Command line completion (CLC)

an illustration of learning and decision making using the imprecise Dirichlet model

Erik Quaeghebeur

Classical CLC in action

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Password:
Last login: Tue Feb 17 08:24:47 on tty1
command-prompt$ _
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command-prompt$ ls<ENTER>
mail/    logic.dvi    logic.tex
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command-prompt$ dvips log_
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mail/    logic.dvi    logic.tex
command-prompt$ dvips log<TAB>
logic.dvi    logic.tex
command-prompt$ dvips logic.d<TAB>
command-prompt$ dvips logic.dvi _
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Properties of classical CLC

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  - return the unique completion.

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  - return the unique completion.
- Rule-based:
  - allows for context dependency, and
  - requires a categorized database of commands.
- User independent:
  - reliable, but
  - does not take command history into account.

Complementing classical CLC

We want to take the command-history into account:

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We want to take the command-history into account:

- Whenever there are multiple completions possible.
- By building and updating a model for the user's behavior.
- To add completion action types, such as
  - returning the 'best guess' completion on the command line,
  - listing a set of 'best guesses',
  - listing all possible completions, but ordered.

The set of possible completions

Two illustrative completions:

- ```
  command-prompt$ ha<TAB>
  halt    hash
  ```

- ```
  command-prompt$ pin<TAB>
  pine    ping    pinky
  ```

The set of possible completions

Two illustrative completions:

- `command-prompt$ ha<TAB>`
  `halt    hash`

  $$\Rightarrow \Omega_{\texttt{ha}} = \{\texttt{halt}, \texttt{hash}\} \ni \omega_{\texttt{ha}}$$

- `command-prompt$ pin<TAB>`
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  $$\Rightarrow \Omega_{\texttt{pin}} = \{\texttt{pine}, \texttt{ping}, \texttt{pinky}\} \ni \omega_{\texttt{pin}}$$

The user as a multinomial process

Model of the user's behavior:

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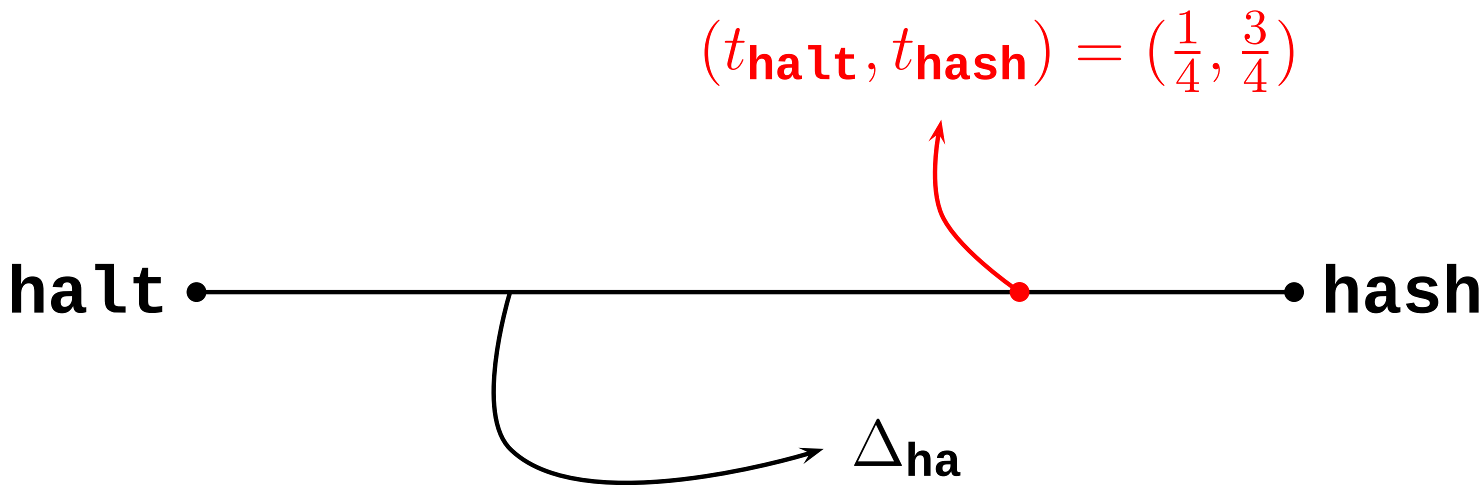
Graphical representation of a user:



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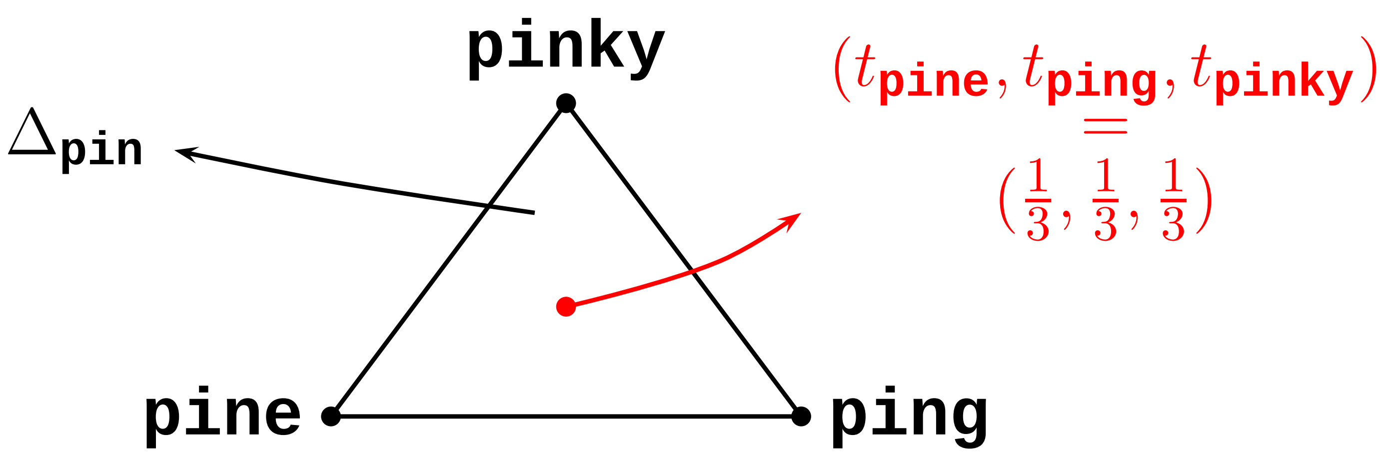

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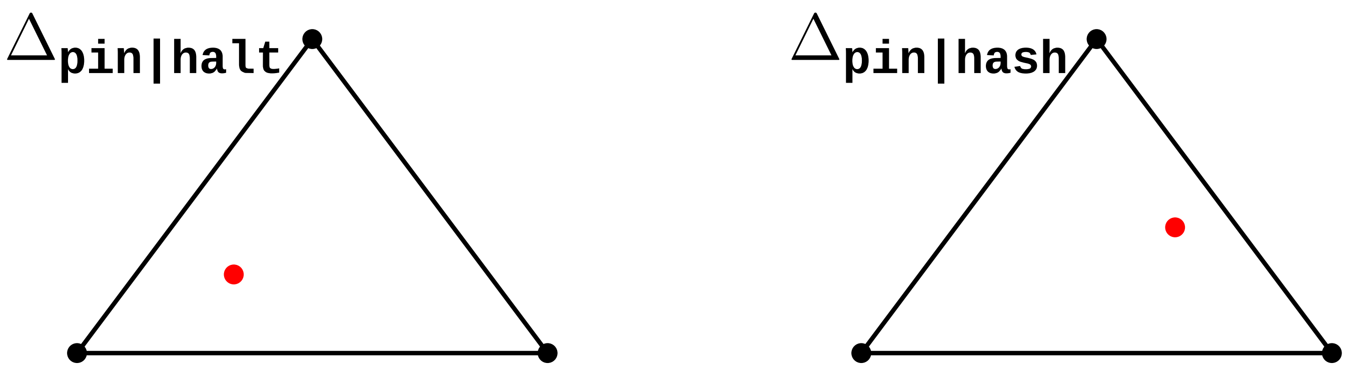

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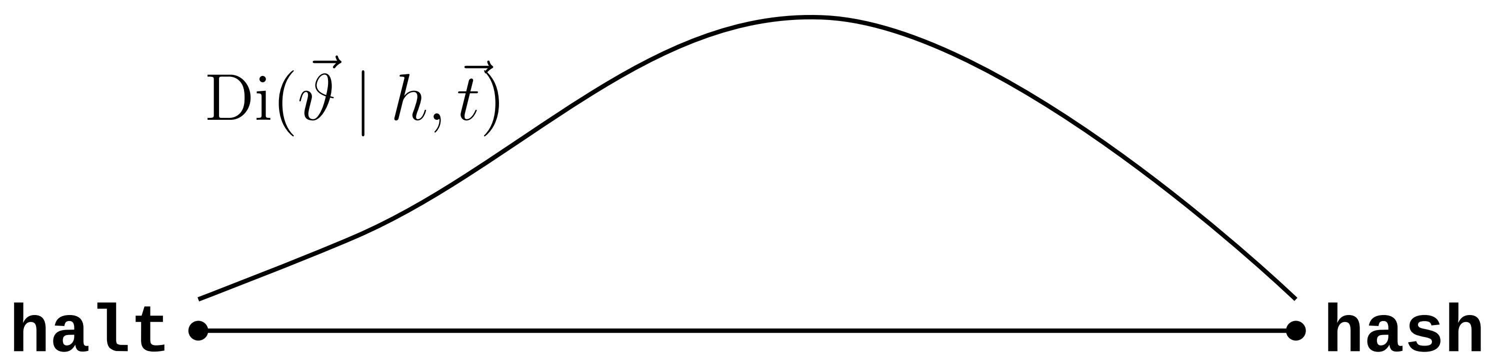

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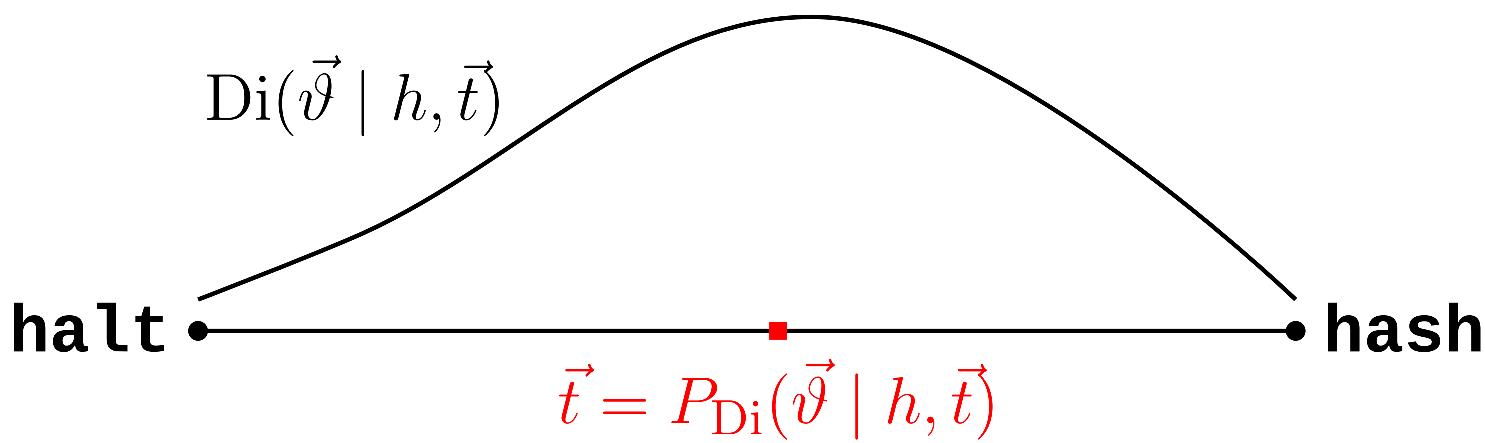

$$P_{\mathrm{Di}}(X \mid h, \vec{t}) = \int_{\Delta_{\mathbf{ha}}} X(\vec{\vartheta})\mathrm{Di}(\vec{\vartheta} \mid h, \vec{t})\mathrm{d}\vec{\vartheta}$$

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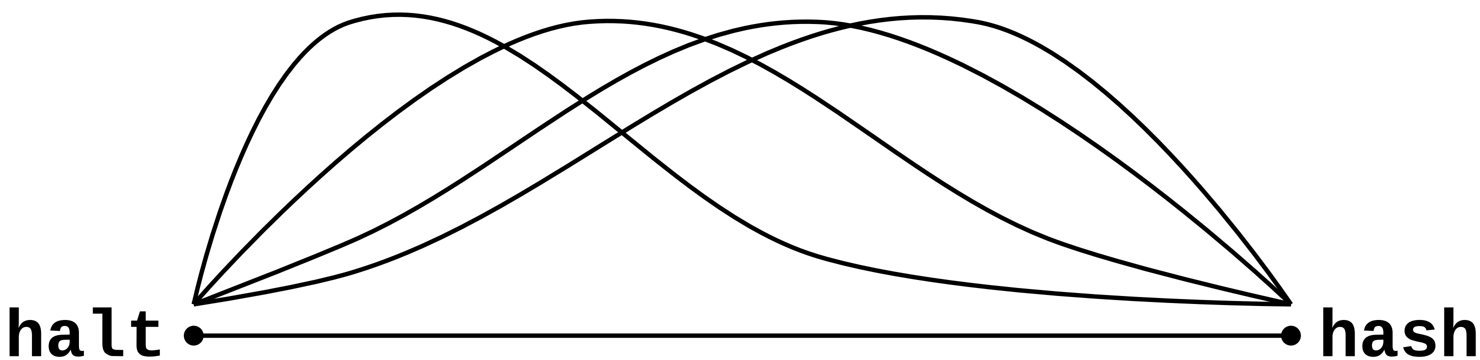

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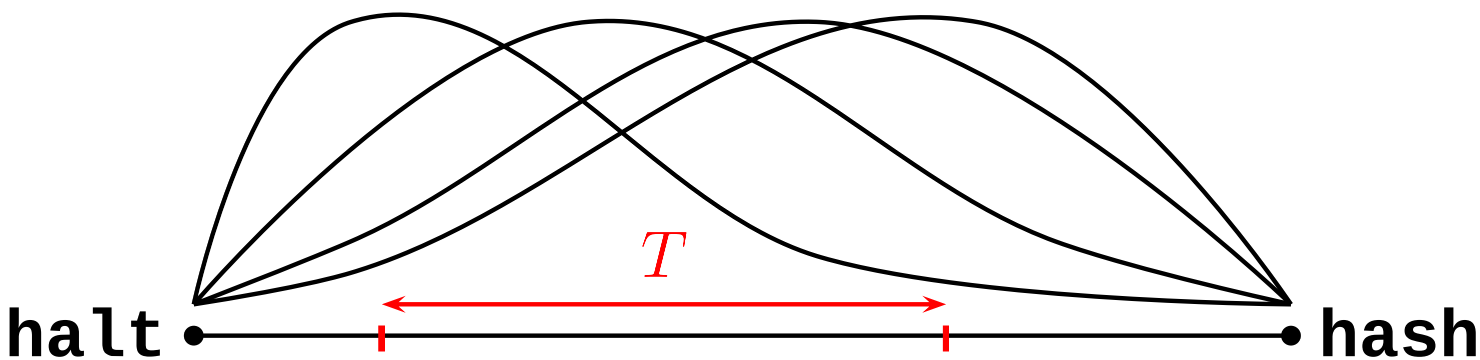

$$\underline{\vec{t}} = \underline{P}(\vec{\vartheta} \mid h, T) \qquad \overline{\vec{t}} = \overline{P}(\vec{\vartheta} \mid h, T)$$

$$\underline{P}_{\mathrm{Di}}(X \mid h, T) = \inf_{\vec{t} \in T} P_{\mathrm{Di}}(X \mid h, \vec{t})$$

$$\overline{P}_{\mathrm{Di}}(X \mid h, T) = \sup_{\vec{t} \in T} P_{\mathrm{Di}}(X \mid h, \vec{t})$$

Observations, Sufficient statistics, and . . .

- Observations:
  - (a sequence of) executed commands for the multinomial model, or
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Observations, Sufficient statistics, and ...

- Observations:
  - (a sequence of) executed commands for the multinomial model, or
  - (a sequence of) consecutively executed commands for the Markov model.
- Keep what's relevant for the model: *sufficient statistic*,
  - the number of occurrences of the commands $\vec{n}$, or
  - the number of occurrences of a transition between commands N.

…Likelihood functions

- *Likelihood function*: likelihood of an exact model given the observations,
  - a multinomial distribution $L_{\vec{n}}(\vec{\vartheta})$, or
  - a Whittle distribution $L_N(\Theta)$, proportional to the product of the $L_{\vec{n}}(\vec{\vartheta})$ for each of the previous commands.

Learning using a PDM/IDM

- Updating a Dirichlet distribution using Bayes' rule:

$$f(\vec{\vartheta} \mid h, \vec{t}, \vec{n}) = \frac{\mathrm{Di}(\vartheta \mid \vec{h}, \vec{t}) L_{\vec{n}}(\vec{\vartheta})}{P(L_{\vec{n}} \mid h, \vec{t})}$$

$$= \mathrm{Di}(\vartheta \mid h_n = h + \vec{n}, \vec{t}_n = \frac{h\vec{t} + \vec{n}}{h + n}).$$

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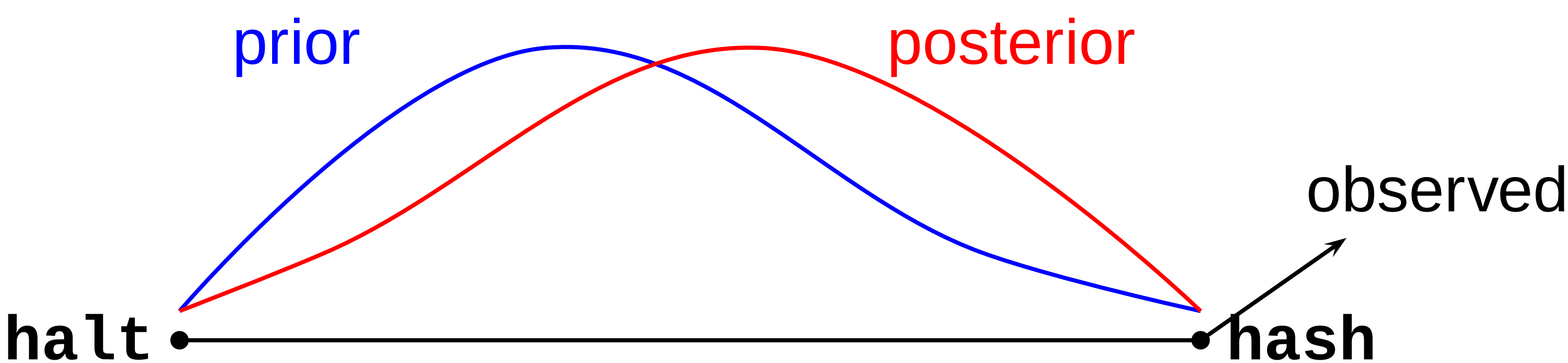

Learning using a PDM/IDM

- Updating a PDM is updating the underlying distribution:

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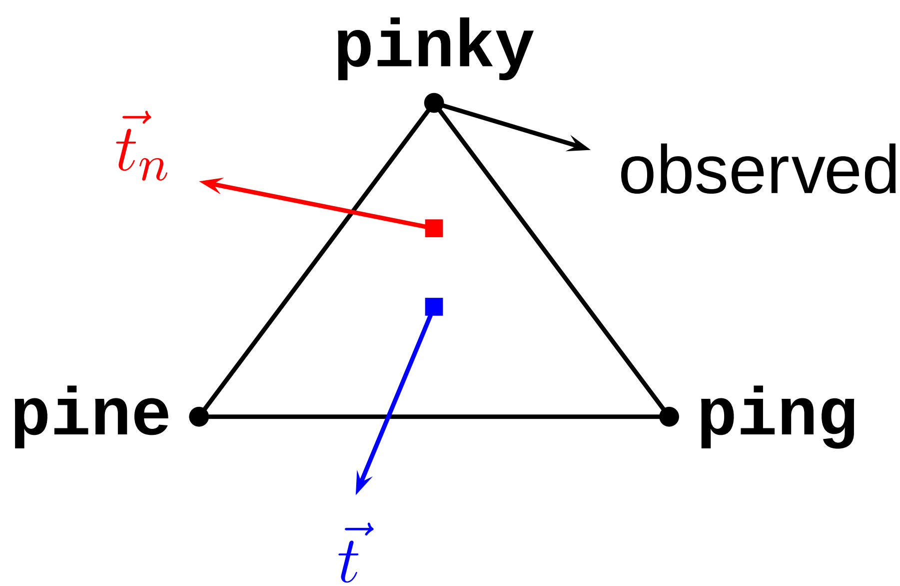

Learning using a PDM/IDM

- Updating an IDM comes down to updating the corresponding (set of) PDM's:

$$\underline{P}(X \mid h_n, T_n) =$$

$$\inf\{P(X \mid h_n, \vec{t}_n) \;\mid\; h_n = h + n, \vec{t}_n = \frac{h\vec{t} + \vec{n}}{h+n}, \vec{t} \in T\}.$$

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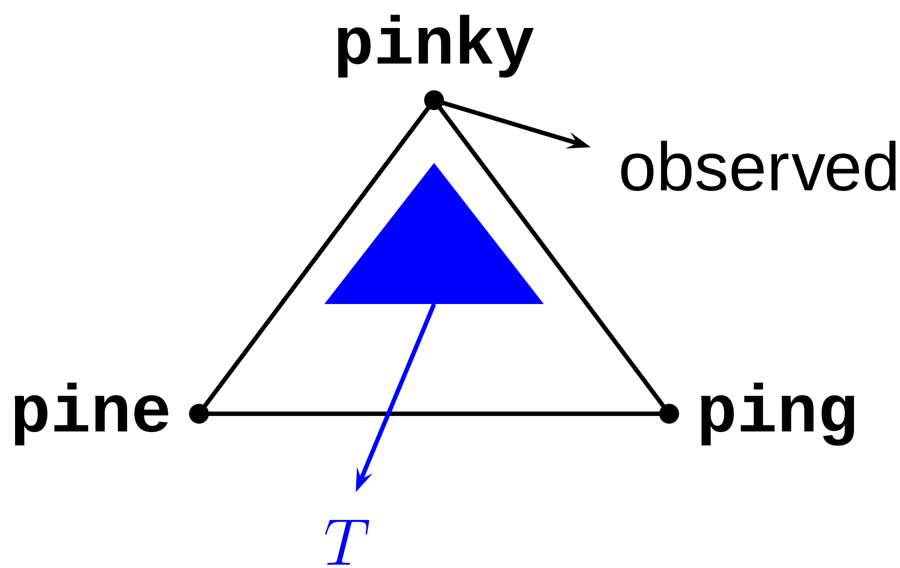

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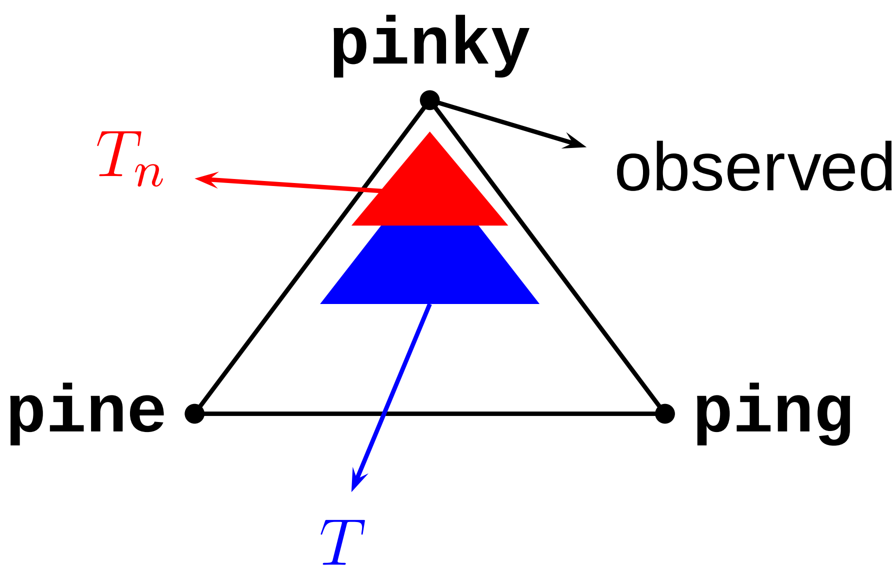

Actions and (expected) utility

- Each completion action has a certain utility for the user (part of the model of the user). Let a gamble X_a correspond to each action a.

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- The expected utility of an action:
  - when a PDM is used: $P(X_a \mid h, \vec{t})$,
  - when an IDM is used: $\underline{P}(X_a \mid h, T)$ and $\overline{P}(X_a \mid h, T)$.

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- The expected utility of an action:
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  - when an IDM is used: $\underline{P}(X_a \mid h, T)$ and $\overline{P}(X_a \mid h, T)$.
- Choosing one action instead of another also has an expected utility. This is the prevision of the difference of the corresponding gambles ($P(X_a - X_b)$ or $\underline{P}(X_a - X_b)$).

Decision making: choosing an action

- Ordering the actions based on the expected utility of choosing one action over the other.

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- When using a PDM:
  - compare the actions:
    $a \succ b \iff P(X_a - X_b) > 0 \iff P(X_a) > P(X_b)$,
  - create an ordering of the actions,
  - identify the maximal action(s)
    a is maximal $\iff \forall b : P(X_a) \geq P(X_b)$.

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- When using an IDM:
  - compare the actions:
    $a \succ b \iff \underline{P}(X_a - X_b) > 0 \iff \overline{P}(X_b - X_a) < 0$,
  - create an ordering of the actions,
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    a is maximal $\iff \forall b : \overline{P}(X_a - X_b) \geq 0$.

Decision making: choosing an action

- Ordering the actions based on the expected utility of choosing one action over the other.
- PDM: complete ordering of actions.
- IDM: partial ordering of actions.

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- Choosing the maximal action:
  - Is there a unique maximal action?
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- Choosing the maximal action:
  - Is there a unique maximal action?
  - If there is a unique maximal action: choose it (e.g., returning a completion).
- The need for a default action:
  - Whenever there isn't a maximal action, then
  - choose this action (e.g., list the actions according to the ordering).

IDM-CLC in action

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login: erik
Password:
Last login: Wed Feb 18 09:25:48 on tty2
command-prompt$ _
```

IDM-CLC in action

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login: erik
Password:
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command-prompt$ pin<TAB>
pine      pinky
    ping
command-prompt$ pin_
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IDM-CLC in action

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login: erik
Password:
Last login: Wed Feb 18 09:25:48 on tty2
command-prompt$ pin<TAB>
pine    pinky
    ping
command-prompt$ pinky<ENTER>
erik, logged on since Wed Feb 18 12:13:38
command-prompt$ _
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command-prompt$ pin<TAB>
command-prompt$ hash<ENTER>
...[some text] ...
command-prompt$ _
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