XML Transformation
by
Tree-Walking Transducers
with
Invisible Pebbles

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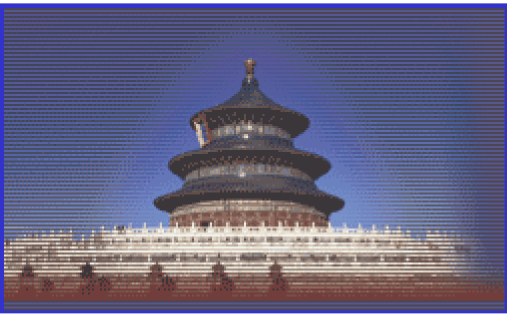
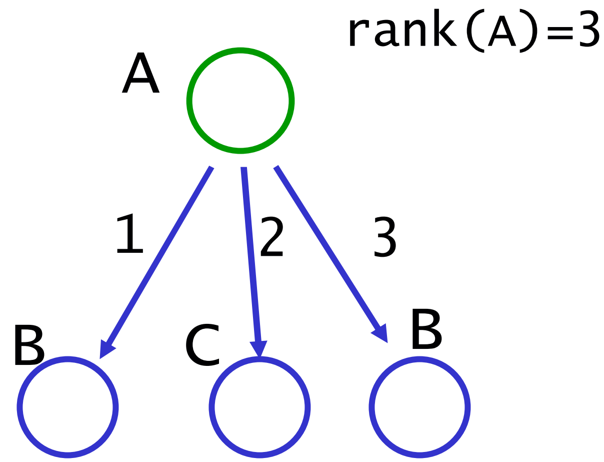


PODS Beijing June 2007

tree model

<A>
<B> …
</B>
<C> …
</C>
<B> …
</B>
</A>



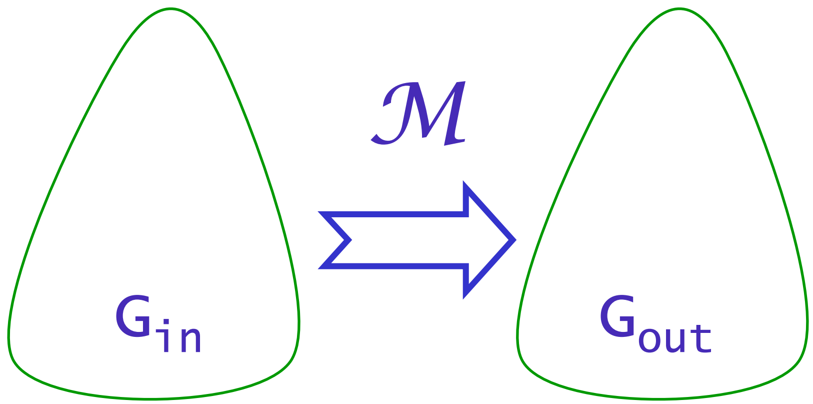
ranked trees
node labels with rank

unbounded number of children
(forests) are to be coded

background

typechecking

decide whether tree (document) generated by transformation $\mathcal{M}$ satisfies description



Milo Suciu Vianu PODS2000

type checking for XML transformers is decidable

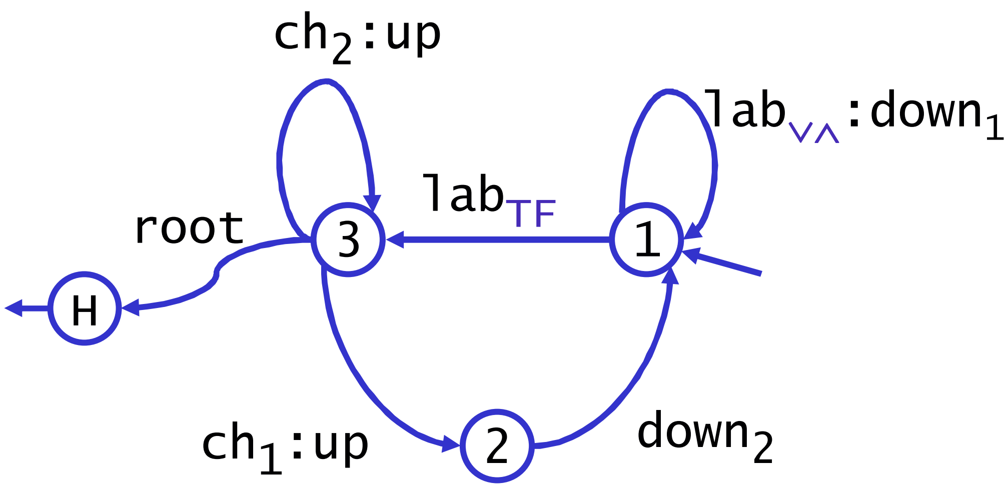
transformers with 'visible' pebbles:
finite number of coloured markers on tree

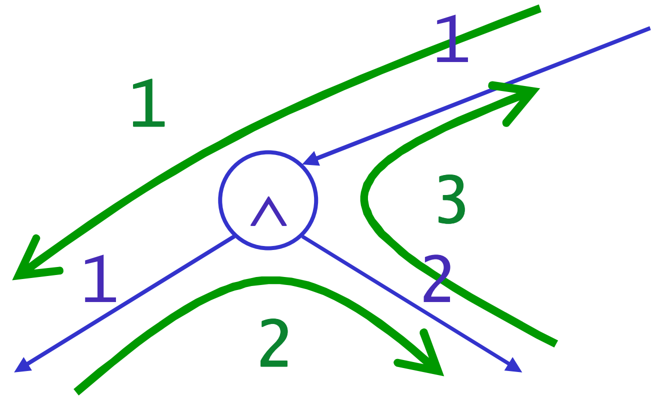
contents

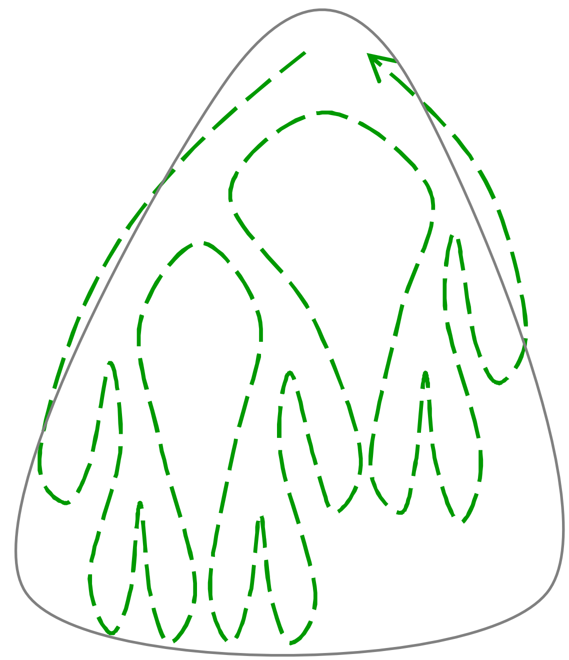
1. automata with pebbles
2. decomposition
3. typechecking
4. regular trees
5. document navigation
6. pattern matching
7. conclusion

without pebbles

example: preorder tree traversal





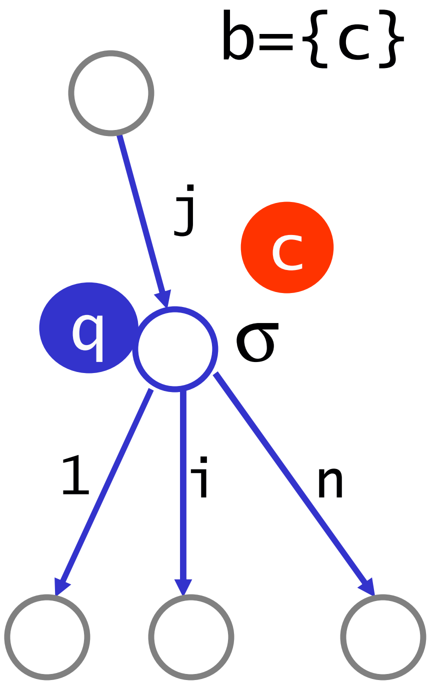


walk along edges, moves based on

- state
- node label
- child number
  (= incoming edge)

tree-walking automata

with pebbles



local configuration

q state

σ node label

j child number

j=0 root

b pebble colours

$b \subseteq C$

instructions

$(q,\sigma,b,j) \rightarrow$

(halt)

(q',stay)

(q',up)

(q',down_i)

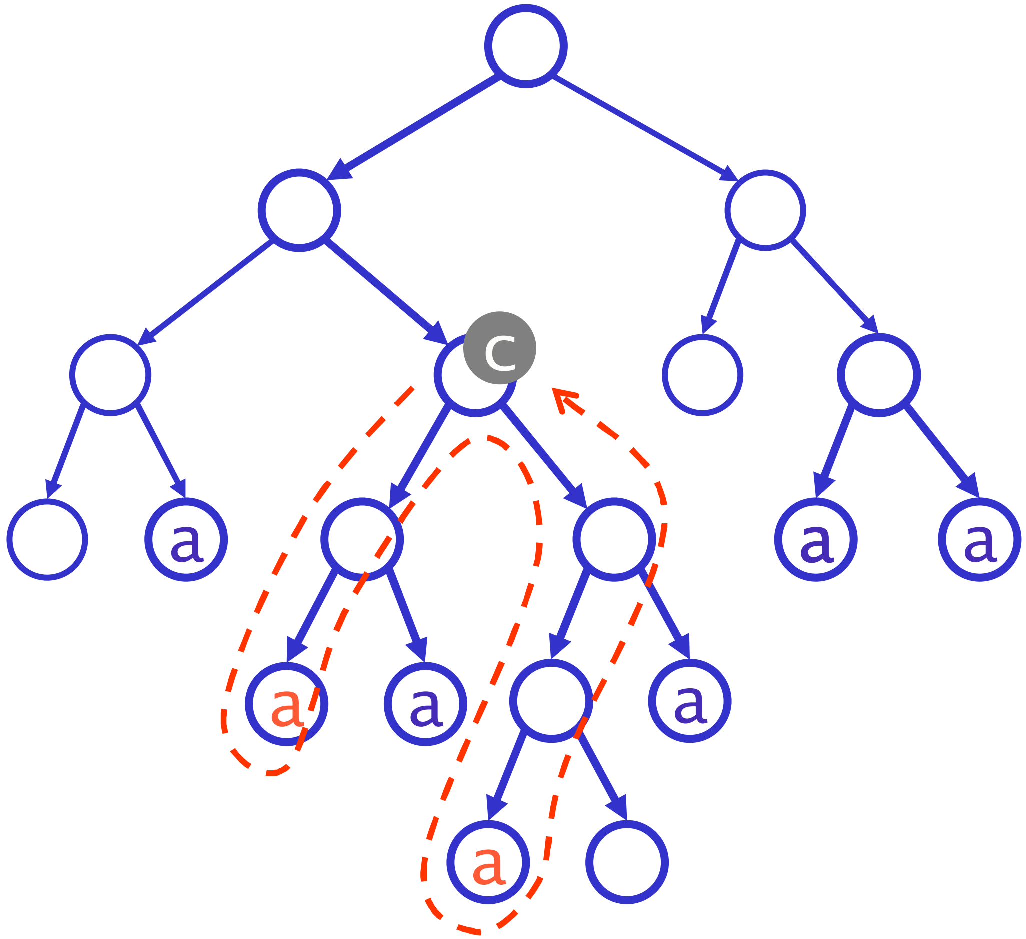
(q',drop_c)

(q',lift_c)

- finite set C of pebbles
- nested lifetimes
  stack behaviour
  only topmost can be lifted
- all observable

example: inspecting a subtree

using a pebble



tree-walking pebble automata

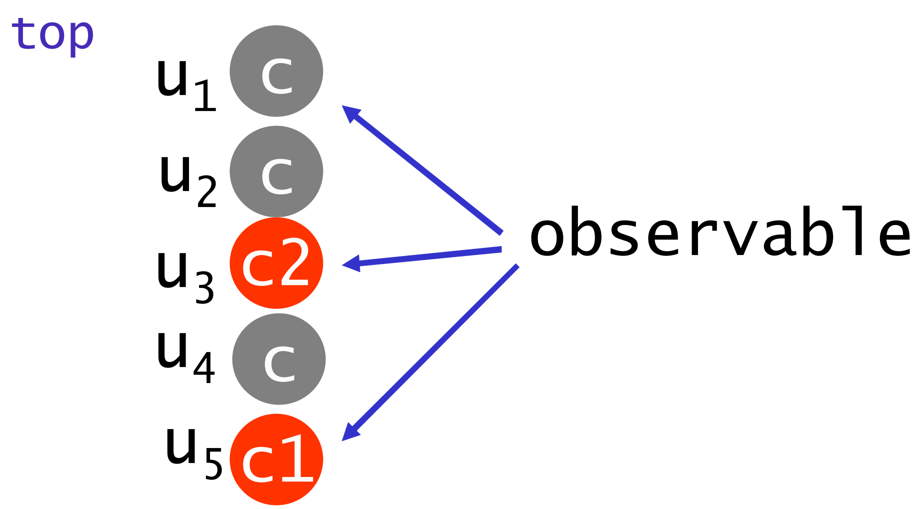
c with visible pebbles
'colours' used once
always observable

☹ do not recognize all regular tree languages
≡ MSO properties

c we add invisible pebbles
colours used many times
only topmost is observable

☺ recognize regular
& decidable type checking
& better complexity

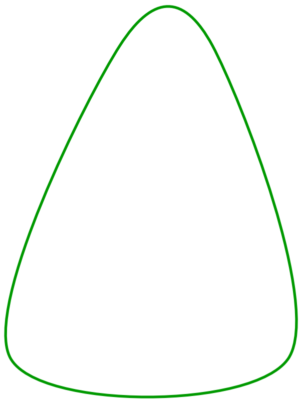
stack behaviour of pebbles!
(avoid 'counting')



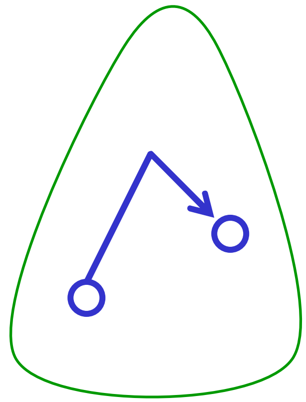
$(q,\sigma,b,j) \to (q',\text{stay})$

b contains
-all visible pebbles
-invisible when topmost

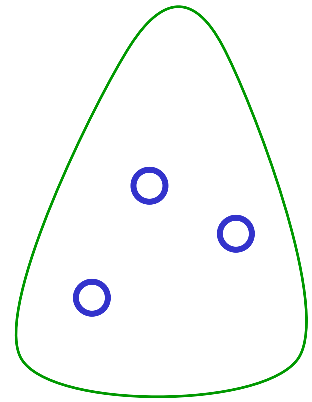
automaton defines …



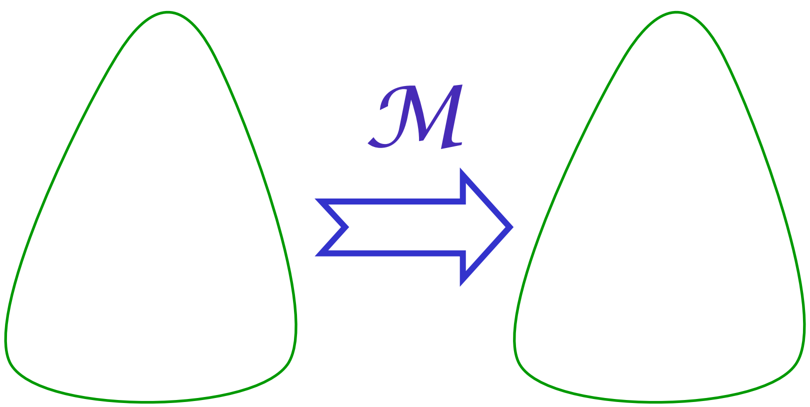
validation



navigation



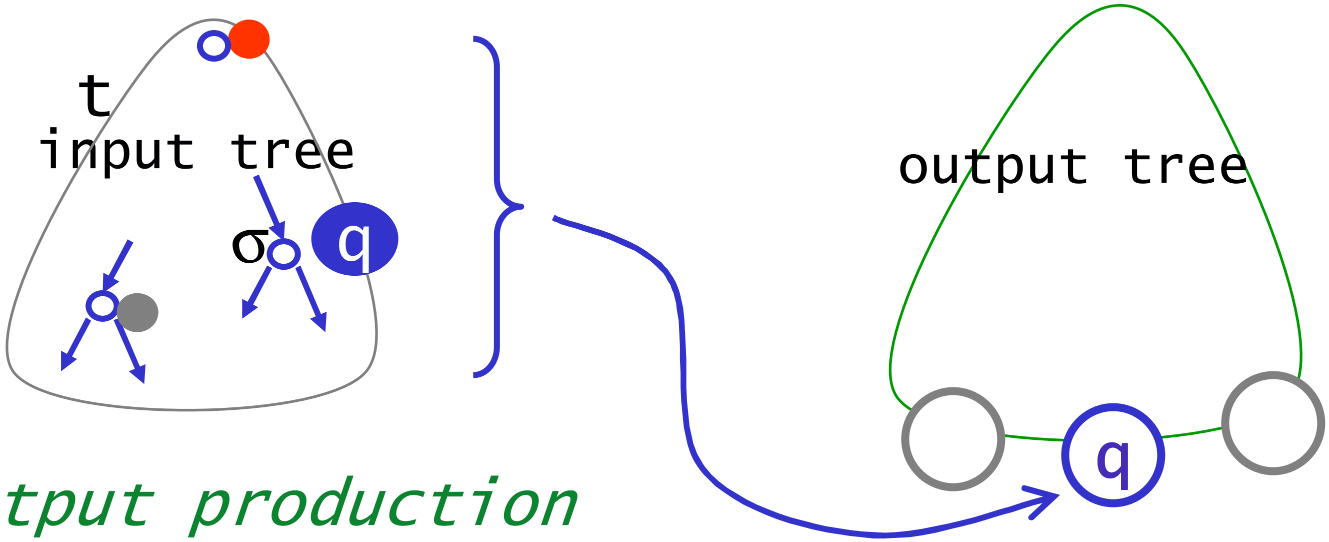
pattern matching



transformation

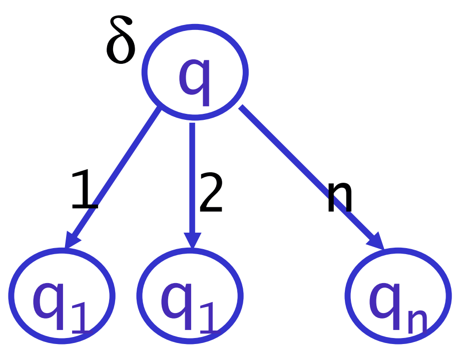
tree-walking pebble tree *transducers*

recursively generate output



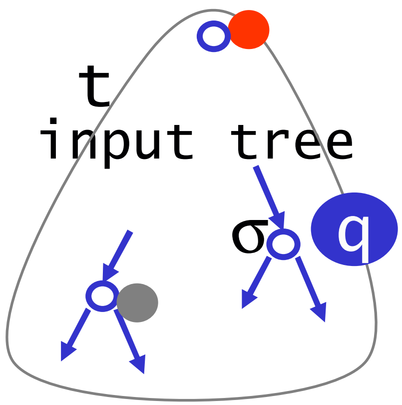
output production

$$(q,\sigma,b,j) \rightarrow \delta(q_1,q_2 \ldots q_n)$$



tree-walking pebble tree transducers

recursively generate output



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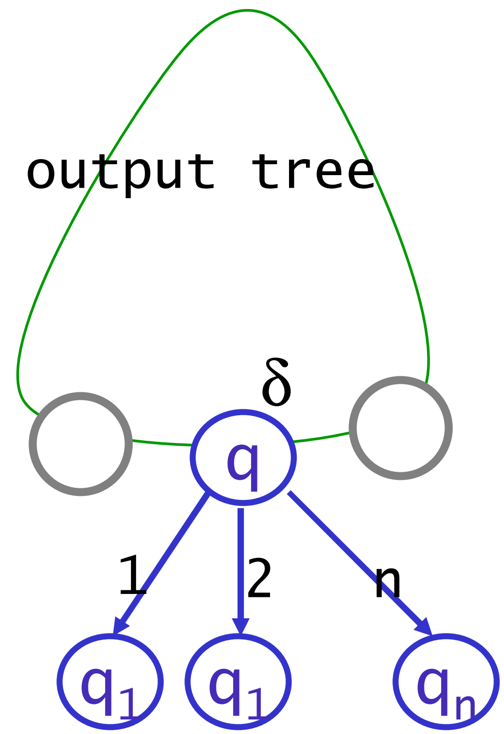
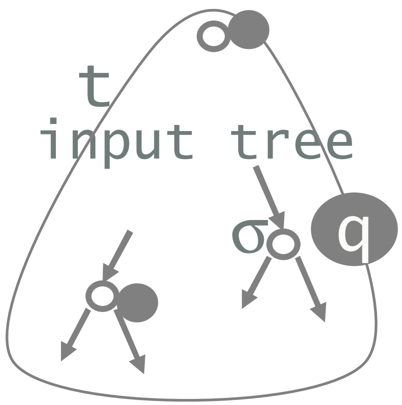
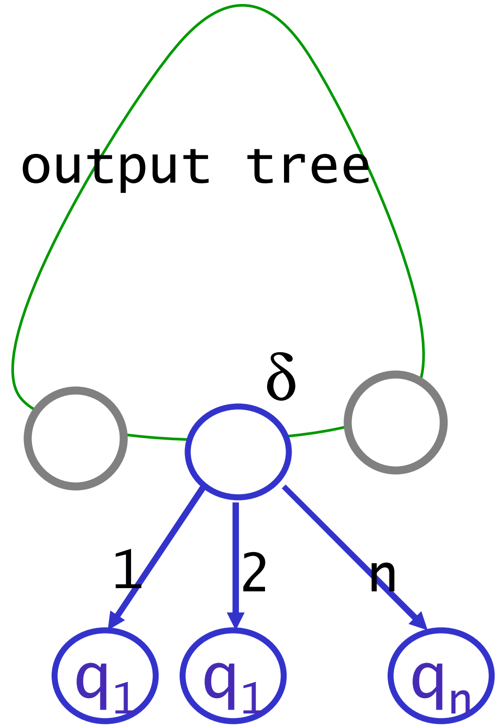


tree-walking pebble tree transducers

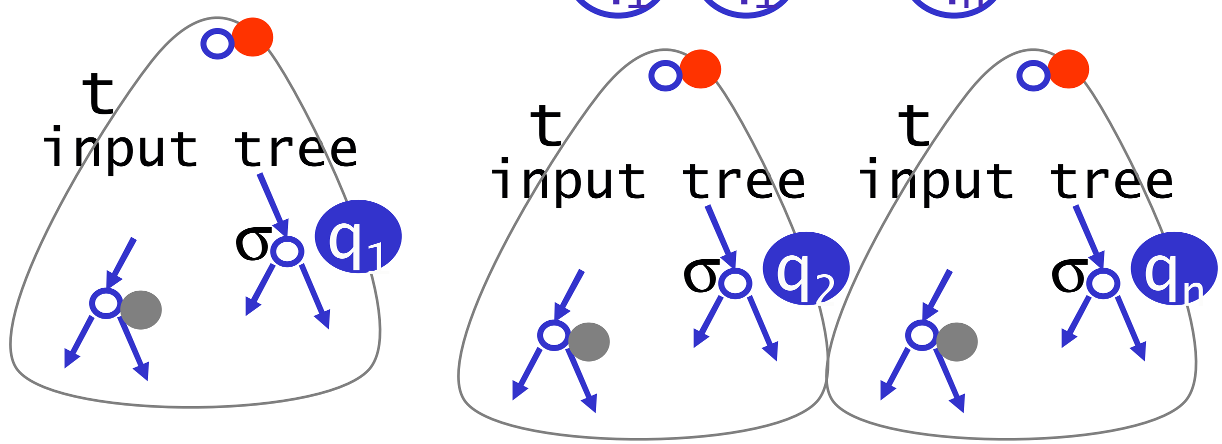
recursively generate output



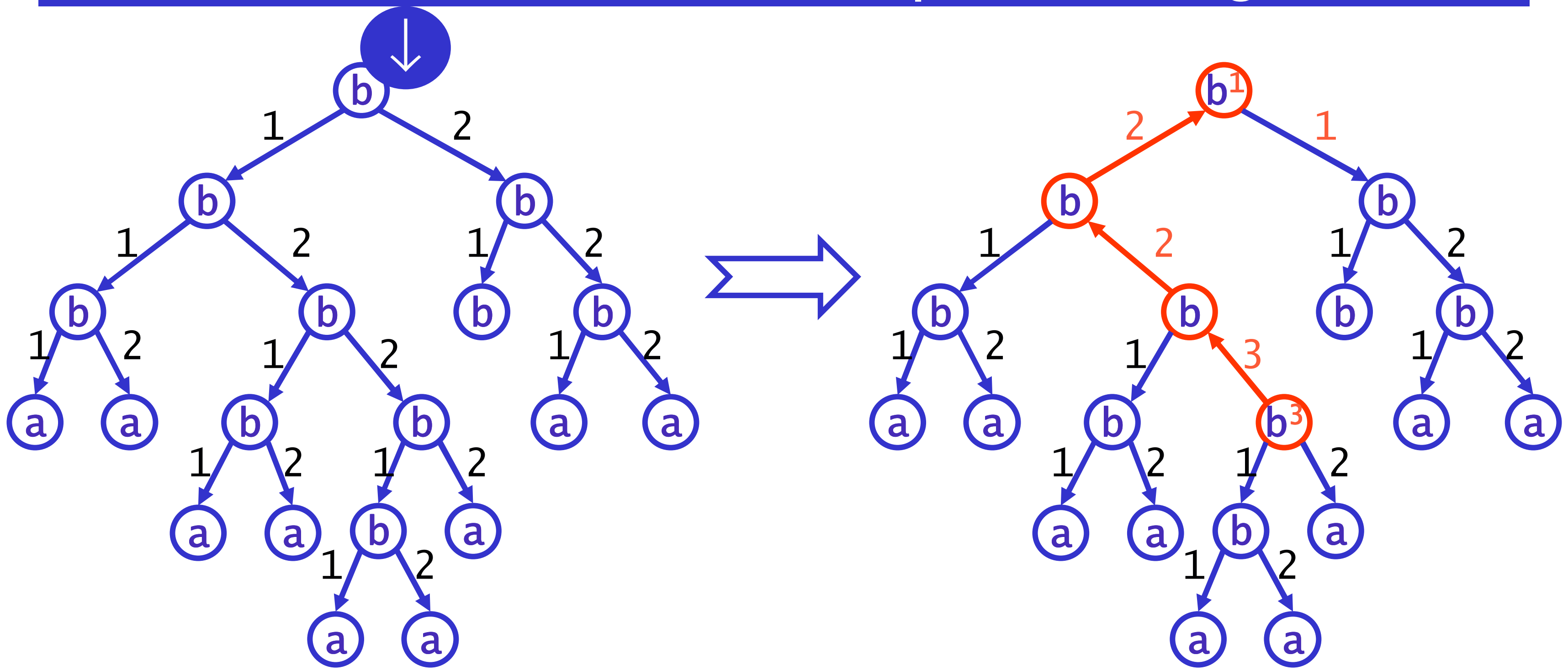


output production

$(q,\sigma,b,j) \to \delta(q_1,q_2 \dots q_n)$



example: moving the root



walk down

$(\downarrow, b, -, j) \rightarrow (\downarrow, down_1)$

$(\downarrow, b, -, j) \rightarrow (\downarrow, down_2)$

copy up

$(\uparrow, b, -, 1) \rightarrow b(\uparrow_1, c_2)$

$(\uparrow, b, -, 2) \rightarrow b(c_1, \uparrow_2)$

$(\uparrow_i, b, -, i) \rightarrow (\uparrow, up)$

copy down

$(copy, a, -, j) \rightarrow a()$

$(copy, b, -, j) \rightarrow b(c_1, c_2)$

$(c_i, b, -, j) \rightarrow (copy, down_i)$

$j=0,1,2 \quad i=1,2$

notation

Pebble Tree Transducers

V_kI-PTT	visible + invisible	
V_k-PTT	k visible pebbles	Milo etal.
I-PTT	invisible only	
TT	tree-walking (no pebbles)	

Pebble Tree Automata

V_kI-PTA
V_k-PTA
I-PTA

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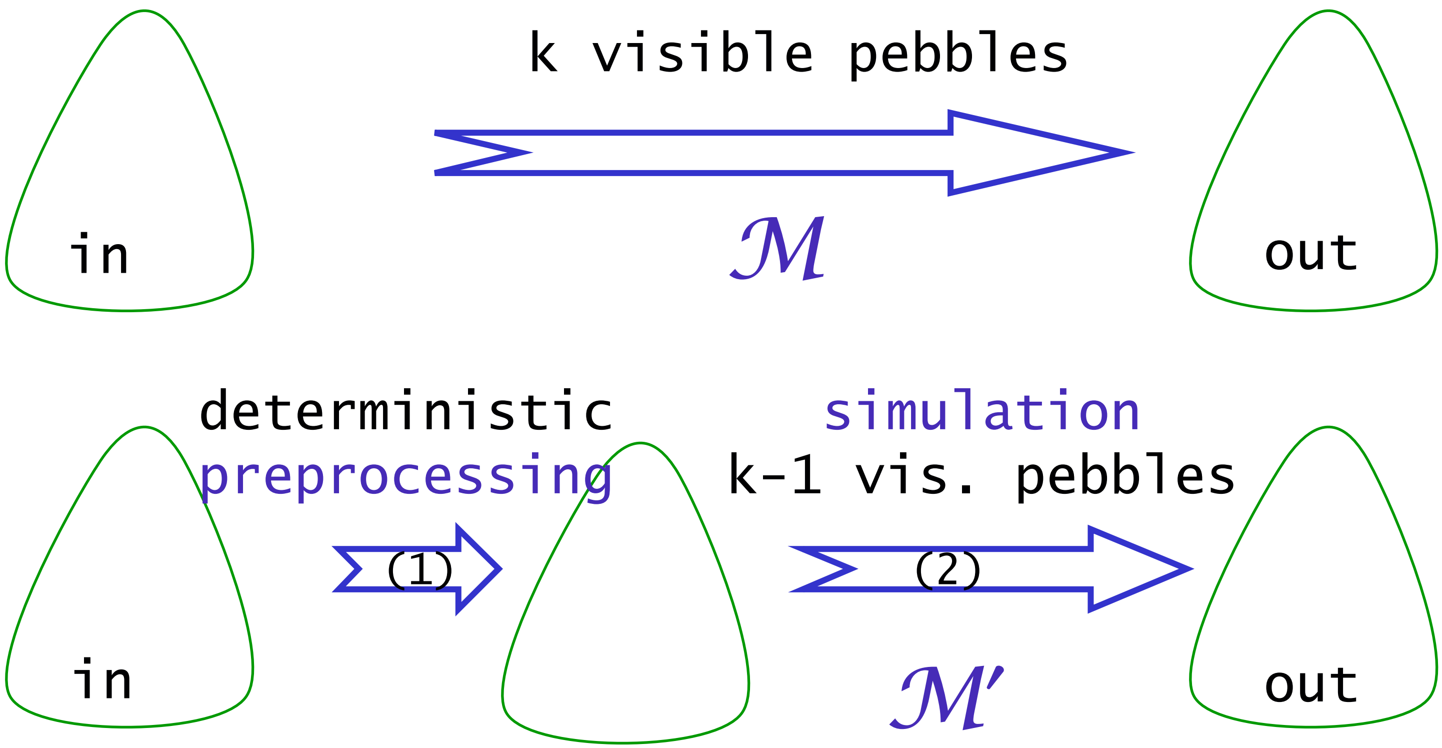
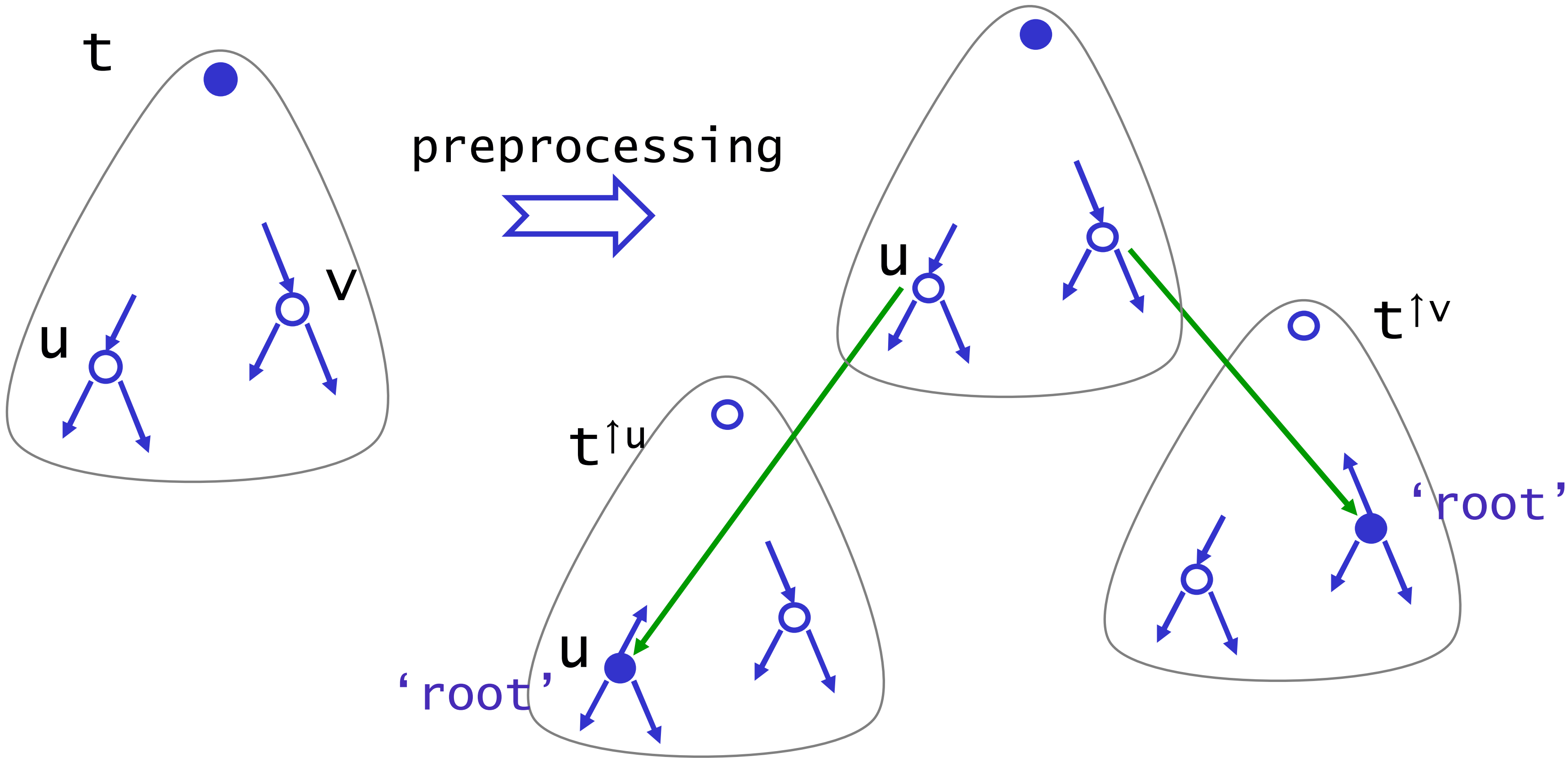
decomposition visible pebbles

$$V_k\text{I-dPTT} \subseteq \text{dTT} \circ V_{k-1}\text{I-dPTT}$$



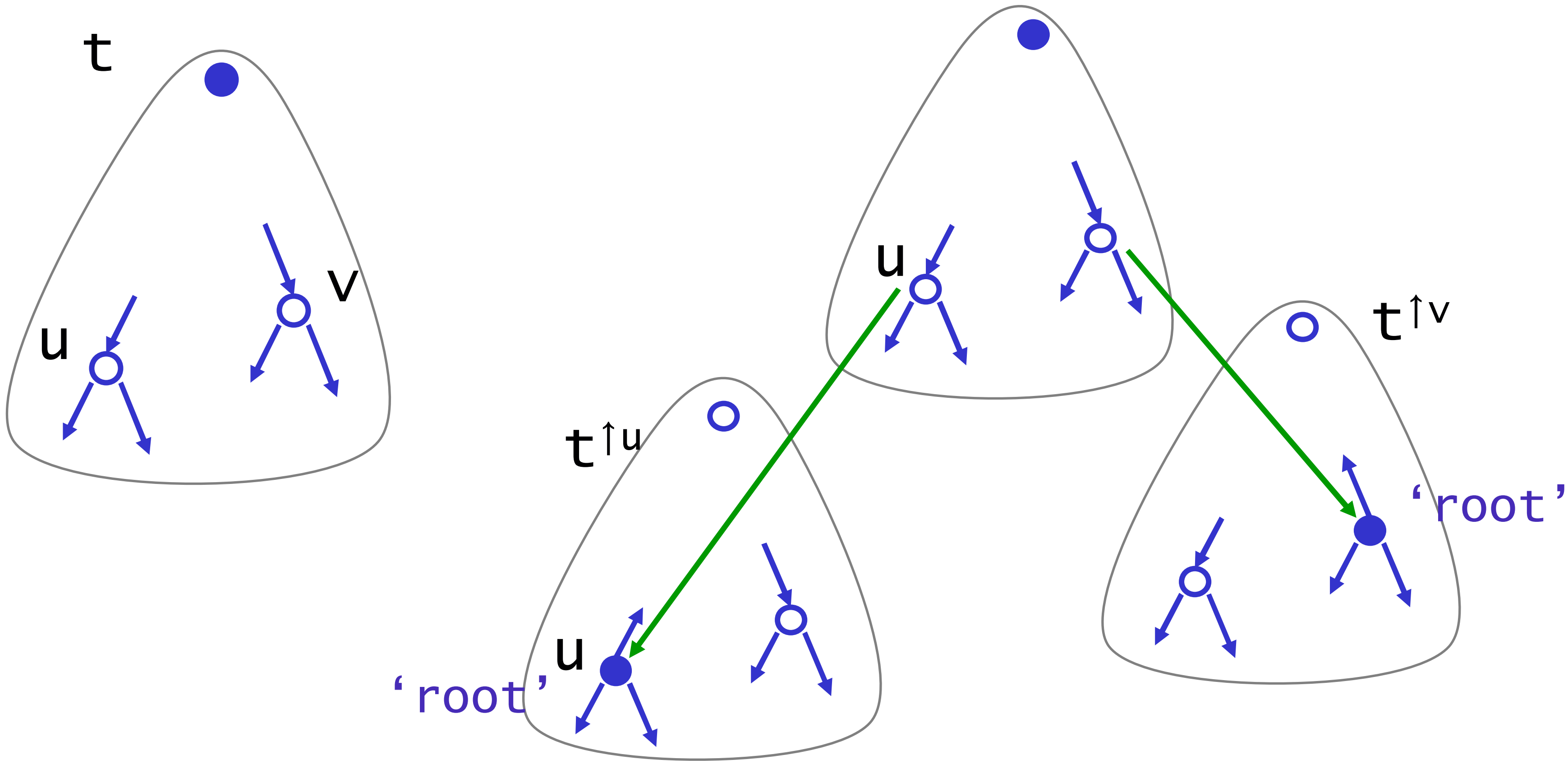
iterate $$V_k\text{I-dPTT} \subseteq \text{dTT}^k \circ \text{I-dPTT}$$

decomposition (1) *preprocessing*



copying can be done without pebbles

decomposition (2) *simulation*



$\mathcal{M}$

drop / lift
first visible pebble

$\mathcal{M}'$

move up /down
into subtree

decomposition

$V_k I\text{-}dPTT \subseteq dTT \circ V_{k-1} I\text{-}dPTT$

$I\text{-}dPTT \subseteq TT \circ dTT$

(deterministic)

THEOREM

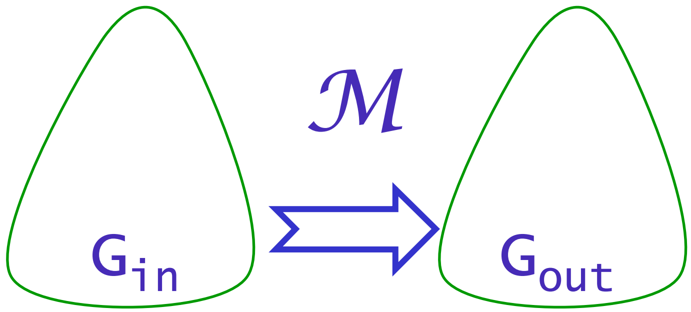
$V_k\text{-}PTT \subseteq TT^{k+1}$

$V_k I\text{-}PTT \subseteq TT^{k+2}$

contents

inverse type inference

given transducer $\mathcal{M}$ and regular G_{out},
construct regular G_{in} such that
$L(G_{in}) = \mathcal{M}^{-1}\ L(G_{out})$



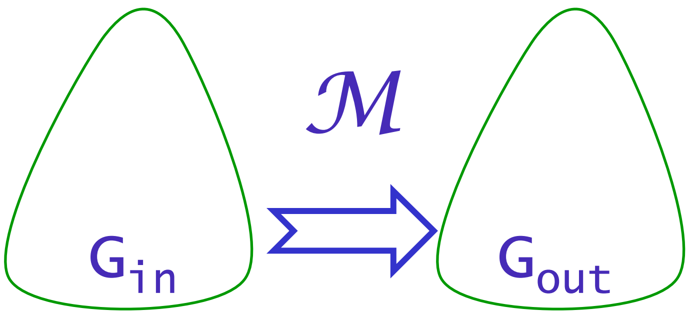
Bartha 1982

regular tree grammar G for the domain
of tree transducer $\mathcal{M}$ can be constructed
in *exponential* time

inverse type inference is solvable
⇒ for TT in exponential time
⇒ for TT^k in k-fold exponential time

type checking

given transducer $\mathcal{M}$ and regular G_{in}, G_{out},
decide whether $\mathcal{M}(L(G_{in})) \subseteq L(G_{out})$



$M(A)\subseteq B$ iff $A\cap M^{-1}(B^{c})=\varnothing$

'typechecking' 'inverse type inference'

$V_k\text{-PTT} \subseteq TT^{k+1}$

$V_kI\text{-PTT} \subseteq TT^{k+2}$

we can typecheck
⇒ TT^k in $(k+1)$-fold exponential time
⇒ V_k-PTT in $(k+2)$-fold exponential time
⇒ V_kI-PTT in $(k+3)$-fold exponential time

invisible pebbles are almost for free!

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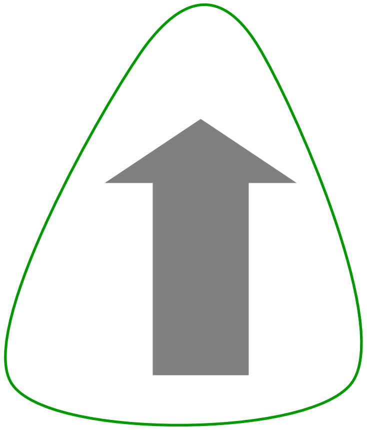
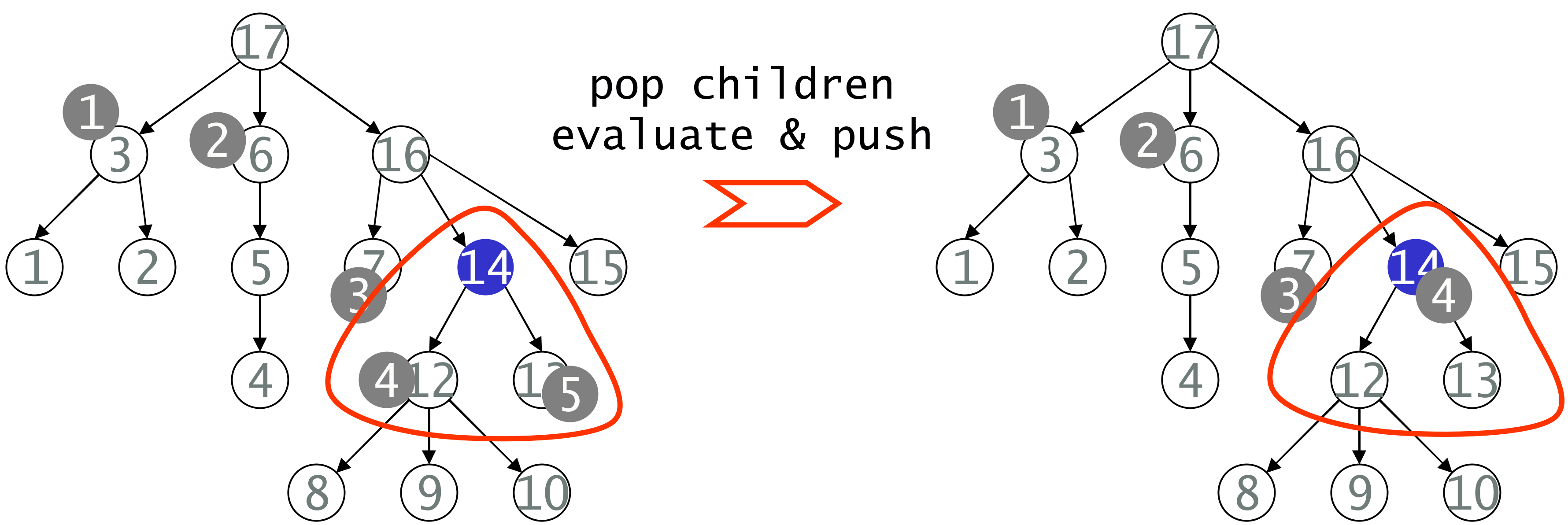
regular trees

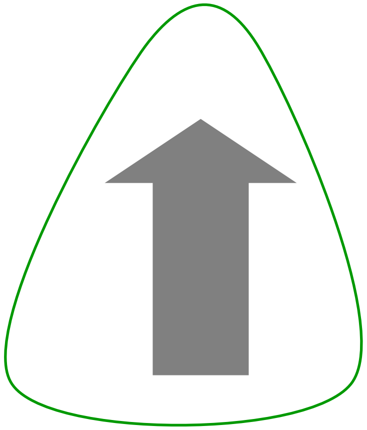


regular tree language
≡ bottom-up tree evaluation
≡ post-order evalation with stack

REGT $\subseteq$ I-PTA



regular trees



regular tree language
≡ bottom-up tree evaluation
≡ post-order evalation with stack

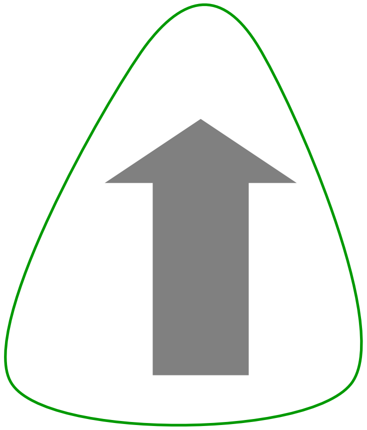
REGT ⊆ I-PTA

REGT ⊈ V_k-PTA Bojańczyk etal.

V_kI-PTT ⊆ TT^{k+2}

V_kI-PTA ⊆ REGT

regular trees



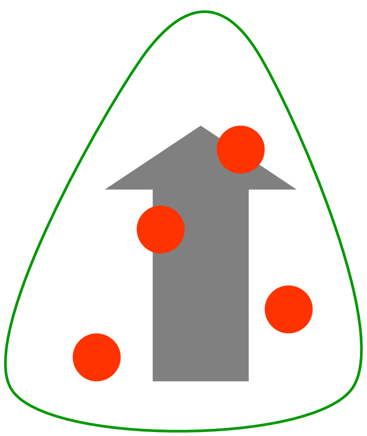
regular tree language
≡ bottom-up tree evaluation
≡ post-order evalation with stack

$\mathrm{REGT} \subseteq \mathrm{I\text{-}PTA}$

$\mathrm{REGT} \not\subseteq \mathrm{V_k\text{-}PTA}$

$\mathrm{V_kI\text{-}PTT} \subseteq \mathrm{TT}^{k+2}$

$\mathrm{V_kI\text{-}PTA} \subseteq \mathrm{REGT}$



I-PTA can
- evaluate *marked* trees
- test their visible configuration

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document navigation

- *Pebble Cat*

caterpillar expressions + pebbles ↔ I-PTA programs

node expressions

φ_0 ::= lab_σ | isleaf | isroot |
isfirst | islast | $pebble_c$

tests

φ ::= φ_0 | $\neg\varphi$ | $\varphi\wedge\varphi$

path expressions

α_0 ::= child | parent | right | left |
$drop_c$ | lift

moves
pebbles

α ::= α_0 | $?\varphi$ | $\alpha\cup\alpha$ | α/α | α^*

Kleene

semantics

$$[?\varphi]_f = \{ ((u,\pi),(u,\pi)) \mid (u,\pi)\in[\varphi]_f \}$$

head pebble stack

document navigation

- *Pebble Cat*

  caterpillar expressions + pebbles

  ↔ I-PTA programs   MSO complete ☺

- *PCat*   ↔ V-PTA programs

  Goris,Marx LICS'05

- *Pebble XPath*

  extends Regular XPath with invisible pebbles

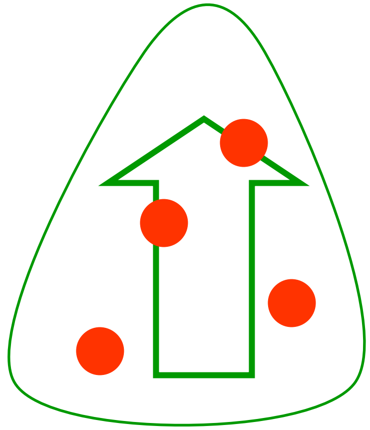
$$\varphi ::= \varphi_0 \mid \langle\alpha\rangle \mid \neg\varphi \mid \varphi\wedge\varphi$$

$$[\langle\alpha\rangle]_f = \{ (u,\pi) \mid \exists(v,\pi'):((u,\pi),(v,\pi'))\in[\alpha]_f \}$$

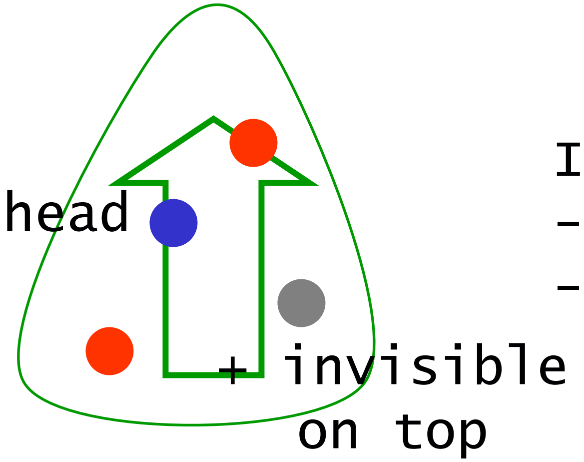
⇒ *look-ahead tests*

contents

pattern matching



I-PTA can
- evaluate *marked* trees
- test their visible configuration



I-PTA can
- evaluate *marked* trees
- test their ~~visible~~ configuration
observable

VI-PTA can test $\varphi(x_1,\ldots,x_n)$ with $n-2$ visible pebbles
(using head)

pattern matching

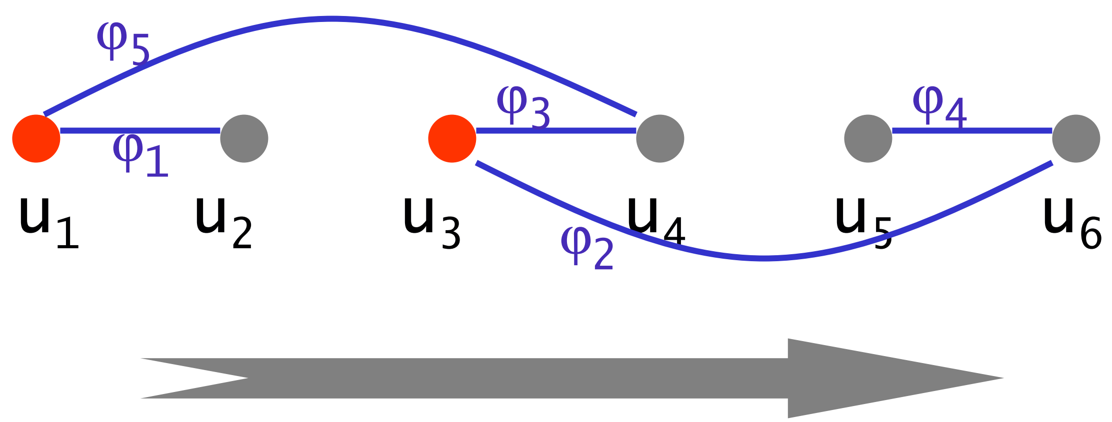
general test $\varphi(x_1,\dots,x_n)$

XQuery **for** $x_1,\dots,x_n$ **with** $\varphi_1\wedge\dots\wedge\varphi_n$ **return** t

φ_i binary

example

$\varphi_1(x_1,x_2)\wedge\varphi_2(x_3,x_6)\wedge\varphi_3(x_4,x_3)\wedge\varphi_4(x_5,x_6)\wedge\varphi_5(x_1,x_4)$



only 2 visible pebbles!

contents

conclusion

- extends known models

  V-PTT Milo,Suciu,Vianu

  I-PTT = TL Maneth etal. PODS'05

  DTL document transformation language

- MSO complete

- invisible pebbles are cheap

‘tossing Pebbles’

Joost Engelfriet
Hendrik Jan Hoogeboom
Bart Samwel
Leiden NL

thank you …