Mapping Human Creativity

H. Zedan, A. Cau
Keno Buss and Sascha Westendorf

Software Technology Research Laboratory (STRL)

June 11, 2008

STRL

```
gttgaggggtgttgagggcggagaaatgcaagtttcattacaaaagttaacgtaacaaa
aatctggtagaagtgagttttggatagtaaaataagtttcgaactctggcacctttcaat
tttgtcgcactctccttgtttttgaca


atgcaatcatatgcttctgctatgttaagcgtattcaacagcgatgattacagtccagct
 M  Q  S  Y  A  S  A  M  L  S  V  F  N  S  D  D  Y  S  P  A
gtgcaagagaatattcccgctctccggagaagctcttccttcctttgcactgaaagctgt
 V  Q  E  N  I  P  A  L  R  R  S  S  S  F  L  C  T  E  S  C
aactctaagtatcagtgtgaaacgggagaaaacagtaaaggcaacgtccaggatagagtg
 N  S  K  Y  Q  C  E  T  G  E  N  S  K  G  N  V  Q  D  R  V
aagcgacccatgaacgcattcatcgtgtggtctcgcgatcagaggcgcaagatggctcta
 L  R  P  M  N  A  F  I  V  W  S  R  D  Q  R  R  K  M  A  L
gagaatcccagaatgcgaaactcagagatcagcaagcagctgggataccagtggaaaatg
 E  N  P  R  M  R  N  S  E  I  S  K  Q  L  G  Y  Q  W  K  M
cttactgaagccgaaaaatggccattcttccaggaggcacagaaattacaggccatgcac
 L  T  E  A  E  K  W  P  F  F  Q  E  A  Q  K  L  Q  A  M  H
agagagaaatacccgaattataagtatcgacctcgtcggaaggcgaagatgctgccgaag
 R  E  K  Y  P  N  Y  K  Y  R  P  R  R  K  A  K  M  L  P  K
aattgcagtttgcttcccgcagatcccgcttcggtactctgcagcgaagtgcaactggac
 N  C  S  L  L  P  A  D  P  A  S  V  L  C  S  E  V  Q  L  D
aacaggttgtacagggatgactgtacgaaagccacacactcaagaatggagcaccagcta
 N  R  L  Y  R  D  D  C  T  K  A  T  H  S  R  M  E  H  Q  L
ggccacttaccgcccatcaacgcagccagctcaccgcagcaacgggaccgctacagccac
 G  H  L  P  P  I  N  A  A  S  S  P  Q  Q  R  D  R  Y  S  H
tggacaaagctgtag
 W  T  K  L  *


gacaatcgggtaacattg
gctacaaagacctacctagatgctccttttttacgataacttacagccctcactttcttat
gtttagtttcaatattgttttcttttctctggctaataaaggccttattcatttca
*********
```

- Modelling the **creative thinking process** is both hard and not new.
- Some dismiss the notion that creativity can be described as a sequence of steps in a model; and while such views are strongly held they are in the minority.
- At least a dozen of models have been proposed during the past century. Most have a common feature:

  they depend on a balance between analytical and synthetic thinking and usually describe the creative process as a sequence of phases that alternate between these states.

STRL

- Older models tend to imply that creative ideas result from subconscious processes, largely outside the control of the thinker.
- Modern models tend to imply purposefulgeneration of new ideas, under the direct control of the thinker.
- The total creative process requires a drive to action and the implementation of ideas. We must do more than simply imagine new things, we must work to make them concrete realities.

STRL

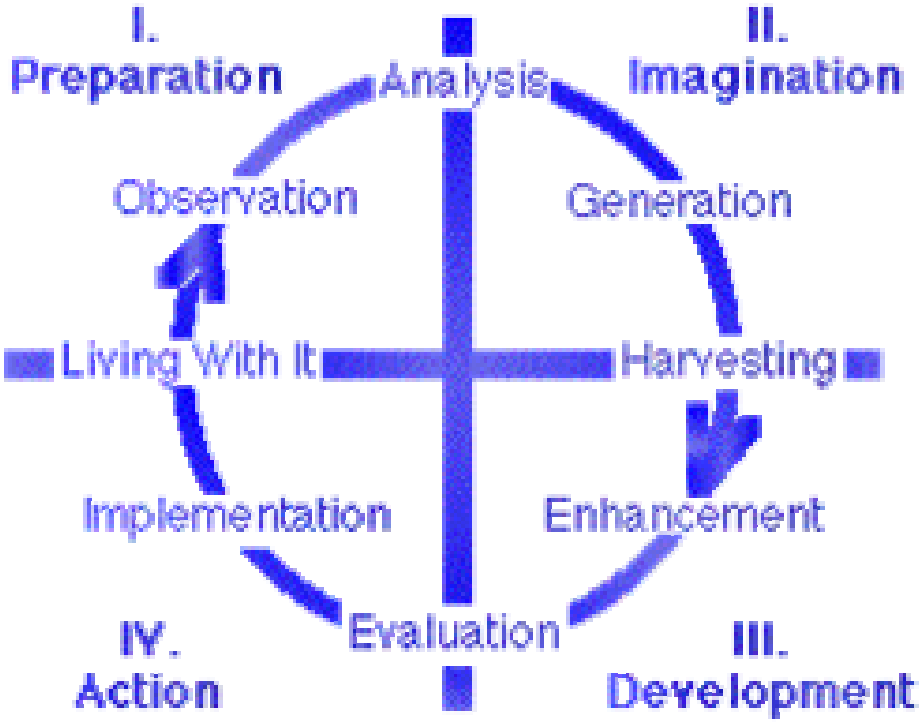
The Wallas Model for the Process of Creativity (1929)

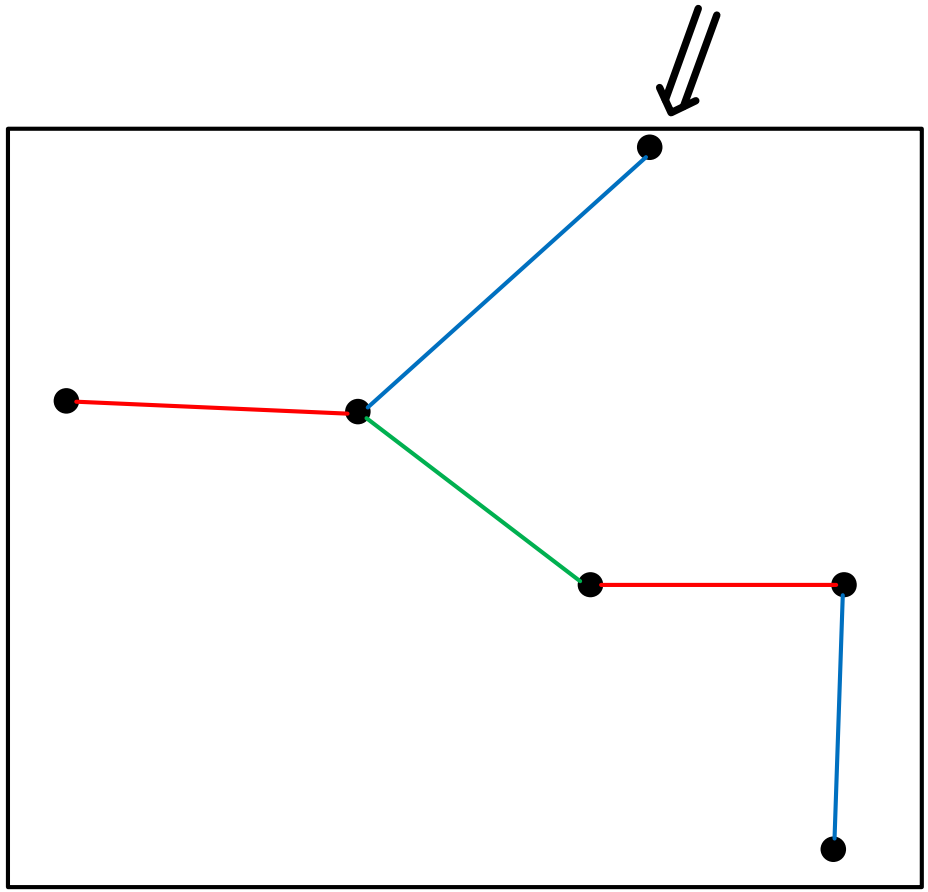
- Preparation (definition of issue, observation, and study)
- Incubation (laying the issue aside for a time)
- Illumination (the moment when a new idea finally emerges)
- Verification (checking it out)

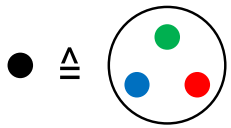
STRL

The implied theory behind Wallas' model – that creative thinking is a subconscious process that cannot be directed, and that creative and analytical thinking are complementary – is reflected to varying degrees in other models of creativity.

The Directed Creativity Cycle (Paul Plsak, 1996)

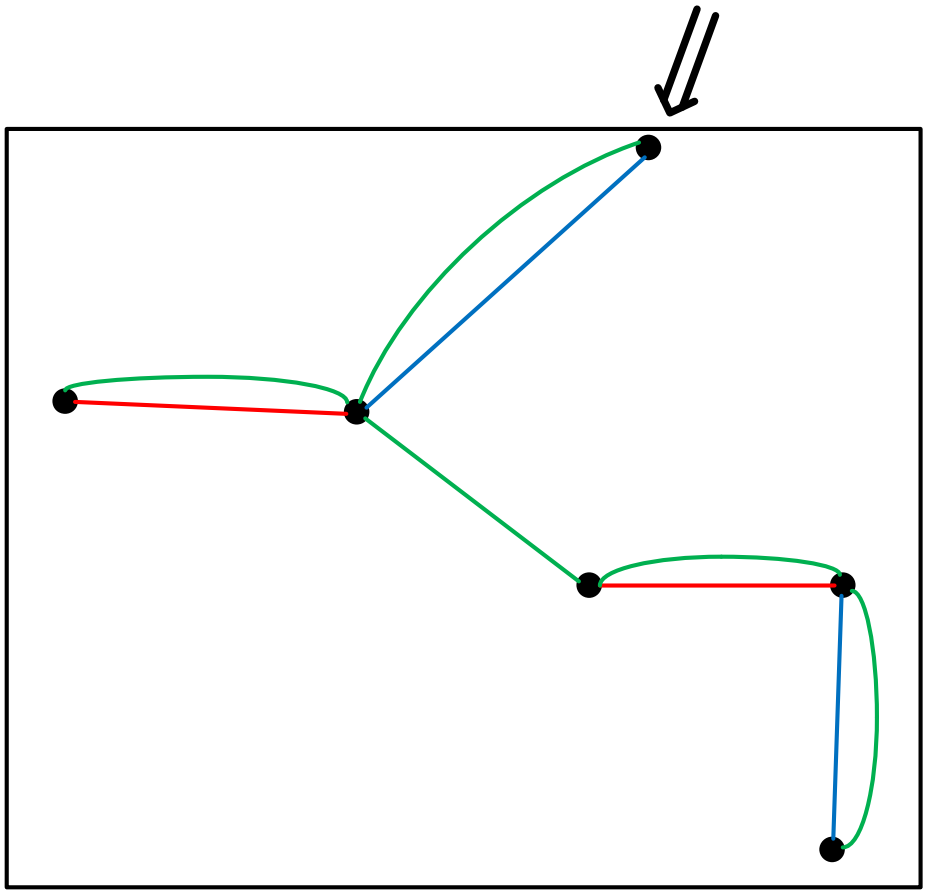


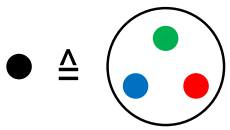




Multiple Views
(Universe!)

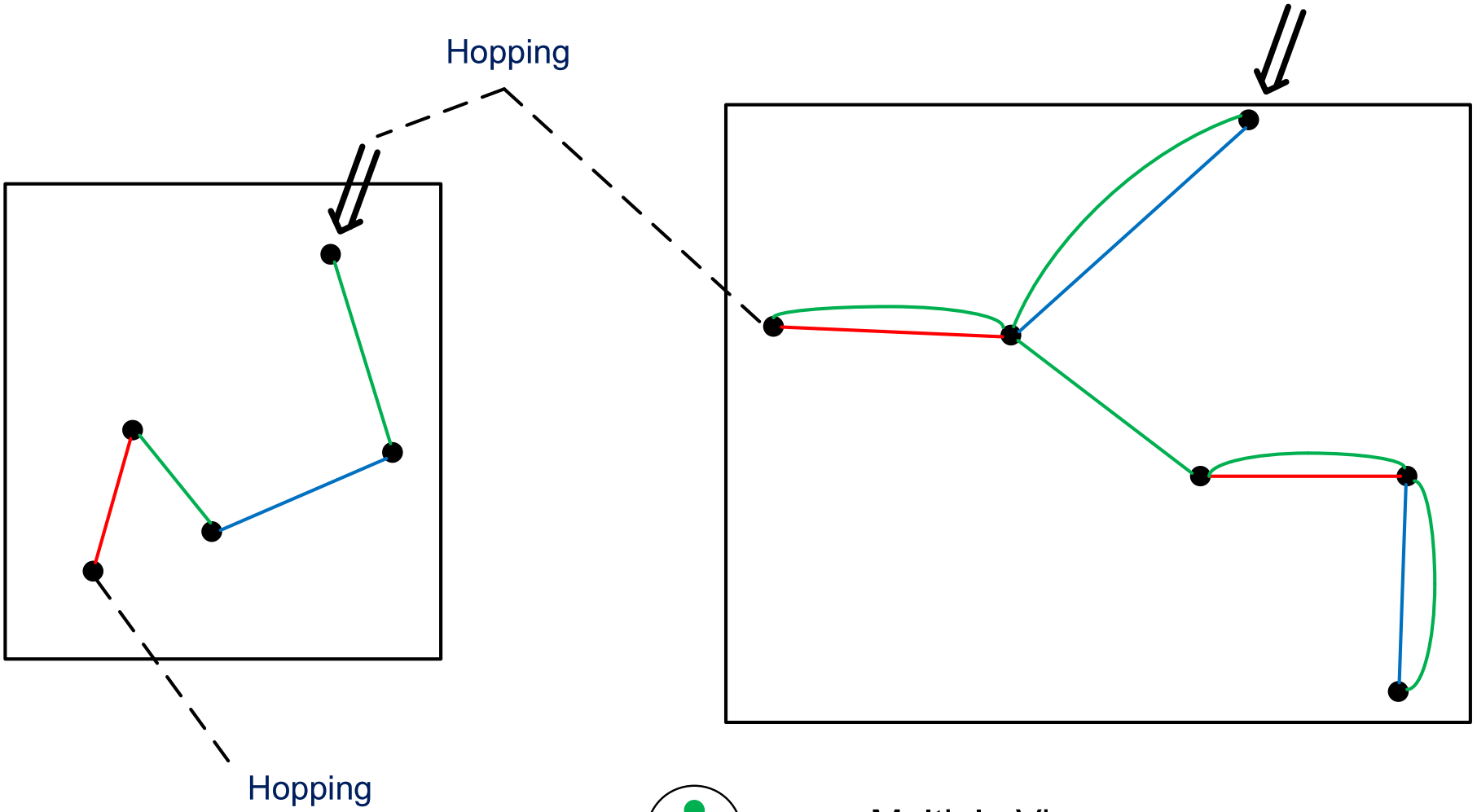
STRL

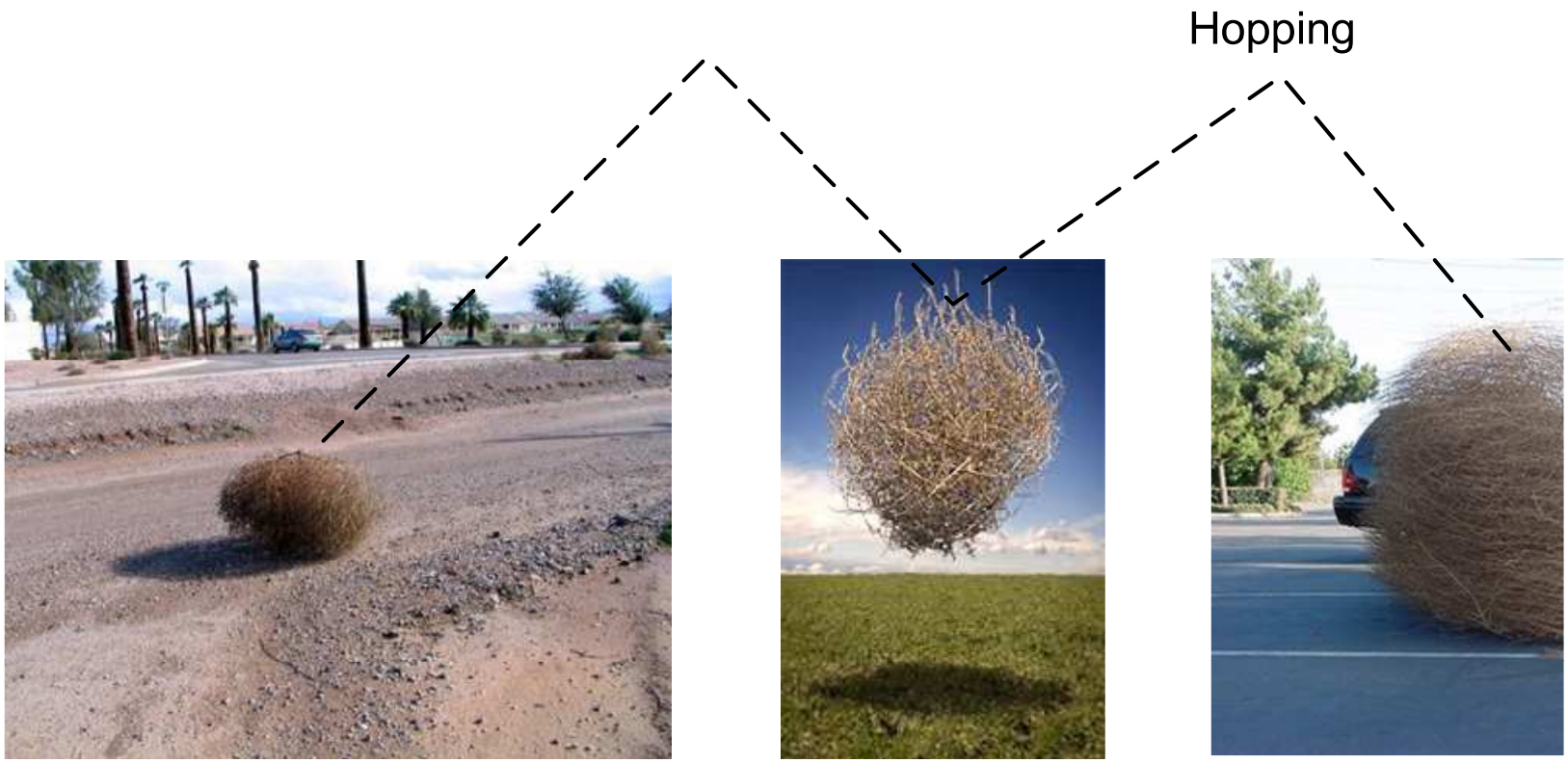




Multiple Views
(Universe!)

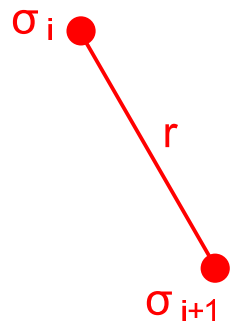
STRL


Hopping
Hopping
≙
Multiple Views
(Universe!)


Hopping

Transitions & Transition Systems

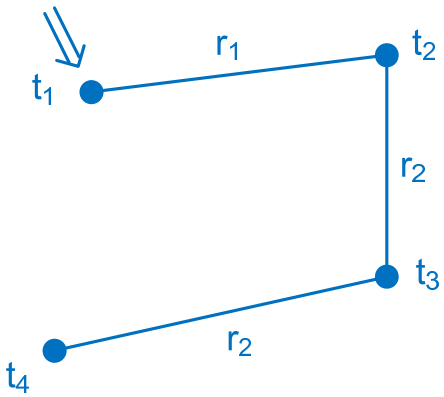
- Let Σ be a set of states ,
  $\sigma_i \in \Sigma$,
  $\sigma_i : Var \rightarrow Val$
- A transition r (sometimes denoted by $\rightarrow_r$)
  is a relation
  $r \in \Sigma x \Sigma$
- Let R be a set $s \cdot t$. $r \in R$, i.e.,
  $R \in P(\Sigma x \Sigma)$



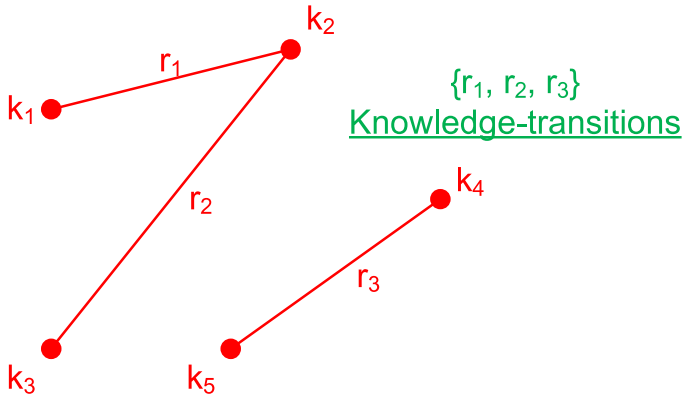
STRL

- (Σ, R) is called a Transition System

Clock



Knowledge



$Var = Clock$
$Val = \mathbb{N}$

$\rightarrow$ $t_i\ r_1\ t_{i+1} \mathrel{\widehat{=}} (t_{i+1} = t_i + 1)$

$\rightarrow$ $t_i\ r_2\ t_{i+1} \mathrel{\widehat{=}} (t_{i+1} \geq t_i)$

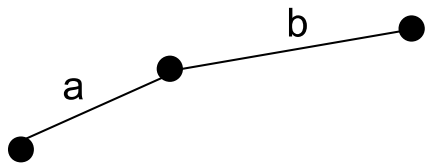
r_1, r_2 is a Clock-transition

Var = Knowledge
Val = $k_1, k_2, k_3, ...$

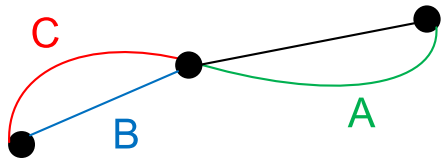
- $k_2\ r_2\ k_3 \mathrel{\widehat{=}} (k_2 = k_3)$
- $k_2\ r_1\ k_1 \mathrel{\widehat{=}} (k_1 > k_2)$
- $k_4\ r_3\ k_5 \mathrel{\widehat{=}} (k_5 \leq k_4)$

STRL

Classic transition systems use fixed relation between states.
Actions are used to label transition.



In our Generalised Transition System, there may be more than one relation between states.
Actions vary from one relation to another.



STRL

Operators & Functions

- For a given transition

$$\sigma_i \; r \; \sigma_j$$

St: $\Sigma \times \Sigma \rightarrow \Sigma$

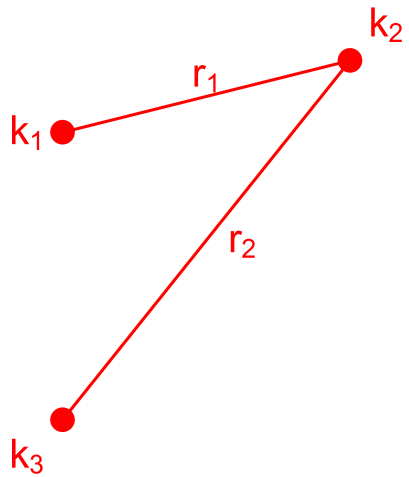
$\sigma_i \; r \; \sigma_j \mapsto \sigma_i$

Et: $\Sigma \times \Sigma \rightarrow \Sigma$

$\sigma_i \; r \; \sigma_j \mapsto \sigma_j$

Knowledge

$$St(r_1) = St(r_2) = k_2$$
$$Et(r_2) = k_3$$
$$Et(r_1) = k_1$$



STRL

- Obviously

$$St(R) \widehat{=} \bigcup_{r \in R} St(r)$$

$$Et(R) \widehat{=} \bigcup_{r \in R} Et(r)$$

ϵ-transition

For any Σ, an ϵ-transition is defined as

$$\forall s \in \Sigma : \quad s \in s.$$

ANY-transition

For any Σ, an Any-transition is defined as

$$ANY \mathrel{\widehat{=}} \Sigma \times \Sigma$$

(all possible transitions)

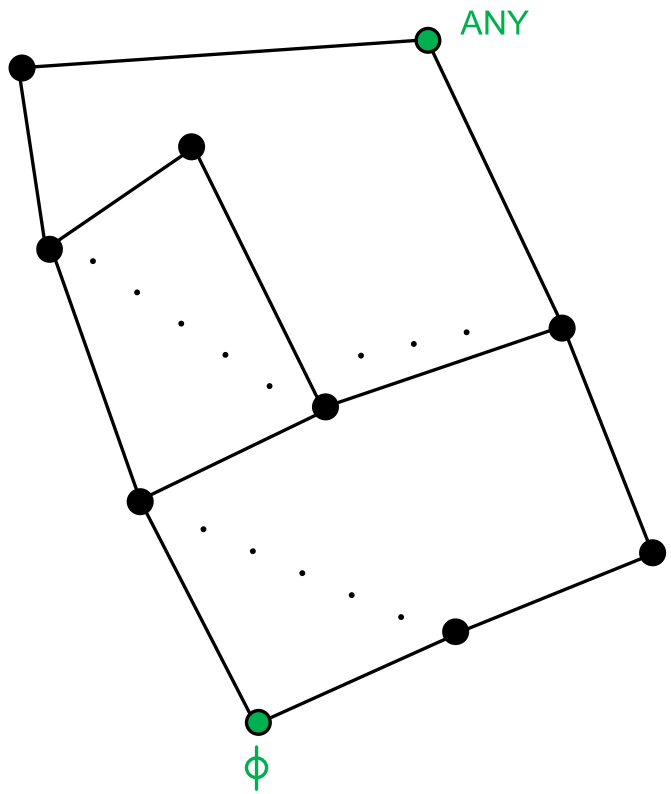
STRL

NULL-transition

For any Σ, a NULL-transition, ϕ, is

$$\forall \sigma, r \in \Sigma : \quad \neg(\sigma \phi r)$$

- ANY is maximal relation
- ϕ is mininmal relation.

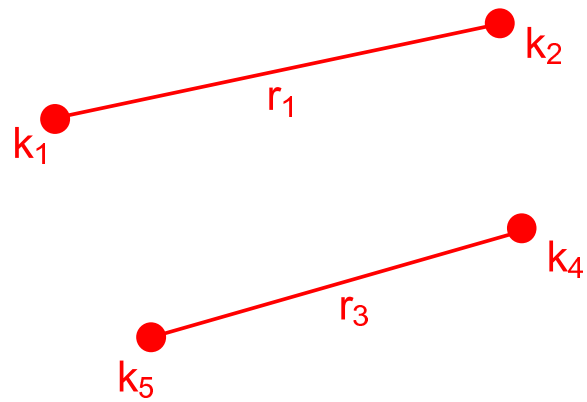


STRL

OR:

$$\rightarrow_{r_1} + \rightarrow_{r_2} \widehat{=} \{(\sigma_i, \sigma_j) : (\sigma_i \rightarrow_{r_1} \sigma_j) \vee (\sigma_i \rightarrow_{r_2} \sigma_j)\}$$

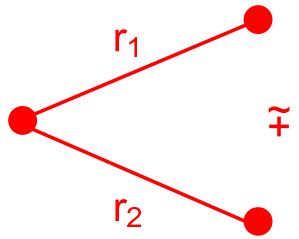
$$\rightarrow_{r_1} + \rightarrow_{r_2} = \{(k_2, k_1), (k_4, k_5)\}$$



STRL

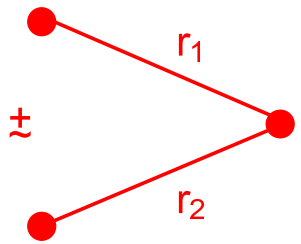
- $\rightarrow_{r_1} \tilde{+} \rightarrow_{r_2} \widehat{=} \begin{cases} \rightarrow_{r_1} + \rightarrow_{r_2}, & St(\rightarrow_{r_1}) = St(\rightarrow_{r_2}) \wedge \\ & Et(\rightarrow_{r_1}) \neq Et(\rightarrow_{r_2}) \\ \phi & otherwise \end{cases}$

Branching



- $\rightarrow_{r_1} \overset{+}{\sim} \rightarrow_{r_2} \widehat{=} \begin{cases} \rightarrow_{r_1} + \rightarrow_{r_2}, & Et(\rightarrow_{r_1}) = Et(\rightarrow_{r_2}) \wedge \\ & St(\rightarrow_{r_1}) \neq St(\rightarrow_{r_2}) \\ \phi & otherwise \end{cases}$

Merge



Sequential

For any Σ and $\rightarrow_{r_i}$,

$\sigma_1 \bullet \rightarrow_{r_i} \bullet\sigma_2 \; ; \; \sigma_3 \bullet \rightarrow_{r_j} \bullet\sigma_4 \mathrel{\widehat{=}}$

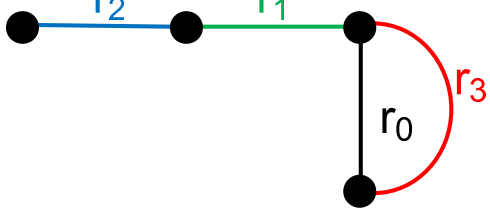
$$\begin{cases} \sigma_1 \bullet \rightarrow \bullet\sigma \rightarrow \bullet\sigma_4 & , \sigma = \sigma_2 = \sigma_4 \\ \textit{null} & , \textit{otherwise} \end{cases}$$

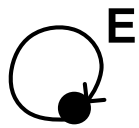
STRL

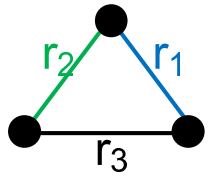
Sequential-Path $\rightarrow^*$

For any Σ, $\rightarrow^*$ is defined as:

$$\rightarrow^* \widehat{=} \in + \rightarrow j \rightarrow^*$$







Algebraic Properties

- $NULL + \rightarrow_r = \rightarrow_r = \rightarrow_r + NULL$
- $\epsilon; \rightarrow_r = \rightarrow_r = \rightarrow_r; \epsilon$
- $ANY + \rightarrow_r = ANY = \rightarrow_r + ANY$
- $NULL; \rightarrow_r = NULL = \rightarrow_r; NULL$ (finite)
- $NULL^* = \epsilon$
- $\epsilon^* = \epsilon$
- $ANY^* = T \qquad (T = (\Sigma \times \Sigma)^*)$

- $\rightarrow_r ; (\rightarrow_t + \rightarrow_w) = (\rightarrow_r ; \rightarrow_t) + (\rightarrow_r ; \rightarrow_w)$
- $\rightarrow_r + (\rightarrow_t + \rightarrow_w) = (\rightarrow_r + \rightarrow_t) + \rightarrow_w$
- $\rightarrow_r ; (\rightarrow_t ; \rightarrow_w) = (\rightarrow_r ; \rightarrow_t) ; \rightarrow_w$

STRL

- $\rightarrow_r^* = \epsilon + \rightarrow_r ; \rightarrow_r^*$
  $= \epsilon + \rightarrow^* ; \rightarrow_r$

- $(\rightarrow_t + \rightarrow_r)^* = \rightarrow_t^* ; (\rightarrow_r ; \rightarrow_t^*)*$

- $\rightarrow_{r_1} + \rightarrow_{r_1} = \rightarrow_{r_1}$

PLUS Many More!

STRL

In our generalised transition system,
we may be interested in

$< T, \rightarrow_T >$ Time

$< K, \rightarrow_K >$ Knowledge

$< A, \rightarrow_A >$ Artifact

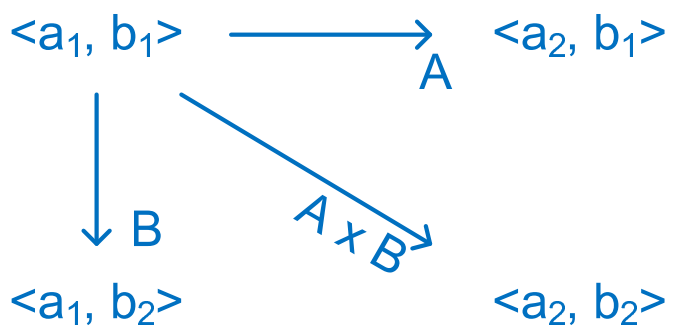
Product

$$< A, \rightarrow_A > \times < B, \rightarrow_B > \widehat{=} < A \times B, \rightarrow_A \times \rightarrow_B >,$$

$$\rightarrow_A \times \rightarrow_B = \{ << a_1, b_1 >, < a_2, b_2 > \mid$$

$$a_i \in A, b_i \in B \wedge$$

$$a_1 \rightarrow_A a_2 \wedge b_1 \rightarrow_B b_2 \}$$

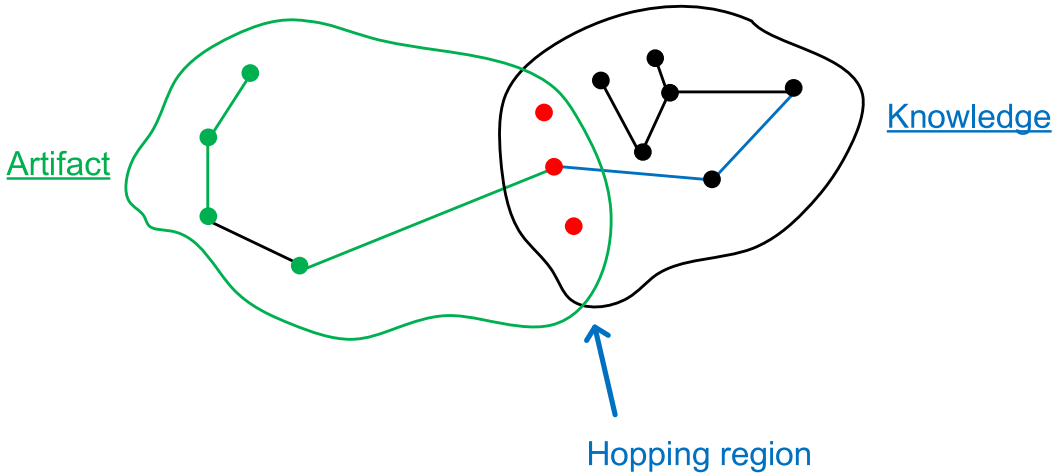


Union

$$< A, \rightarrow_A > \cup < B, \rightarrow_B > = < A \cup B, \rightarrow_A \cup \rightarrow_B >$$

Hopping

- If $A \cap B \neq \phi$, then hopping is possible



Creative System

A creative system $< C, \rightarrow_c >$ is defined as

$$< C, \rightarrow_C > \widehat{=} < T, \rightarrow_T > \times [< A, \rightarrow_A > \cup < K, \rightarrow_K >]$$

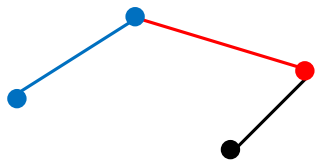
We need to fin a way to glue transition systems together.

Behaviours

Given Σ, a behaviour is defined as

$$B \subset (\Sigma \times \Sigma)^*$$

Cor. A Path is a singe Behaviour.



STRL

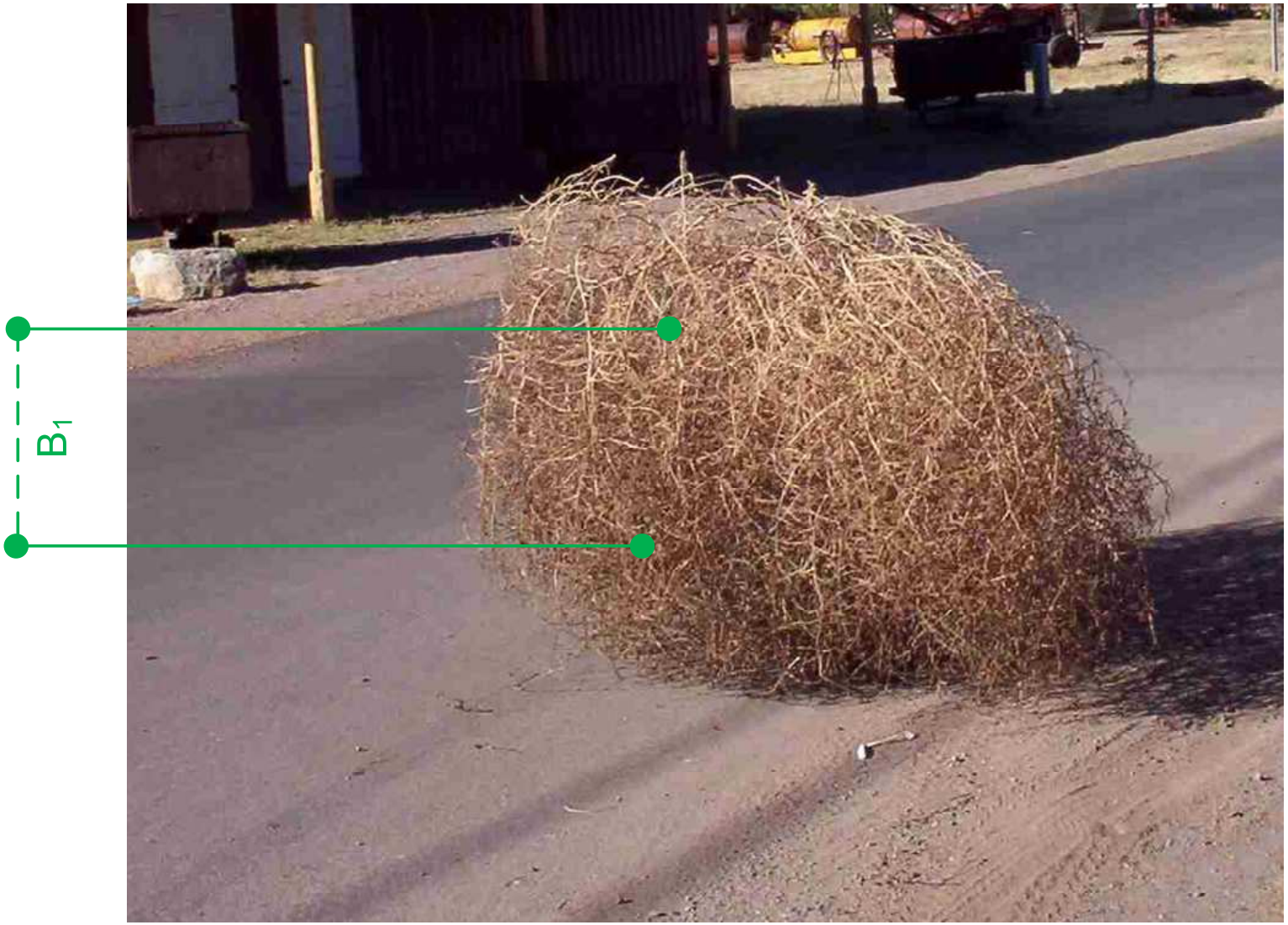
Creative Process

A creative process is a behaviour.

In fact $(\Sigma \times \Sigma)^*$ is a set of all possible creative paths.

$(\Sigma \times \Sigma)^*$ and any of its subsets, each is Tumbleweed.

STRL



STRL

The Hugill Creativity Map!

$K = \textit{Reading}, \textit{Contemplate}, \textit{Inspiration}$

$A = \textit{Experimenting}, \textit{Creating}$

$\mathrm{T} = 40$ minutes

STRL

$[T = 40][R; (C|I|E)]$