Appendix A
MELA semantics

In this section we present the complete MELA semantics. In Figure 1 we represent the behaviour of atomic components, starting from the semantic rules of influence and passive actions. The possible updates are the change of state, the creation/destruction of an agent of the same type and the change of location. The function $loc : \mathscr{C}_{at} \to \mathscr{L}$ returns the current location of an atomic component. We then present the actions performed by the environment agent. For the standard atomic rules Choice1 and Choice2 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 decorate the compound components with P and Q to indicate that they are produced by the atomic component P and Q respectively. 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 we indicate information that is related with agent of type i using Com_I, m_i and l_i, to better explain the concepts. Specifically, with $I(l_i)$ we want to indicate an agent of type I in location l_i and with Com_I its possible evolution. l_i is used to explicitly define the relation between the current location of the agent and the influence set L; however, $I(l_i)$ and $I(l)$ refer exactly to the same type of agent: when the agent $I(l)$ becomes $I(l_i)$, only the location is changed. In the influence action rule both the atomic components are affected by the action α and they might be in different locations. In the label we indicate l_q as the *location* entry, recording the location where the action is felt. The last rule of this first section 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. In this case we use the index i to indicate the influence set L_{E_i} related to the specific environment agent E_i.

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. We use Com_1 and Com_2 to indicate two different compound components. In this last section, the *influence* and *location* entries refer to the specific agent of the compound component which is involved in the action; similarly L_{E_i} refers to the specific environment agent.

In the semantic rules we use different values for the *location* entry and for the location attribute, to be able to explain and to define concepts. We use l_i to indicate that the update is a change of location for the involved agent, due to the performed movement action. l_i belongs to the set of possible locations of the resulting agent and $\bar{p}_i$ indicates its probability, according to the function $new(l)$. After a movement action, only the location of the agent is changed. Therefore $P(new(l))$ and $P(l_i)$ represent the same agent P in different locations. In the rules in Figures 2 and 3 we indicate with $'$ the update of the considered compound component.

influence action . $$\frac{(\alpha,r).Com \xrightarrow{(.,\emptyset,\alpha,r,\bar{l})} Com}{\rightarrow\{L\}(\alpha,r).Com \xrightarrow{(.,L,\alpha,r,\bar{l})} Com}$$

influence action $\star$ $$\frac{(\alpha,r)\star P(l) \xrightarrow{(\star,\emptyset,\alpha,r,\bar{l})} Com}{\rightarrow\{L\}(\alpha,r)\star P(l) \xrightarrow{(\star,L,\alpha,r,\bar{l})} Com} \qquad \star ::= \uparrow \mid \downarrow$$

influence action $\triangleright$ $$\frac{(\alpha,r)\triangleright P(new(l)) \xrightarrow{(\triangleright,\emptyset,\alpha,r\times\bar{p}_i,\bar{l})} P(l_i)}{\rightarrow\{L\}(\alpha,r)\triangleright P(new(l)) \xrightarrow{(\triangleright,L,\alpha,r\times\bar{p}_i,\bar{l})} P(l_i)} \qquad \bar{p}_i = \begin{cases} p_i, & \text{if } new(l) = (l_1[p_1],\ldots,l_n[p_n]) \\ \frac{1}{n}, & \text{if } new(l) = U(l_1,\ldots,l_n). \end{cases}$$

passive action . $$\frac{}{\leftarrow(\alpha,p).Com \xrightarrow{(.,\leftarrow,\alpha,p,\bar{l})} Com} \qquad \bar{l} = loc(\leftarrow(\alpha,p).Com)$$

passive action $\star$ $$\frac{}{\leftarrow(\alpha,p)\star P(l) \xrightarrow{(\star,\leftarrow,\alpha,p,\bar{l})} Com} \qquad \bar{l} = loc(\leftarrow(\alpha,p)\star P(l)) \text{ and } \star ::= \uparrow \mid \downarrow$$

passive action $\triangleright$ $$\frac{}{\leftarrow(\alpha,p)\triangleright P(new(l)) \xrightarrow{(\triangleright,\leftarrow,\alpha,p\times\bar{p}_i,\bar{l})} P(l_i)}$$

$$\bar{l} = loc(\leftarrow(\alpha,p)\triangleright P(new(l)))$$

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

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

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

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

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

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

Fig. 1: Behaviour of atomic components

parallel $$\frac{P(l_p) \xrightarrow{(m,i,\alpha,v,l_p)} Com_P}{P(l_p) \parallel Com \xrightarrow{(m,i,\alpha,v,l_p)} Com_P \parallel Com}$$

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 $$\frac{E_i \xrightarrow{(.,L_{E_i},\alpha,r,-)} E_i}{Env \xrightarrow{(.,L_{E_i},\alpha,r,-)} Env} \qquad \text{where } Env = E_1 \parallel \cdots \parallel E_n \text{ and } 1 \leq i \leq n$$

Fig. 2: Lifting 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

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

influence action - Env - no effect

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

Fig. 3: Behaviour of compound components