# Introducing Social Groups and Group Exchanges in the PopOrg Model

# (Extended Abstract)

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## ABSTRACT

This paper presents a summary of the formal notions that introduce social groups and group exchanges in the Population-Organization model of multiagent systems.

## Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*multiagent systems*

## General Terms

Theory

## Keywords

Population-Organization model, social groups, social exchanges, dynamics of organization structures

## 1. INTRODUCTION

The PopOrg (Population-Organization) model is a semantical model introduced in [3] aiming to account for the structural dynamics of the organization of multiagent systems (MAS). The model was extended in different ways (cf. [2]) to tackle different aspects of such structural dynamics.

In this paper, we split the organization structure of the PopOrg model into two levels, namely, the micro and macro-level organization structures, to allow for the formal introduction of the notions of *social groups* and *organizational links between social groups*.

## 2. THE POPORG MODEL WITH MICRO-MACRO ORGANIZATION STRUCTURE

The *PopOrg model with micro-macro organization structure* ($\omega\Omega$-structure, for short) is a structure $POPORG = (POP, ORG_{\omega\Omega}, IMP_{\omega\Omega})$ where $POP$ is the population structure, $ORG_{\omega\Omega} = (ORG_\omega, ORG_\Omega)$ is the $\omega\Omega$-organization structure, with a micro-level organization structure $ORG_\omega$ and a macro-level organization structure $ORG_\Omega$, and $IMP_{\omega\Omega} = (IMP_\omega, IMP_\Omega)$ is the two-level $\omega\Omega$-implementation relation of $ORG_{\omega\Omega}$ over $POP$.

A *population structure* is a time-indexed set $POP$ of states of population structure $POP^t = (AG^t, ACT^t, BH^t, EP^t_{Ag}, Bc^t, Ec^t)$, where for all $t \in T$: (i) $AG^t$, $ACT^t$, $BH^t$, $EP^t_{Ag}$ are, respectively, the system's *population*, the subset of possible *agent actions*, the subset of possible *agent behaviors*, and the subset of possible *exchange processes* between agents, existing at time $t$; (ii) $Bc^t : AG^t \to \wp(BH^t)$ is the *behavioral capability function* of agents at time $t$, such that, for each agent $a \in AG^t$, the set of all behaviors that $a$ is able to perform at time $t$ is $Bc^t(a)$; (iii) $Ec^t : AG^t \times AG^t \to \wp(EP^t_{Ag})$ is the *exchange capability function* at time $t$, such that, for each pair of agents $a_1, a_2 \in AG^t$, the set of exchange processes that $a_1$ and $a_2$ can perform between them at time $t$ is $Ec^t(a_1, a_2)$; (iv) $\forall a_1, a_2 \in AG^t\ \forall e \in Ec^t(a_1, a_2)\ \forall t' \in T$ :

$$\begin{aligned} Prj_1(e(t')) &\subseteq \bigcup\{b(t') \mid b \in Bc^t(a_1)\} \\ Prj_2(e(t')) &\subseteq \bigcup\{b(t') \mid b \in Bc^t(a_2)\}, \end{aligned}$$

where $Prj_1, Prj_2$ are *projection functions*, so that exchange capabilities are constrained by behavioral capabilities.

A *micro-role* $r$ is as a non-empty subset of role behaviors. A *micro-link* $l$ between a pair of micro-roles $r_1, r_2$ is defined as a tuple $l = (r_1, r_2, e)$, specifying an *exchange process* $e$ that the linked micro-roles $r_1$ and $r_2$ may have to perform.

A *micro-level organization structure* is a time-indexed set $ORG_\omega$ of states of micro-level organization structures $ORG^t_\omega = (RO^t_\omega, LI^t_\omega, Lc^t_\omega)$, where for all $t \in T$: (i) $RO^t_\omega$ and $LI^t_\omega$ are, respectively, the sets of micro-roles and micro-links existing in the organization at time $t$; (ii) $Lc^t_\omega : RO^t_\omega \times RO^t_\omega \to \wp(LI^t_\omega)$ is the *micro-link capability* function at time $t$, specifying the set of micro-links that may be established between pairs of micro-roles; (iii) $\forall l = (r_1, r_2, e) \in LI^t_\omega : l \in Lc^t_\omega(r_1, r_2)$, i.e., each micro-link has to be in the micro-link capability of the two micro-roles that it links at time $t$; (iv) $\forall r_1, r_2 \in RO^t_\omega\ \forall e \in \mathbf{Ep}\ \forall t \in T : (r_1, r_2, e) \in LI^t_\omega \Rightarrow$

$$\begin{aligned} \forall t' \in T : Prj_1(e(t')) &\subseteq \bigcup\{b(t') \mid b \in r_1\} \\ Prj_2(e(t')) &\subseteq \bigcup\{b(t') \mid b \in r_2\}, \end{aligned}$$

so that the micro-roles' exchange capabilities are constrained by their respective behavior capabilities (**Ep** is the set of all exchange processes).

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A *social group of micro-roles and micro-links* is a time-indexed set $\mathbb{G}$ of states of groups of micro-roles and micro-links $\mathbb{G}^t = (R^t, L^t, GB^t)$, where, for $t \in T$: (i) $R^t$ is the set of micro-roles that constitute the group at time $t$; (ii) $L^t$ is the set of micro-links between the micro-roles of the group, existing at time $t$; (iii) $GB^t$ is the set of group behaviors at time $t$; (iv) $\forall l = (r_1, r_2, e) \in L^t : r_1, r_2 \in R^t$, that is, micro-links only link micro-roles that belong to the group.

A *macro-link* is a time-indexed set $\mathbb{L}$ of states of macro-links $\mathbb{L}^t = (\mathbb{G}_1^t, \mathbb{G}_2^t, GE^t)$, where, for all $t \in T$: (i) $\mathbb{G}_1, \mathbb{G}_2$ are groups of micro-roles; (ii) $GE^t$ is a set of exchange processes between $\mathbb{G}_1^t$ and $\mathbb{G}_2^t$, such that: $\forall e \in GE^t \; \forall t' \in T$ :

$$Prj_1(e(t')) \subseteq \bigcup \{Gb_1(t') \mid Gb_1 \in GB_1^t\}$$
$$Prj_2(e(t')) \subseteq \bigcup \{Gb_2(t') \mid Gb_2 \in GB_2^t\}$$

so that each exchange process $e$ in $GE^t$ is supported by the pair of group behaviors $GB_1^t$ and $GB_2^t$.

A *macro-level organization structure* is a time-indexed set $ORG_\Omega$ of states of groups and macro-links $ORG_\Omega^t = (GR_\Omega^t, LI_\Omega^t)$, where, for all $t \in T$: (i) $GR_\Omega^t$ and $LI_\Omega^t$ are the sets of groups and macro-links, respectively, existing in $ORG_\Omega$ at $t$; (ii) $\forall \mathbb{L} = (\mathbb{G}_1, \mathbb{G}_2, GE) \in LI_\Omega^t : \mathbb{G}_1, \mathbb{G}_2 \in GR_\Omega^t$, that is, macro-links only link groups that belong to the macro-level organization structure.

An *$\omega\Omega$-implementation relation* of the $\omega\Omega$-organization structure $ORG_{\omega\Omega}$=$(ORG_\omega, ORG_\Omega)$ on the population structure $POP$ is a pair $IMP_{\omega\Omega} = (IMP_\omega, IMP_\Omega)$, where $IMP_\omega$ and $IMP_\Omega$ are the micro and macro-level implementation relations, respectively, defining how $POP$ implements the micro-level organization structure $ORG_\omega$, and how $ORG_\omega$ implements the macro-level organization structure $ORG_\Omega$.

A micro-role $r$ in $ORG_\omega^t$ is said to be *properly implemented* by $IMP_\omega$ on $POP^t$ if and only if there is a subset $A$ of agents such that: (i) every agent in $A$ participates in the implementation of $r$ at time $t$; (ii) the set of behaviors required by the micro-role $r$ can be performed by the agents in $A$ (in a possibly shared way). A micro-link $l$=$(r_1, r_2, e)$ in $ORG_\omega^t$ is said to be *properly implemented* by $IMP_\omega$ on $POP^t$ if and only if there is a subset $E$ of exchange processes that belong to the exchange capability of the agents that implement $r_1$ and $r_2$ at time $t$, such that: (i) each exchange process in $E$ participates in the implementation of $l$ at time $t$; (ii) every projection $Prj_i$ of the exchange process required by $l$ can be realized by the set of corresponding projections of the exchange processes of $E$ (in a possibly shared way).

$IMP_\omega$ is said to be a *proper $\omega$-level implementation relation* of $ORG_\omega$ on $POP$ if and only if, at each time $t$, each micro-role and micro-link in $ORG_\omega^t$ are properly implemented by $IMP_\omega$ on $POP^t$ .

$IMP_\Omega$ is said to be a *proper macro-level implementation relation* if and only if, at each time $t \in T$: (i) each group behavior is properly implemented by the set of behaviors of the group roles that belong to the group; (ii) for each group there is a set of micro-roles such that each behavior of each group role is properly implemented by the set of behaviors of that set of micro-roles; (iii) for each group there is a set of micro-links such that each link between group roles is properly implemented by that set of micro-links; (iv) for each macro-link there is a set of micro-links such that each exchange process in the macro-link is properly implemented by the set of exchange processes of that set of micro-links.

A $\omega\Omega$-implementation relation $IMP_{\omega\Omega} = (IMP_\omega, IMP_\Omega)$ of $ORG_{\omega\Omega} = (ORG_\omega, ORG_\Omega)$ on $POP$ is *proper* if and only if $IMP_\omega$ is a proper implementation relation of $ORG_\omega$ on $POP$, and $IMP_\Omega$ is a proper implementation relation of $ORG_\Omega$ on $ORG_\omega$.

A *PopOrg structure with $\omega\Omega$-organization* (micro-macro organization) $POPORG_{\omega\Omega}$=$(POP, ORG_{\omega\Omega}, IMP_{\omega\Omega})$ is *properly implemented* if and only if its $\omega\Omega$-implementation relation $IMP_{\omega\Omega}$ is proper.

## 3. MAIN RESULTS

PROPOSITION 1. *If $POPORG_{\omega\Omega}$ is properly implemented, each group action in $ORG_\Omega$ is properly implemented by a set of agent actions in $POP$.*

COROLLARY 1. *If $POPORG_{\omega\Omega}$ is properly implemented then: (i) each group behavior in $ORG_\Omega$ is properly implemented by a set of agent behaviors in $POP$; (ii) each group exchange process in $ORG_\Omega$ is properly implemented by a set of agent exchange processes in $POP$.*

## 4. CONCLUSION

This paper presented an initial approach for the formal concepts of social groups and group exchanges in the PopOrg model. The organization structure of the model was split into a micro and a macro-level organization structures. Social groups were defined at the macro-level organization as sets of roles defined at the micro-level organization, together with micro-links between such roles. Group exchanges were defined on the basis of the behavior of the social groups. An implementation relation between the macro and the micro-level organization structures was defined, as well as an implementation relation between the micro-level organization structure and the population structure of the model, and an indirect implementation relation between the macro-level organization structure and the population structure.

We showed that properly implemented $\omega\Omega$-organization structures guarantee that group behaviors and exchanges that occur at the macro-level are effectively implemented by agent behaviors and exchanges at the population level.

The split $\omega\Omega$-organization structure is the foundation for the way in which the PopOrg model deals with the micro-macro link problem [1], namely, by placing what is strictly individual (subjective, etc.) about each of the agents at the level of the population structure, and what is strictly social (objective, etc.) about each of them at the micro-organization level, in terms of micro-roles and micro-links.

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