Project Planning Under Temporal Uncertainty

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Project Planning

- Project schedule vital for SW developers
  - Calculate costs, meet project deadlines
- Support by present-day PM tools?
  - Highlighting off-schedule project threads
  - "Please provide adequate buffer times"
- AI planning offers effective support during project definition
  - Adequate formalism for capturing procedures and supporting abstract action specification
  - Reasoning about uncertainty
HTN Formalism

- STRIPS-like operator instances as primitive tasks
- Abstract actions represented by complex tasks
- Methods implement complex tasks by task networks

\[ o = (\text{prec}(o), \text{add}(o), \text{del}(o)) \]

\[ d = (T, \prec, V) \]

\[ m = (t, (T_t, \prec_t, V_t)) \]

\[ T' = (T \setminus t) \cup T_t \]

\[ \prec' = (\prec \setminus \prec_{\delta}) \cup \prec_t \cup \{(t_a, t_t) \mid (t_a, t) \in \prec, t_t \in T_t\} \cup \{(t_t, t_a) \mid (t, t_a) \in \prec, t_t \in T_t\} \]

\[ V' = V \cup V_t \]
Stochastics

- Continuous random variable
- Duration of operator
- Convolution for operator sequences
- Normal distribution
- Convolution computation
- Can approximate most stochastic processes

\[ r\nu(o) = \mathcal{X}_{\mathcal{N}(\mu, \sigma^2)} \]

\[
D_{\chi^1_{\mathcal{D}_1} + \chi^2_{\mathcal{D}_2}}(t) := \int_{-\infty}^{+\infty} D_1(\tau) D_2(t - \tau) d\tau
\]

\[ \mathcal{X}^i \sim \mathcal{N}(\mu_i, \sigma^2_i) : \]

\[
\sum_i \mathcal{X}^i \sim \mathcal{N} \left( \sum_i \mu_i, \sum_i \sigma^2_i \right)
\]
Probability of success

Convolute path operators

Approximate anti-derivate

Critical Path: minimal probability of success

\[ Pr[I + Y_i \geq 0] \]

\[ Pr[\mathcal{X}_N(\mu, \sigma^2) < a] := \int_{-\infty}^{a} \mathcal{N}(\mu, \sigma^2) dx \]

\[ = \int_{-\infty}^{a} \frac{1}{\sqrt{2\sigma^2 \pi}} e^{-\frac{(x-\mu)^2}{\sigma^2}} dx \]
Propagating Durations

- Preprocessing Phase
  - Compute underestimating distributions for paths in primitive task networks
  - Propagate into abstract tasks
  - Compute distributions for processed networks, etc.

- Heuristic for Task Expansion

\[
\min \left( \mathcal{X}_{\mathcal{N}(\mu_i, \sigma_i^2)} \right) := \mathcal{Y}_{\mathcal{N}(-\min_i(|\mu_i|), \min_i(\sigma_i^2))}
\]
Example

-2.7/0.8 Underestimation for SD/I

Propagated duration

-19/3.7 -11/2.1 -11/2.3 -2.7/0.8
Example

Project deadline is 36 days, acceptable prob. of success is 85%

\[ Pr[Z_{N(28.3, 2.8)} \geq 0] = Pr[I_{N(36, 0)} + Y^1_{N(-7.7, 2.8)} \geq 0] \approx 100\% \]
Example

\[ Pr[Z \sim N(-5,9.2) \geq 0] = Pr[I \sim N(36,0) + \chi^1_{N(-41,9.2)} \geq 0] \approx 4.96\% \]
Example

\[ Pr[Z_N(7,7.8) \geq 0] = Pr[I_N(36,0) + Y_N^1(-29,7.8) \geq 0] \approx 85.86\% \]
Conclusion

- HTN Planning with probabilistic action durations and resource consumption for risky scenarios
- Propagation of distribution under-estimations for cutting futile expansions
- Implemented in a multi-agent based planning framework