Modelling role-playing games using PEPA nets

Leïla Kloul

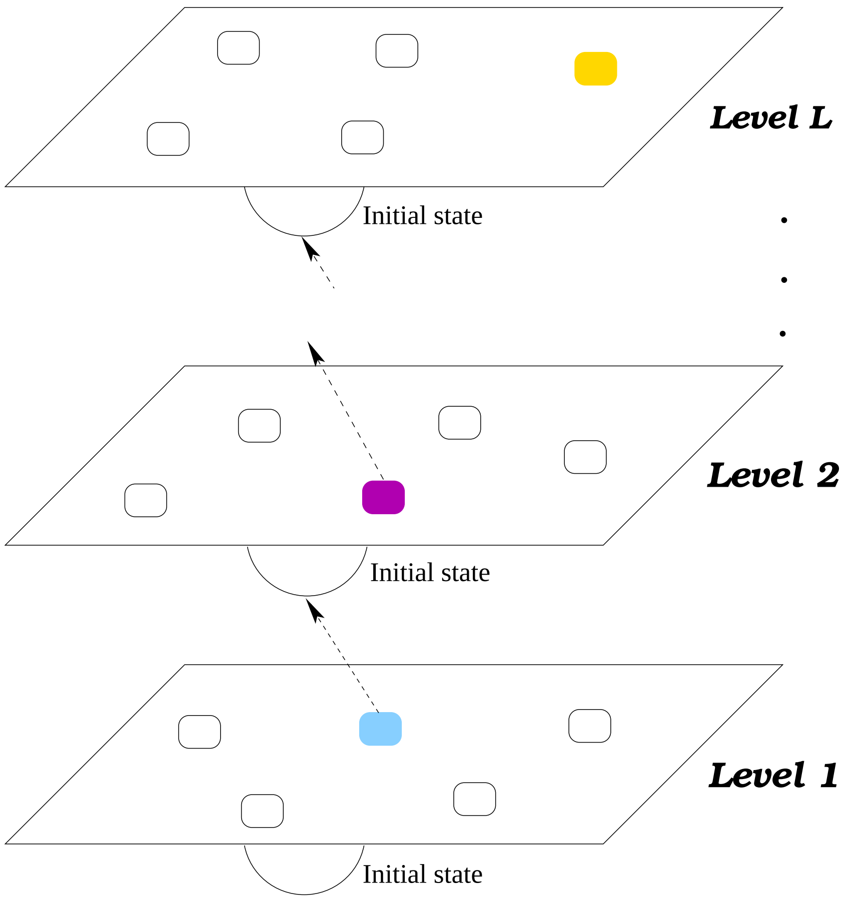
Join work with S. Gilmore and D. Piazza

Outline

- The Role-playing game (MMPORG)
- PEPA nets formalism
- Applying PEPA nets to the MMPORG
- The Model analysis
  - Flow-equivalent replacement technique
  - Model solution
  - Performance criteria
- Model results

The Role-playing game

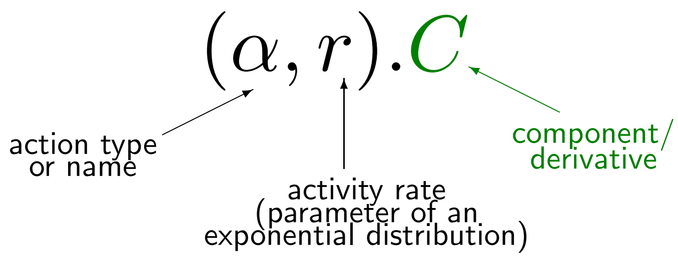
- Characters
  - Players
  - Non playing characters
- Rewards
  - Objects (weapons, medecine, food, ...)
  - Cards (increase the offensive and defensive skills)
  - Points



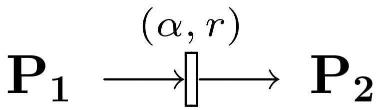
PEPA nets

Combination of *coloured stochastic Petri nets* and *process algebras PEPA* to form a single, *structured* performance modelling formalism.

- The colours used as the tokens of the net are PEPA components.



- Net transitions labelled by PEPA activities



PEPA nets

- Transition
  - models *small-scale changes* of state as components undertake activities (individually or in cooperation).
  - has *local* effect as it causes a change *only* in the place hosting the PEPA component.

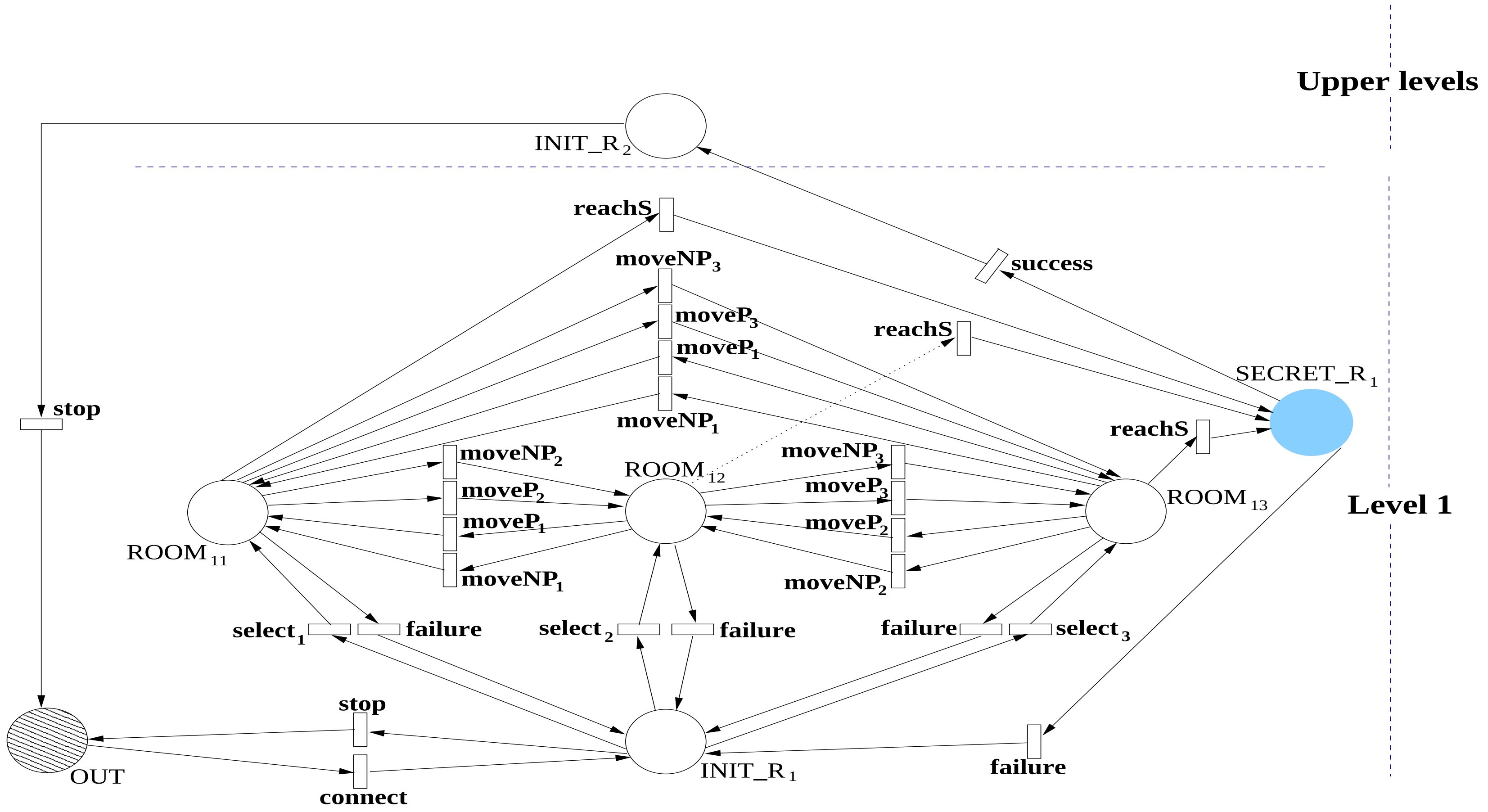
- Firing
  - models *macro-step changes* of state as one token (PEPA component) is transferred from one place to another.
  - causes a change in *both* the *input place* (existing co-operations can now no longer take place) and the *output place* (previously disabled cooperations are now enabled).

PEPA nets (syntax)

$$
\begin{array}{rcll}
S & ::= & & (\textit{sequential components}) \\
 & & (\alpha, r).S & (\textit{prefix}) \\
 & | & S + T & (\textit{choice}) \\
 & | & I & (\textit{identifier}) \\
\\
P & ::= & & (\textit{model components}) \\
 & & P \underset{L}{\bowtie} Q & (\textit{cooperation}) \\
 & | & P/L & (\textit{hiding}) \\
 & | & I & (\textit{identifier}) \\
 & | & P[C] & (\textit{cell})
\end{array}
$$

$$
\begin{array}{rcll}
C & ::= & & (\textit{cell terms}) \\
 & & \text{‘\_’} & (\textit{empty}) \\
 & | & P & (\textit{component})
\end{array}
$$

Applying PEPA nets to MMPORG



The PEPA net model

- **Component Player**

$$
\begin{aligned}
Player &\stackrel{\text{def}}{=} (\mathbf{connect}, r).Player_0 \\
Player_0 &\stackrel{\text{def}}{=} \textstyle\sum_{i=1}^{N_j}(\mathbf{select_i}, p_i \times r_0).(RImage, \top).Player_1 + (\mathbf{stop}, s).Player \\
Player_1 &\stackrel{\text{def}}{=} (observe, \alpha_1).Player_1 + (walk, \alpha_2).Player_1 + (talk, \alpha_3).Player_1 \\
&+ (fightNP, \beta_1).Player_{21} + (fightP, \beta_2).Player_{31} \\
&+ (use_{obj}, \delta_1).Player_4 + (take_{obj}, \delta_2).Player_5 \\
&+ \textstyle\sum_{i=1}^{N_j-1}(\mathbf{moveP_i}, q_i \times r_1).Player_1 + (\mathbf{reachS}, r_2).Player_{70}
\end{aligned}
$$

$$
\begin{aligned}
Player_{21} &\stackrel{\text{def}}{=} (PlossNP, \top).Player_{22} + (PwinNP, \top).Player_{23} \\
Player_{22} &\stackrel{\text{def}}{=} (less_{pts}, \gamma_1).Player_1 + (zero_{pts}, \gamma_2).Player_6 \\
Player_{23} &\stackrel{\text{def}}{=} (new_{crd}, \gamma_3).Player_1
\end{aligned}
$$

The PEPA net model

$$
\begin{aligned}
Player_{31} &\stackrel{\text{def}}{=} (PlossP, \top).Player_{32} + (PwinP, \top).Player_{33} \\
Player_{32} &\stackrel{\text{def}}{=} (less_{pts}, \gamma_1).Player_1 + (zero_{pts}, \gamma_2).Player_6 \\
Player_{33} &\stackrel{\text{def}}{=} (get_{pts}, \gamma_4).Player_1
\end{aligned}
$$

$$
\begin{aligned}
Player_{4} &\stackrel{\text{def}}{=} (less_{pts}, \gamma_1).Player_1 + (get_{pts}, \gamma_4).Player_1 + (zero_{pts}, \gamma_2).Player_6 \\
Player_{5} &\stackrel{\text{def}}{=} (accept_{obj}, \top).Player_1 + (refuse_{obj}, \top).Player_1 \\
Player_{6} &\stackrel{\text{def}}{=} (\mathbf{failure}, f).Player_0
\end{aligned}
$$

$$
\begin{aligned}
Player_{70} &\stackrel{\text{def}}{=} (RImage, \top).(test, \beta_3).Player_7 \\
Player_{7} &\stackrel{\text{def}}{=} (win, \top).Player_8 + (lose, \top).Player_6 \\
Player_{8} &\stackrel{\text{def}}{=} (get_{pts}, \gamma_4).(\mathbf{success}, c).Player_0
\end{aligned}
$$

The PEPA net model

- **Component NPlayer**

$$
\begin{aligned}
NPlayer &\stackrel{\text{def}}{=} (generateNP, \top).NPlayer_1 \\
NPlayer_1 &\stackrel{\text{def}}{=} (walk, \delta_1).NPlayer_1 + (talk, \top).NPlayer_1 \\
&+ (fightNP, \delta_2).NPlayer_2 + \textstyle\sum_{i=1}^{N-1}(\mathbf{moveNP_i}, q_i \times v_1).NPlayer_1 \\
NPlayer_2 &\stackrel{\text{def}}{=} (PlossNP, \top).NPlayer_1 + (PwinNP, \top).NPlayer_3 \\
NPlayer_3 &\stackrel{\text{def}}{=} (destroyNP, \top).NPlayer
\end{aligned}
$$

The PEPA net model

- **Component Room**

$$\begin{aligned}
Room &\stackrel{\text{def}}{=} (generateNP, \sigma_1).Room + (RImage, \sigma).Room + (fightP, \top).Room_2 \\
&\quad +(fightNP, \top).Room_3 + (take_{obj}, \top).Room_1 + (use_{obj}, \top).Room \\
Room_1 &\stackrel{\text{def}}{=} (accept_{obj}, \rho_1).Room + (refuse_{obj}, \rho_2).Room \\
Room_2 &\stackrel{\text{def}}{=} (PlossP, \phi_1).(PwinP, \phi_2).Room \\
Room_3 &\stackrel{\text{def}}{=} (PlossNP, \phi_3).Room + (PwinNP, \phi_4).Room_4 \\
Room_4 &\stackrel{\text{def}}{=} (destroyNP, \sigma_2).Room
\end{aligned}$$

The PEPA net model

- **Component SRoom**

$$SRoom \stackrel{\text{def}}{=} (RImage, \sigma).(test, \top).SRoom_1$$

$$SRoom_1 \stackrel{\text{def}}{=} (lose, \phi_3).SRoom + (win, \phi_4).SRoom$$

- **The places**

- i: the room number $(1 \ldots N)$

- j: the game level number $(1 \ldots L)$

The PEPA net model

$$ROOM_{ji}\,[\_,\ldots,\_] \stackrel{\mathit{def}}{=} \left(Room \underset{\mathcal{K}_1}{\bowtie} \left(Player\,[\_] \underset{\mathcal{K}_2}{\bowtie} \ldots \underset{\mathcal{K}_2}{\bowtie} Player\,[\_] \right) \right) \underset{\mathcal{K}_3}{\bowtie} \left(NPlayer\,[\_] \parallel \ldots \parallel NPlayer\,[\_] \right)$$

$$SECRET\_R_j\,[\_,\ldots,\_] \stackrel{\mathit{def}}{=} SRoom \underset{\mathcal{K}_4}{\bowtie} Player\,[\_]$$

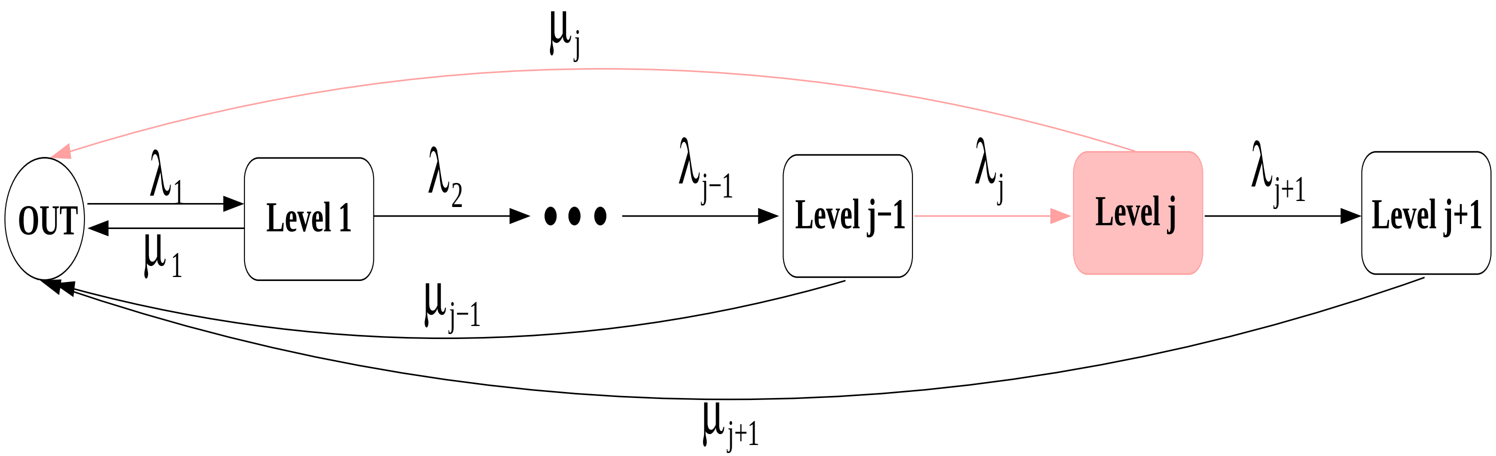
$$INIT\_R_j\,[\_,\ldots,\_] \stackrel{\mathit{def}}{=} Player\,[\_] \parallel \ldots \parallel Player\,[\_]$$

$$OUT\,[\_,\ldots,\_] \stackrel{\mathit{def}}{=} Player\,[Player] \parallel \ldots \parallel Player\,[Player]$$

The Model analysis

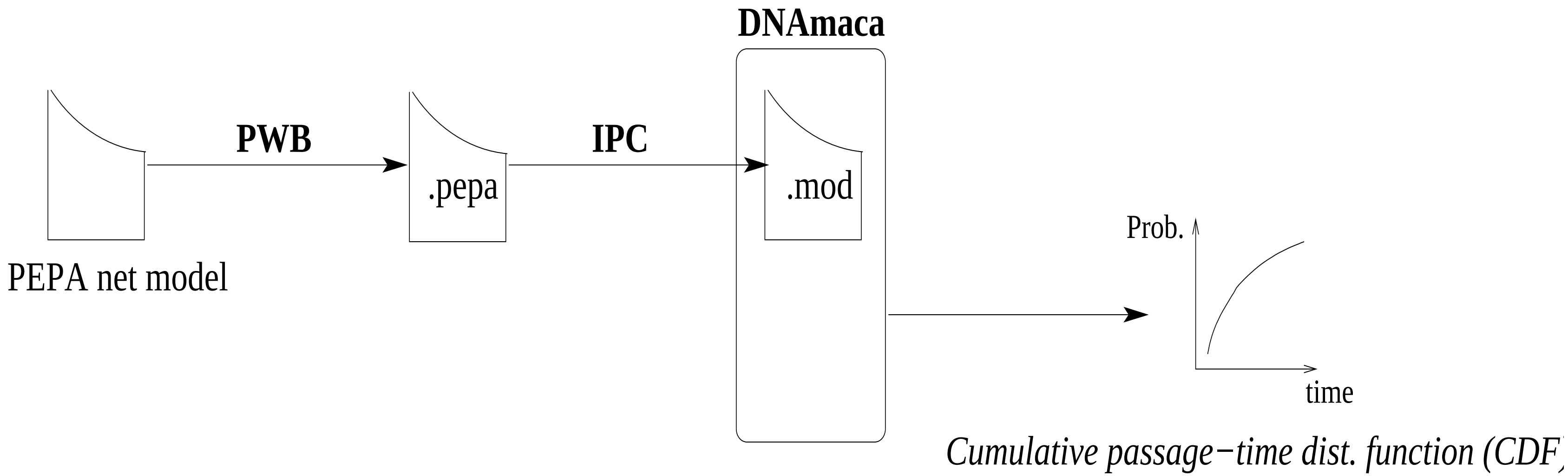
- **Flow-equivalent replacement technique**

- λ_j: arrival rate of the players to level j
- μ_j: departure rate of the players from the game



The Model analysis

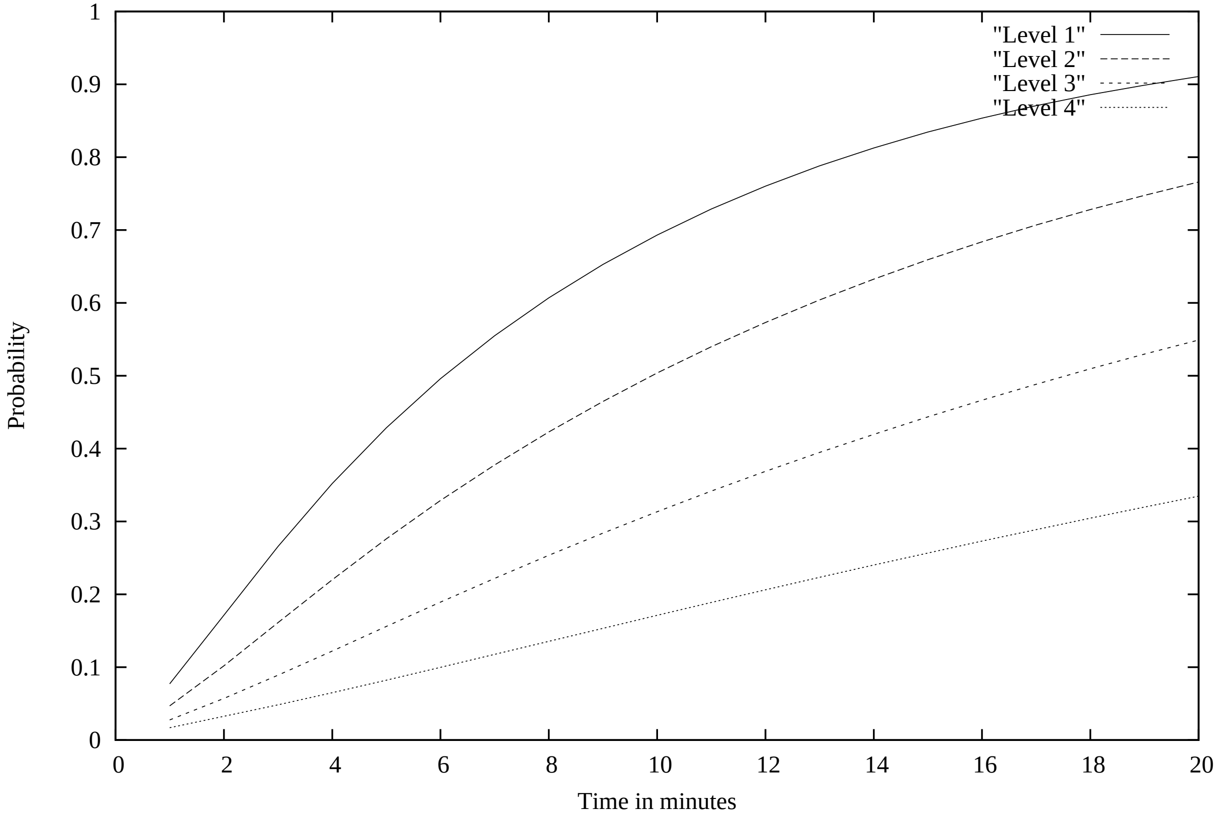
- **Model solution**



- **Performance criteria:** difficulty of completion

- quick progress in the game: *unchallenging* game
- very arduous to make progress: *too challenging* game

Model results



Model results