Grammar in a Landscape of Affordances

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Outline

what is the nature of grammar: the view from DS-TTR

- **DS-TTR**: blend of DS and TTR [Purver et al. (2010); Eshghi et al. (2013); Hough (2015); Purver et al. (2011); Gregoromichelaki (2018); Gregoromichelaki et al. (2019b)]

- grammatical/metaphysical ontology of **processes**
  - rather than *representations*

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- grammatical/metaphysical ontology of **processes**
  - rather than *representations*
- **incrementality**, **underspecification**, and **predictivity** as properties of the grammar
- domain-general processes for **multimodal interaction** [e.g.,Yu et al. (2015, 2017); Yu et al., 2016)]
- learnable from minimal data via Reinforcement Learning [e.g.,Kalatzis et al. (2016); Eshghi et al. (2017b)]

DS-TTR: syntactic mechanisms

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  - no phrase-structure rules;
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- **grammatical affordances** are dynamic regularities extending over multiple time-steps

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- types induce **predictions** for
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- at each time-step, affordances need to be **selected** from a landscape of possible affordances

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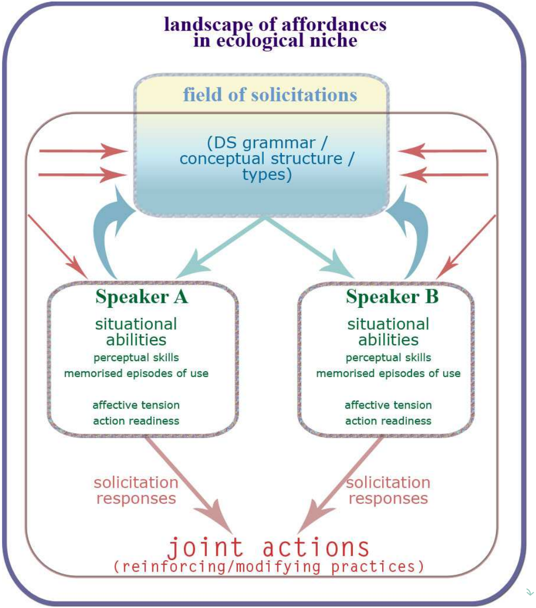
- incrementality and temporality means that such fields are **redefined** and **transformed** with each utterance (verbal or otherwise)



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- **interactions**: both comprehension and production modelled together in the same space
- syntactic or meaning procedures formulated as (probabilistic) **transitions** from states to states

- a specialised **Propositional Dynamic Logic** (**PDL**) with states as ⟨NL string, context⟩ and transition operators modelling basic actions and macros (packages) of such actions

  [Kempson et al. (2001)]

the dynamics of interaction

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  [Kempson et al. (2001)]
- Dynamic Logics
  - have the means to model any type of action and event (physical, instrumental, epistemic, etc.) [e.g. Segerberg (1992)]: hence multimodal grammar definitions are seamless
  - model an internal perspective in a computation, an observer's view located at a state (node) considering the possibilities
  - potential to bring Dynamic Quantum Logic [Baltag and Smets (2012)] to interface with DS Vector Space Semantics
    [Purver et al. (forthcoming); Sadrzadeh et al. (2018); Gregoromichelaki et al. (2019a)]
- however, ideally, the π-calculus might be more suitable

fractal structure of state transition system

(red path indicates the selected course of action)

?$\texttt{make}_{A,B}$(TTR-type)

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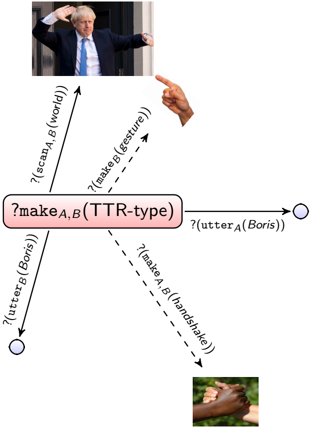

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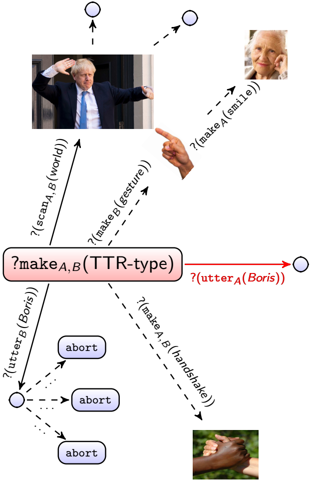

Alice to Bob: "Boris!"

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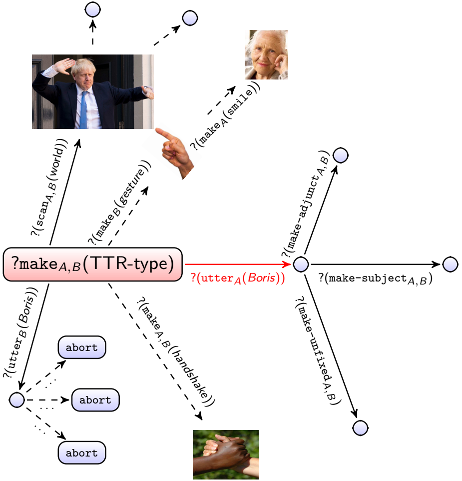

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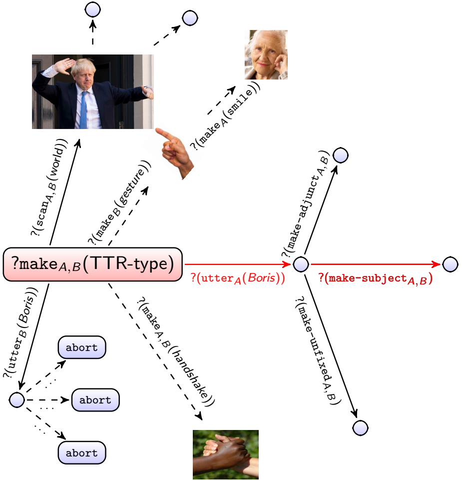

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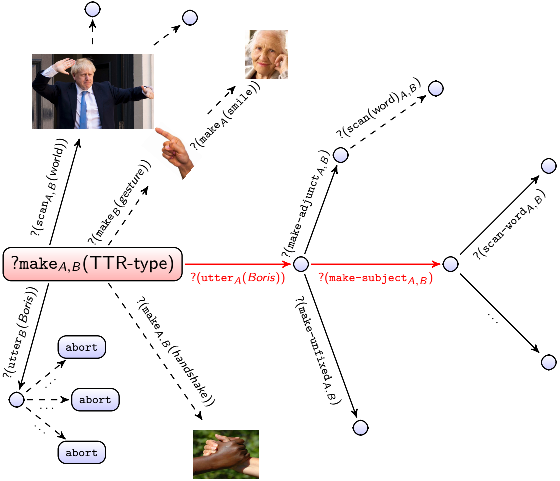

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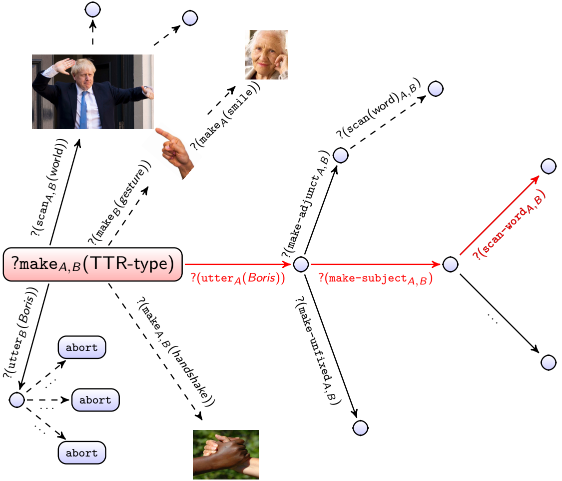

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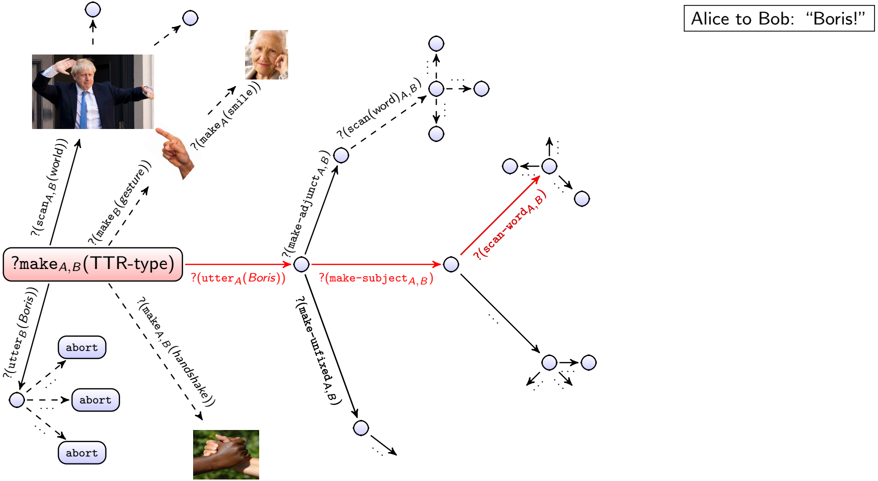

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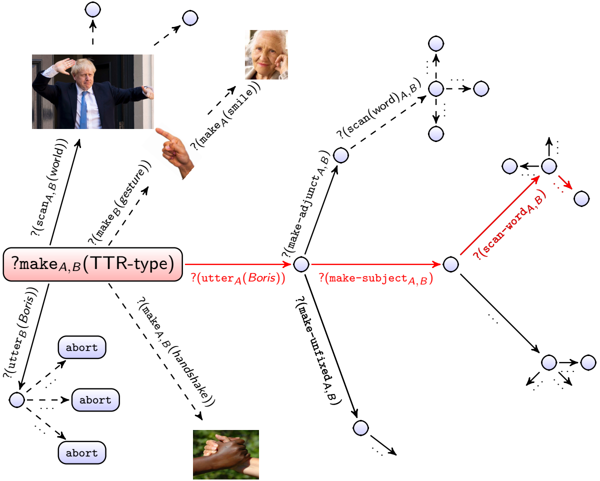

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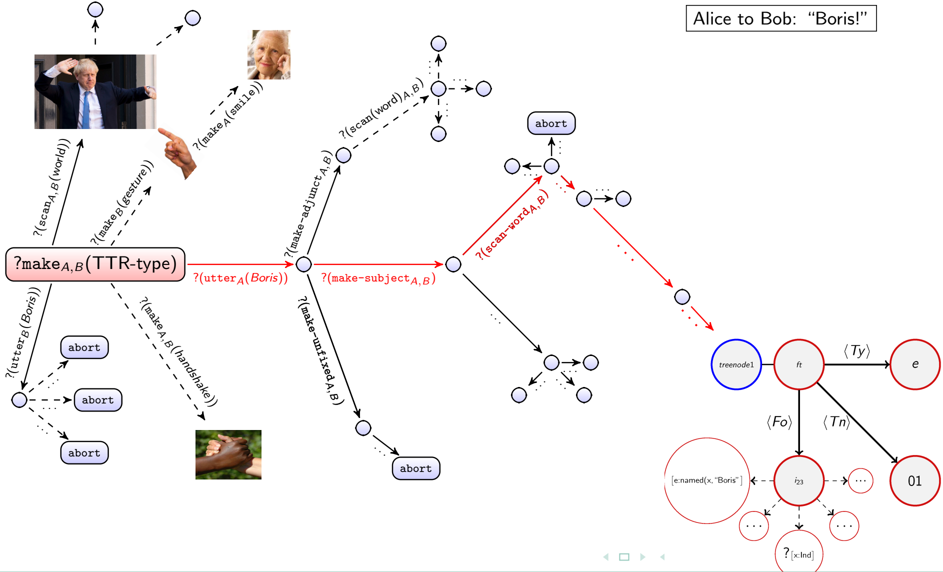
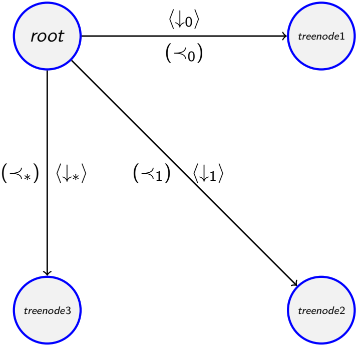
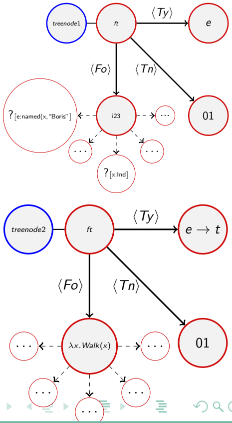


Outline

- DS explains all allegedly syntactic phenomena as properties of processing mechanisms or the structuration of affordances into hierarchical structures
- (partial) **tree-structures** emerge as an intermediate structural bottleneck in the DS-TTR landscape of affordances
  - trees express the bifurcation of processes





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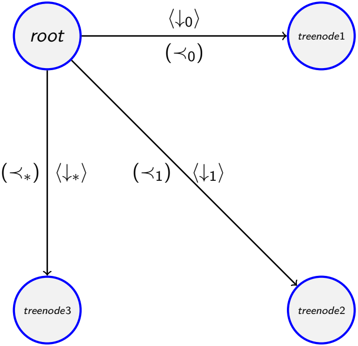
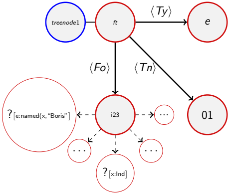
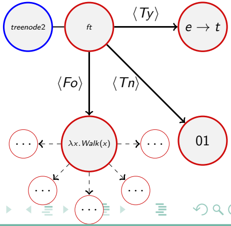
- (if necessary,) representation as an aspect of successful interaction [Bickhard (2009)] via predictivity







DS-TTR: parsing and generation

- from **strings** to **conceptual structure** (TTR) or vice-versa

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John arrived.

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John arrived
$\longmapsto$

$$\diamondsuit, Ty(t), \begin{bmatrix} x & : & john' \\ p & : & arrive'(x) \end{bmatrix}$$

$$Ty(e), \begin{bmatrix} x & : & john' \end{bmatrix}$$

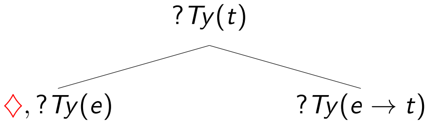
$$Ty(e \rightarrow t), \lambda r : \begin{bmatrix} x & : & e \end{bmatrix} . \begin{bmatrix} x & : & e \\ p & : & arrive'(x) \end{bmatrix}$$

incremental construction

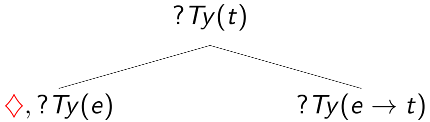
$[\text{START}] \overset{\dots \ \text{PREDICTION}}{\longmapsto}$ $\diamondsuit, ?Ty(t)$

incremental construction

$\overset{\text{PREDICTION}}{\longmapsto}$

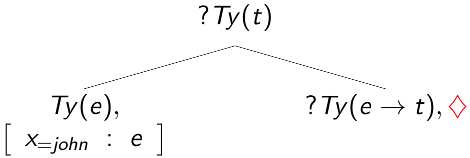


John $\longmapsto$



John	IF	$?Ty(e)$
	THEN	$\mathtt{put}(Ty(e))$
		$\mathtt{put}([\ x_{=john}\ :\ e\ ])$
	ELSE	$\mathtt{abort}$

John,...,POINTER-MOVEMENT $\longmapsto$



$$
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\end{array}
$$

incremental construction

$\ldots, \ldots, \underset{\longrightarrow}{}$ *arrives*

$$?Ty(t)$$

$$Ty(e), \left[\begin{array}{lcl} x_{=john} & : & e \end{array}\right]$$

$$Ty(e \rightarrow t), \diamondsuit \quad \lambda \; r : \left[\begin{array}{lcl} x & : & e \end{array}\right] . \left[\begin{array}{lcl} x & : & e \\ s_{=arrive} & : & e_s \\ p_{=agent(s,x)} & : & t \\ \ldots & : & \ldots \end{array}\right]$$

incremental construction

$\ldots[\textsc{tense},\ \ldots] \xrightarrow{,}\ \textsc{completion}$

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underspecification: structural

- processing **non-contiguous dependencies**
  - e.g. 'Mary, John upset'

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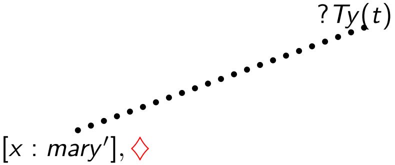

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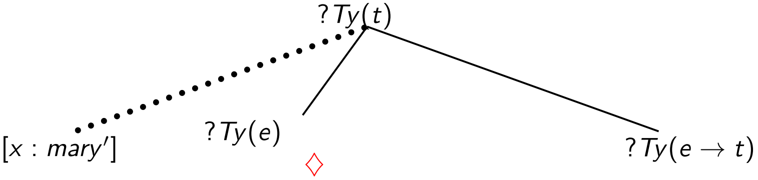

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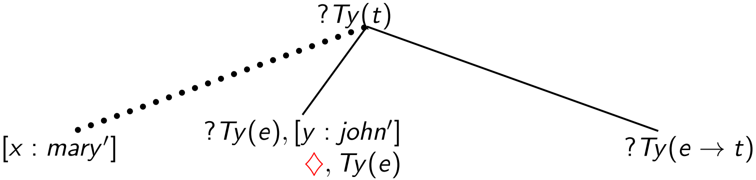

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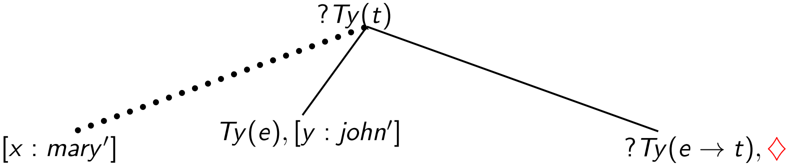

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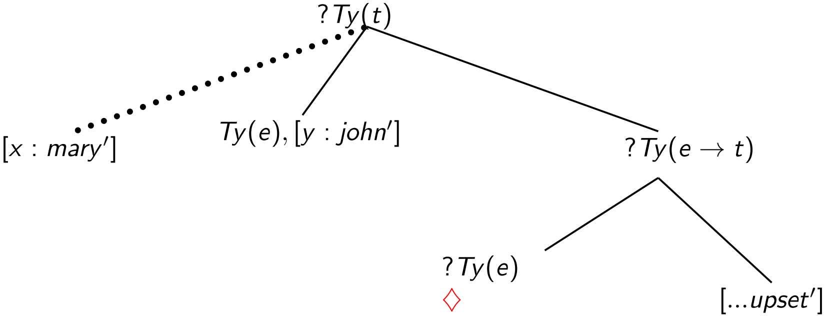

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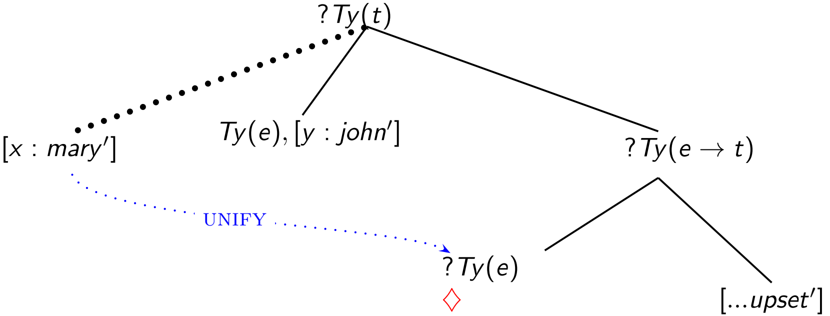

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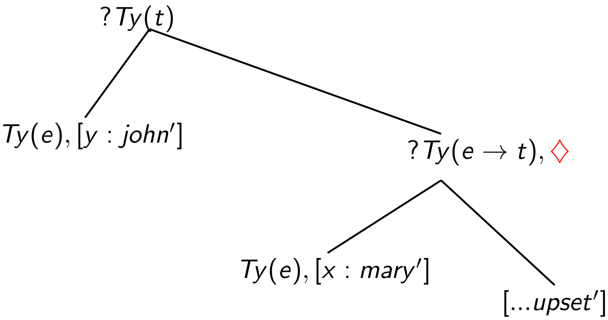

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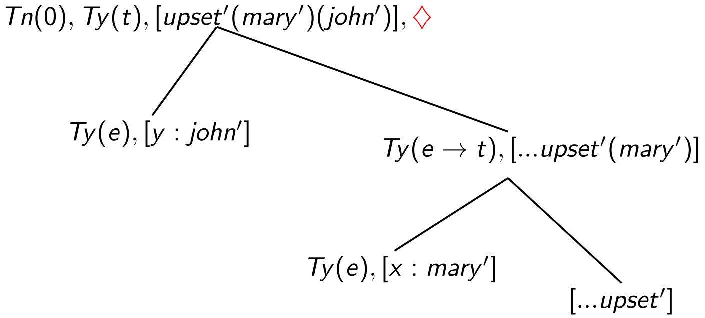
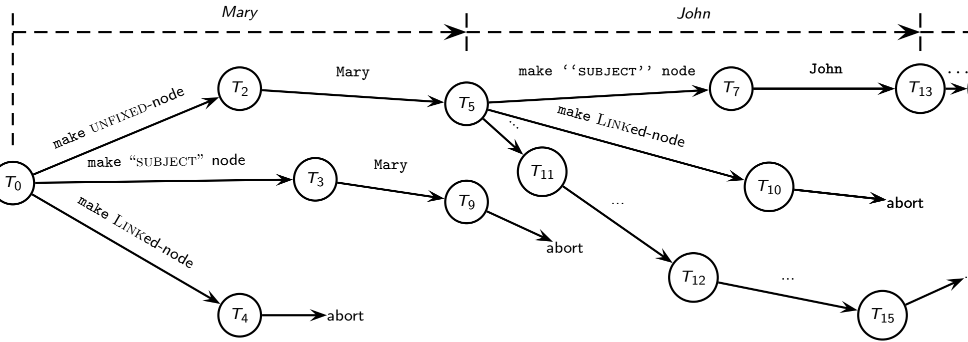


a field of affordances

(simplified) options for starting to parse/produce *Mary, John upset*



utterance micro-events

$$\diamondsuit, Ty(t), \begin{bmatrix} \text{CONTEXT}: & u_1 \oplus u_2 \\ \text{CONTENT}: & \begin{bmatrix} x & : & e \\ p & : & f(x) \end{bmatrix} \end{bmatrix}$$

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including contextual parameters

John arrived $\longmapsto$

$$\diamondsuit, Ty(t), \begin{bmatrix} \textsc{context}: & \begin{bmatrix} a & : & participantA \\ b & : & participantB \\ \ldots & : & \ldots \\ u_1 & : & utt-event \\ s_{s1} & : & spkr(u_1, a) \\ s_{a1} & : & addr(u_1, b) \\ u_2 & : & utt-event \\ s_{s2} & : & spkr(u_2, a) \\ s_{a2} & : & addr(u_2, b) \\ \ldots & : & \ldots \end{bmatrix} \\ \textsc{content}: & \begin{bmatrix} x & : & john \\ p & : & arrive(x) \end{bmatrix} \end{bmatrix}$$

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  - they bring about properties of the environment to be picked up by agents
  - they are agent-relative (perspectival) properties of the environment [(Chemero, 2010)]
- types are not paired instantaneously with labels: types induce fields of potential paths of interaction with patterns in the environment
  - "the whole system of input and output resonates to the external information" [Gibson, 1966: 5].

Outline

1. DS-TTR
2. Zoom into trees and treenodes
3. DS-TTR+
4. Appendix

logical structure of DS

- an NL is a set of actions describing the licensed transitions from an initial state to a result state

logical structure of DS

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- states are structured objects
  - e.g., in DS, states are decorated partial trees which map to more elaborate trees as you go along

logical structure of DS: trees

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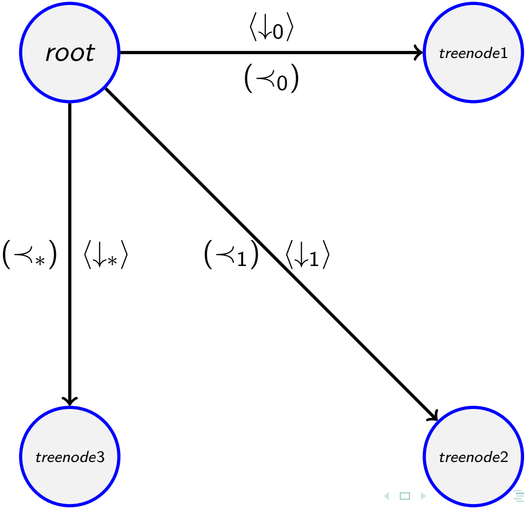
- in DS, states are partial trees (in the description language DU, they are accessed by means of modal operators)



logical structure of DS: treenodes

- DS **trees** are sets of states related by dominance (modal) operators
- in turn, each **tree node** is inhabited by a feature structure
  - an instance of "fibred semantics" [Finger, Marcelo and Gabbay, Dov (1992)]
- **feature structures** are labelled directed graphs
- features (partial functions) like *Fo*, *Tn*, *Ty*, ...
  - nesting of features is possible
- values ("decorations") like *e*, *eleni′*, 010, ...
- AVM notation:

$$tn_{01}: \begin{bmatrix} Type & e \rightarrow t \\ Formula & \lambda x Walk(x) \\ TreeNode & 01 \end{bmatrix}$$

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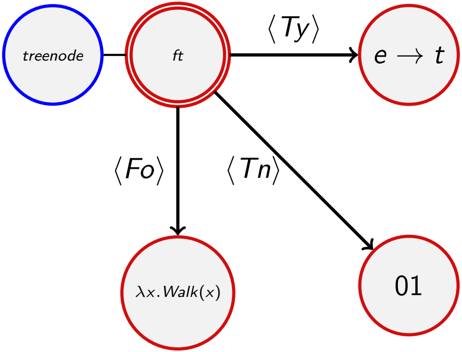

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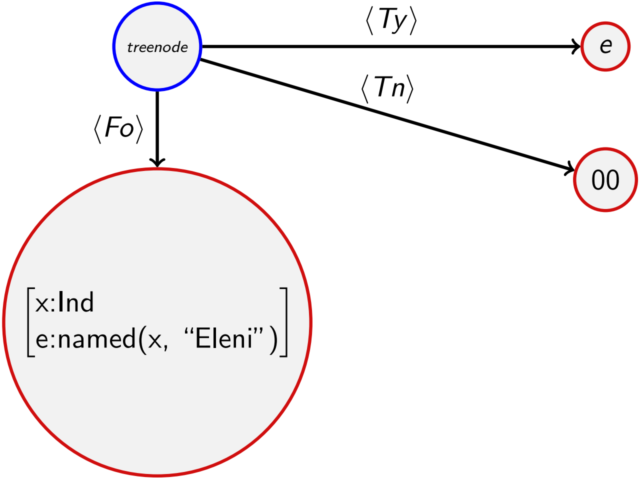
- DU_F(?) language notation

$\langle Tn\rangle(01) \bullet ?\langle Ty\rangle(e), ?\exists(\mathbf{x})\langle Fo\rangle(\mathbf{x})$

DS-TTR: TTR types as Fo values



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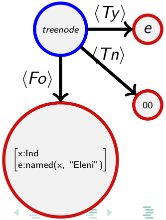

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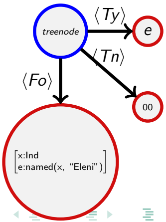

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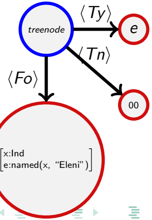

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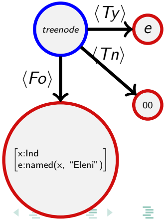

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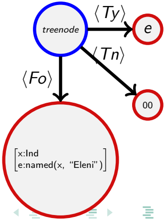

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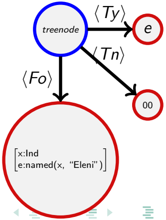
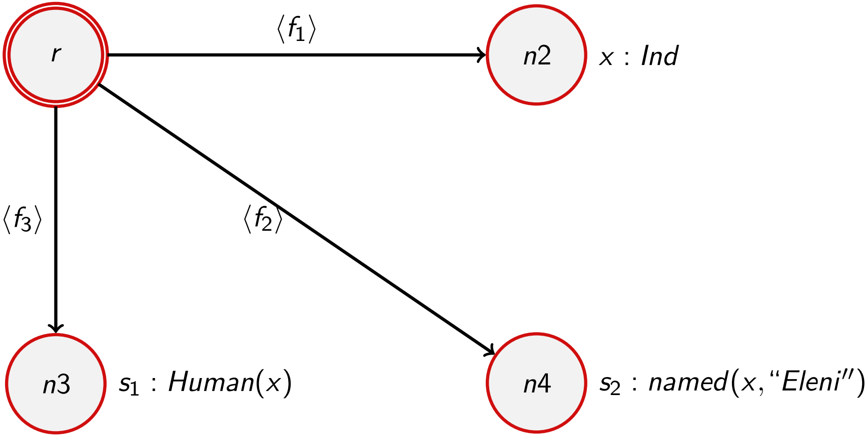
  - introduce requirements to impose further specification
- additionally, we can "internalise" trees in TTR types so that it is whole TTR types that are extended by DS actions



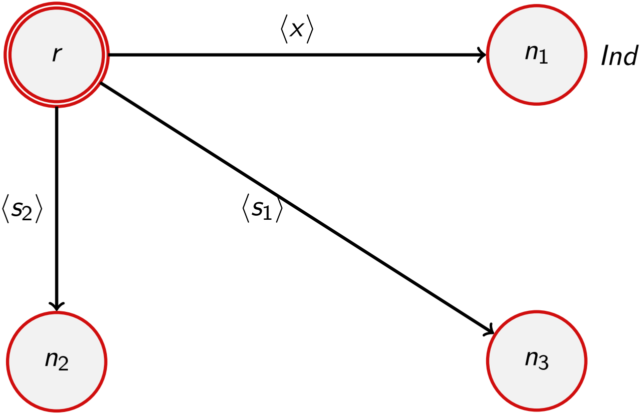
logical structure of TTR: version 1 (conservative)

- assign syntactic structure to **record types**
- **typing judgements** are propositions that hold at nodes
- fields are indexed



logical structure of TTR: version 2a

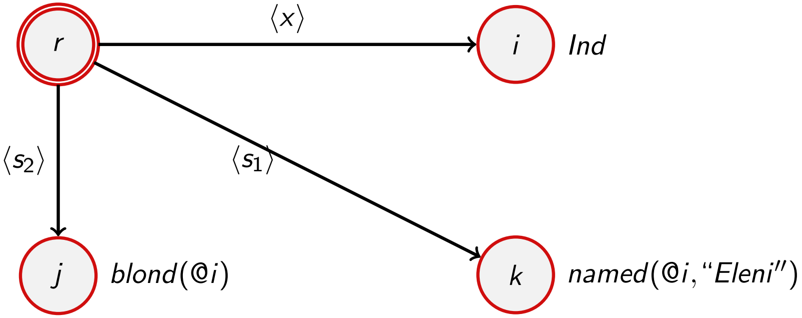
- a **record type** is a state (an initial, base, state)
- labels (discourse referents) are represented as modal operators (features)
- entities are nodes



$\lambda z.blond(z) \wedge \left\langle z : \langle s_2 \rangle \langle x \rangle :\triangleq \langle 0 \rangle n_1 \right\rangle$ $\lambda y.named(y, \text{“}Eleni''') \wedge \left\langle y : \langle s_1 \rangle \langle x \rangle \triangleq \langle 0 \rangle n_1 \right\rangle$

logical structure of TTR: version 2b

- a **record type** is a state (an initial state)
- labels are represented as modal operators
- node names are *nominals* in Hybrid Logic [(Blackburn, 2000)]
  - this will bring us close to the Duesseldorf Frames implementation [Kallmeyer and Osswald (2013); Kallmeyer et al. (2015)]
- types are (predicates of) states:



- but then do we still need labels?

logical structure of TTR: set-theoretic structures

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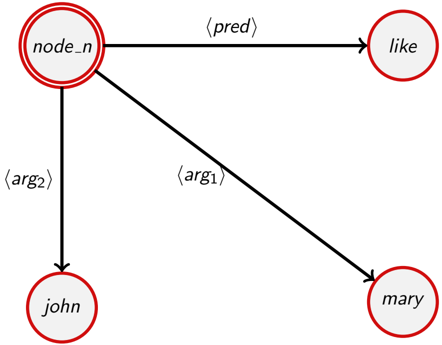

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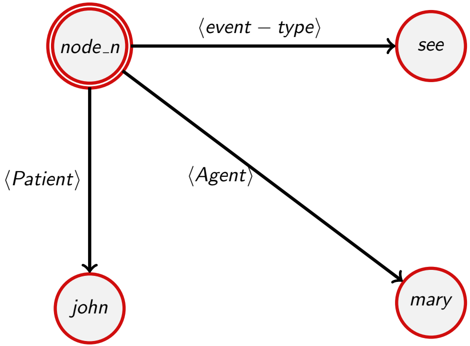

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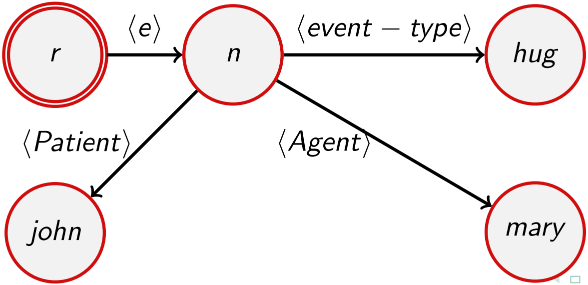

logical structure of TTR: version (4a)

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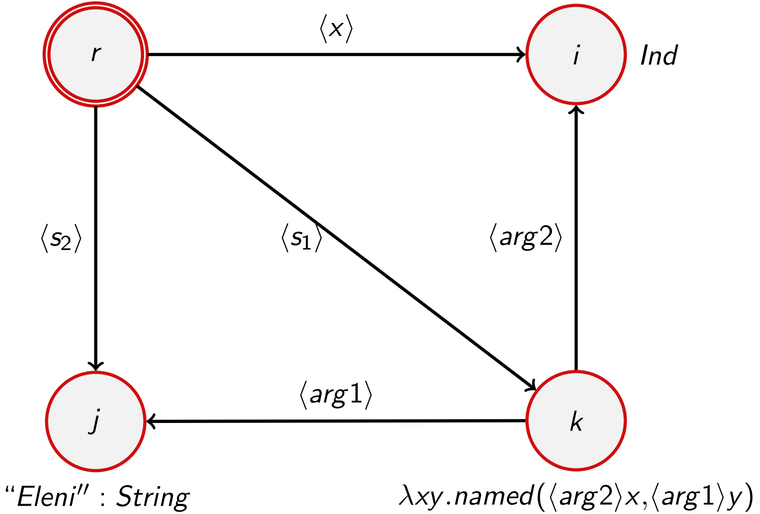

logical structure of TTR: situational version 4b

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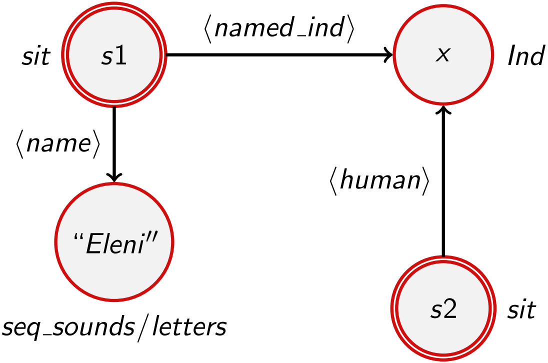

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- for each program α and each formula (tree, TTR-type) φ, $\langle\alpha\rangle\varphi$ or $\langle do(\alpha)\rangle\varphi$ is a formula
  - this means that there is an execution of program α that ends in a state where φ holds

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- DS actions:
  - lexical
  - computational
  - pragmatic (*Substitution*, scope resolution, inference)

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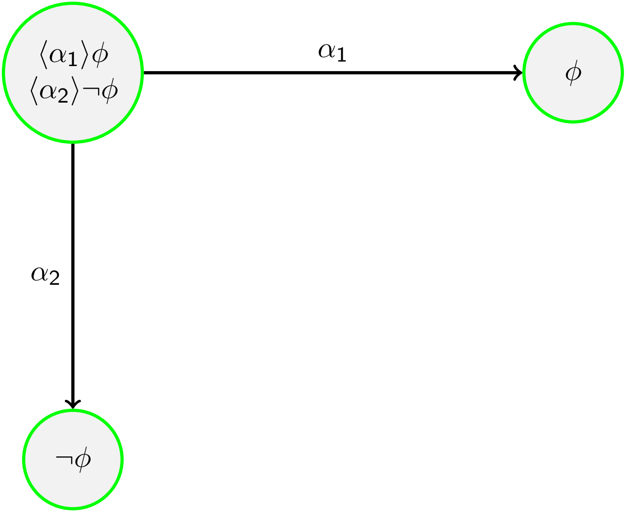
actions as modal operators in DS



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- basic actions are combined by the regular operations
- plus an IF THEN ELSE construction

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- the set $\mathcal{A}(ACT)$ is the smallest set in $PPTM \times PPTM$ satisfying

1. $ACT \subseteq \mathcal{A}(ACT)$, and
2. for $\alpha, \alpha' \in \mathcal{A}(ACT), \Sigma(\bar{x}) \subseteq DU_F(?)$,
   where $\bar{x}$ is a sequence of all variables occurring free in Σ, we have $\alpha;\alpha', \alpha + \alpha', \alpha^*, \langle \Sigma(\bar{x}), \alpha, \alpha' \rangle \in \mathcal{A}(ACT)$ where $;, +, *$ have their usual interpretation and
   $\langle \Sigma(\bar{x}), \alpha, \alpha' \rangle =$
   $\{\langle \mathcal{T}n, \mathcal{T}'n' \rangle \in \alpha[\bar{t}/\bar{x}] \,|\bar{t} \in (\mathcal{D} \cup MV)^*, \langle \mathcal{PPTM}, \mathcal{T}n \rangle| = \Sigma[\bar{t}/\bar{x}]\}$
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actions in DS: macros

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- DS-TTR actions: use extended set of DS actions to build incrementally structured *Fo* values as shown earlier
  - each state is a (partial) TTR record type
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- but remove maximal states from DS models
- remove restriction that elimination of requirements (predictions) is criterion of wellformedness
  - requirements are constantly generated and always present to guide further development

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- e.g., for coverbal gestures, exploit ASL formalisation of gesture formats and assign interpretations, e.g., social relation affordances instituted

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- plus a set of requirements ($?\phi$) for each $\mathrm{L}^{\mathrm{DS-TTR}}$ formula ϕ
- the language contains:
  - (at least) the propositional connectives (plus TTR operations),
    the execution and result operator $\langle \mathrm{do}\_(\_) \rangle\ \_$,
    the ability operator AB_ _,
    the action constructors:

    `confirm_` (confirmations/tests),
    `_;_` (sequential composition),
    `if _ then _ else _` (conditional composition) and
    `while_ do_` (repetitive composition)

the language $\mathrm{L}^{\mathrm{DS-TTR}}$

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application: proper names in DS-TTR

(1a) DS

IF	$?\,Ty(e)$
THEN	$\texttt{put}(Ty(e))$
	$\texttt{put}(Fo(john'))$
ELSE	$\texttt{abort}$

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(1b) DS-TTR

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- lexical entry for proper name:

$$
\begin{array}{ll}
\text{IF} & ?Ty(e) \wedge \langle do_H(\texttt{hear})\rangle \text{“Eleni”} \\
\text{THEN} & ?\langle do_{S\&H}(\texttt{make-go})\rangle(\langle f_1\rangle)); \ \text{put}(?\mathbf{AB}_{S\&H}(\left[\text{x}:Ind\right])), \\
 & ?\langle do_{S\&H}(\texttt{make-go})\rangle(\langle f_2\rangle); \ \text{put}?\mathbf{AB}_{S\&H}(\left[\text{s}_1:(\text{named}(\text{x}, \text{“Eleni”})\right])) \\
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 & ?\langle do_{S\&H}(\texttt{make-go})\rangle; \ \text{put}?(\left[\text{s}_3:(\text{scared}(\text{Pipkin, x})\right])) \\
 & ?\langle do_{Pipkin}(\texttt{run})\rangle\top \wedge [do_{Pipkin}(\texttt{avoid-Eleni})]\bot \\
 & \ldots \\
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Thank you for your attention!

Outline

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