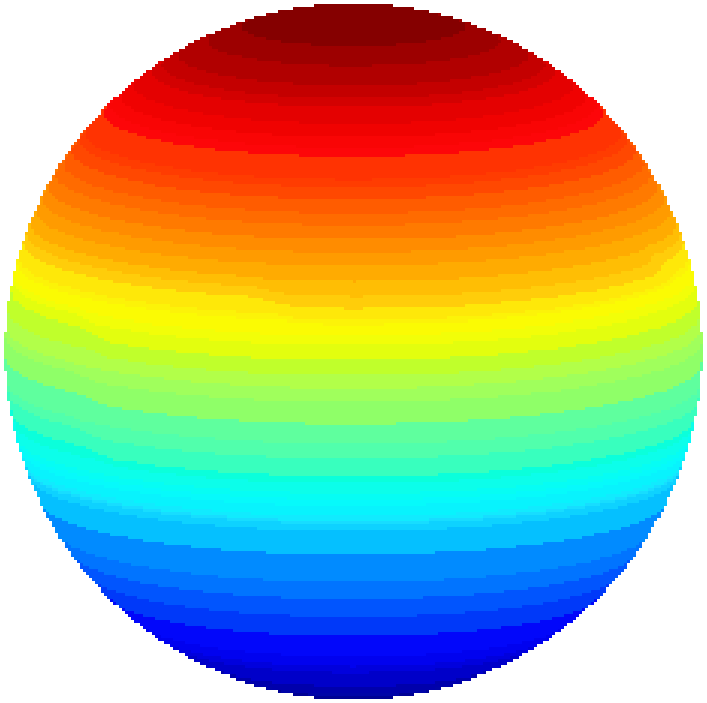


default path

Hale (2011)

Dynamic Field Parser

The horse raced past the barn fell.



'the horse'

Conclusion

- Syntactic parsing represented by sequential dynamics in geometric space
- Intermediate representational states as saddle nodes connected through stable heteroclinic sequences
- Gardenpath states as unwanted attractors
- A* search as high risk sequential decision strategy
- Syntactic repair as bifurcation of SHS

Acknowledgements

Thank you for your attention!

Funding: DFG Heisenberg-Stipendium GR 3711/1-1