Appendix A
MELA semantics and complete MELA model

1 MELA semantics

In this section we present the complete MELA semantics. In Figure 1 we represent the behaviour of atomic components, presenting the semantic rules of probabilistic movement, influence and passive actions with or without a movement update, and environment action, where:

$$m := \ . \mid \downarrow \mid \uparrow \qquad\qquad Com_P := \mathbf{nil} \mid P(l) \mid P(l_i) \mid P(l) \parallel P(l)$$

Com_P represents the possible updates: the destruction of the agent, the change of state, the change of location and the creation of a new agent. For the standard atomic rules Choice1, Choice2 and Constant we use the generic label (m, i, α, v, l), to represent the tuple $(mode, influence, action, value, location)$ arising from the considered atomic component. We then describe the behaviour of the atomic components with an *influence* action. This action may change the state of the agents, their location or the number of agents present in the system. Also in this case

$$Com_P := \mathbf{nil} \mid P(l) \mid P(l_i) \mid P(l) \parallel P(l) \qquad Com_Q := \mathbf{nil} \mid Q(l) \mid Q(l_i) \mid Q(l) \parallel Q(l)$$

$$m_P := \ . \mid \downarrow \mid \uparrow \qquad\qquad m_Q := \ . \mid \downarrow \mid \uparrow$$

We also introduce the rule that represents the absence of influence of the action α on the agents. In Figure 2 we represent the rules that lift the behaviour of atomic components to the level of compound components. The final set of rules, presented in Figure 3, captures the possible effect of influence actions at the level of compound components, considering both when an influence action is effective and when not. In the first rule both the atomic components are affected by the action α and they might be in different locations. In the conclusion we indicate l_q as the *location* entry, giving priority to the location where the action is felt.

probabilistic movement

$$\frac{}{(\alpha,r).P(new(l)) \xrightarrow{(\_,\emptyset,\alpha,r\times\bar{p}_i,\bar{l})} P(l_i)} \qquad \bar{l} = loc((\alpha,r).P(new(l)))$$

$$\bar{p}_i = \begin{cases} p_i, & \text{if } new(l) = (l_1[p_1],\ldots,l_n[p_n]) \\ \frac{1}{n}, & \text{if } new(l) = U(l_1,\ldots,l_n). \end{cases} \tag{1}$$

influence action - no movement $$\frac{(\alpha,r)\star P(l) \xrightarrow{(m,\emptyset,\alpha,r,\bar{l})} Com_P}{\to\{L\}(\alpha,r)\star P(l) \xrightarrow{(m,L,\alpha,r,\bar{l})} Com_P} \qquad \bar{l} = loc(\to\{L\}(\alpha,r)\star P(l))$$

influence action - movement $$\frac{(\alpha,r).P(new(l)) \xrightarrow{(\_,\emptyset,\alpha,r\times\bar{p}_i,\bar{l})} P(l_i)}{\to\{L\}(\alpha,r).P(new(l)) \xrightarrow{(\_,L,\alpha,r\times\bar{p}_i,\bar{l})} P(l_i)} \qquad \bar{l} = loc(\to\{L\}(\alpha,r)\star P(new(l)) \quad \bar{p}_i \text{ as defined in } (1)$$

passive action - no movement $$\frac{}{\leftarrow(\alpha,p)\star P(l) \xrightarrow{(m,\leftarrow,\alpha,p,\bar{l})} Com_P} \qquad \bar{l} = loc(\leftarrow(\alpha,p)\star P(l))$$

passive influence action - movement $$\frac{}{\leftarrow(\alpha,p).P(new(l)) \xrightarrow{(\_,\leftarrow,\alpha,p\times\bar{p}_i,\bar{l})} P(l_i)} \qquad \bar{l} = loc(\leftarrow(\alpha,p)\star P(new(l)) \quad \bar{p}_i \text{ as defined in } (1)$$

environment factor $$\frac{}{\to\{L_E\}(\alpha,r).E \xrightarrow{(\_,L,\alpha,r,-)} E}$$

choice1 $$\frac{P(l) \xrightarrow{(m,i,\alpha,v,l)} P'(l')}{P(l)+Q(l) \xrightarrow{(m,i,\alpha,v,l)} P'(l')}$$ **choice2** $$\frac{Q(l) \xrightarrow{(m,i,\alpha,v,l)} Q'(l')}{P(l)+Q(l) \xrightarrow{(m,i,\alpha,v,l)} Q'(l')}$$

constant $$\frac{P(l) \xrightarrow{(m,i,\alpha,v,l)} P'(l')}{C(l) \xrightarrow{(m,i,\alpha,v,l)} P'(l')} \text{ with } C(l) \stackrel{def}{=} P(l)$$

influence action $m_P\ m_Q$ $$\frac{P(l_p) \xrightarrow{(m_P,L,\alpha,r,l_p)} Com_P \qquad Q(l_q) \xrightarrow{(m_Q,\leftarrow,\alpha,p,l_q)} Com_Q}{P(l_p) \parallel Q(l_q) \xrightarrow{(m_P m_Q,L,\alpha,r\times p,l_q)} Com_P \parallel Com_Q} \quad \text{if } l_q \in L$$

influence action - no effect $$\frac{P(l_p) \xrightarrow{(m_p,L,\alpha,r,l_p)} Com_p \qquad Q(l_q) \xrightarrow{(m_q,\leftarrow,\alpha,p,l_q)} Com_q}{P(l_p) \parallel Q(l_q) \xrightarrow{(m_p m_q,L,\alpha,r\times(1-p),l_q)} P(l_p) \parallel Q(l_q)} \quad \text{if } l_q \in L$$

Fig. 1: Behaviour of atomic components

parallel $$\frac{P(l_p) \xrightarrow{(m,i,\alpha,v,l_p)} P'(l'_p)}{P(l_p) \parallel Com \xrightarrow{(m,i,\alpha,v,l_p)} P'(l'_p) \parallel Com}$$ **parallel - Env** $$\frac{Com \xrightarrow{(m,i,\alpha,v,l_p)} Com'}{Com \parallel Env \xrightarrow{(m,i,\alpha,v,l_p)} Com' \parallel Env}$$

environment action $$\frac{E_i \xrightarrow{(\_,L,\alpha,r,-)} E_i}{Env \xrightarrow{(\_,L,\alpha,r,-)} Env} \quad \text{where } Env = E_1 \parallel \cdots \parallel E_n \text{ and } 1 \le i \le n$$

Fig. 2: From the behaviour of atomic components to the level of compound components

influence action - compound component

$$\frac{Com_1 \xrightarrow{(m1,L,\alpha,r,l_p)} Com_1' \qquad Com_2 \xrightarrow{(m2,\leftarrow,\alpha,p,l_q)} Com_2'}{Com_1 \parallel Com_2 \xrightarrow{(m1m2,L,\alpha,r\times p,l_q)} Com_1' \parallel Com_2'} \quad \text{if } l_q \in L$$

influence action - compound component - no effect

$$\frac{Com_1 \xrightarrow{(m1,L,\alpha,r,l_p)} Com_1' \qquad Com_2 \xrightarrow{(m2,\leftarrow,\alpha,p,l_q)} Com_2'}{Com_1 \parallel Com_2 \xrightarrow{(m1m2,L,\alpha,r\times(1-p),l_p)} Com_1 \parallel Com_2} \quad \text{if } l_q \in L$$

influence action - Env

$$\frac{Env \xrightarrow{(.,L,\alpha,r,-)} Env \qquad Com \xrightarrow{(m,\leftarrow,\alpha,p,l_q)} Com'}{Env \parallel Com \xrightarrow{(.m,L,\alpha,r\times p,l_q)} Env \parallel Com'} \quad \text{if } l_q \in L$$

influence action - Env - no effect

$$\frac{Env \xrightarrow{(.,L,\alpha,r,-)} Env \qquad Com \xrightarrow{(m,\leftarrow,\alpha,p,l_q)} Com'}{Env \parallel Com \xrightarrow{(.m,L,\alpha,r\times(1-p),-)} Env \parallel Com} \quad \text{if } l_q \in L$$

Fig. 3: Behaviour of compound components