Implementing Social Smart Environments with a Large Number of Believable Inhabitants in the Context of Globalization

Alexander Osherenko
alexander.osherenko@alumni.hu-berlin.de

Humboldt Innovation
Humboldt-Universität zu Berlin
Ziegelstraße 30, 10117 Berlin

Abstract. This chapter discusses Social Smart Environments (SSEs) with a large number of believable Embodied Conversational Agents (ECAs) in the context of globalization. It focuses on SSE architecture, rapid prototyping and scalability with respect to size, geography, and administration. SSE is a software environment installed in a physical place representing, for example, a city inhabited by believable ECAs that interact comprehensibly with each other; believable ECAs are software agents that stand for humans from different cultures. To ensure believability, the ECAs maintain various determinants of processing, for instance, emotional, personal and cultural, identified through an analysis of 35 scenarios of intercultural interaction. This chapter shows implementation of these determinants and development of an SSE prototype on the basis of a specification defining interaction between ECAs. In conclusion, this contribution provides insight into future work addressing, for example, innovation in societies simulated by SSEs.

Keywords: Rapid prototyping of social smart environments with a large number of believable embodied conversational agents; determinants of believable embodied conversational agents in the context of globalization; scalability of social smart environments with respect to size, geography and administration

1 Introduction

Technological innovation changes human lives, including the spaces in which humans live. The modern world is now not only populated with humans who perform everyday tasks, but also with technical artifacts that carry out routine and intelligent jobs [13, 19, 30, 39]. Moreover, these technical artifacts are no longer seen as servants, but rather as clever companions. They can master actions that a human cannot and they are very efficient in said actions. Such technical artifacts are smart, meaning they behave and react comprehensibly and in a human manner.

Technical artifacts are supposed to make human life more comfortable [17, 18]. However, they can also cause problems, for instance, interaction problems. Erroneous communication with technical artifacts can backfire and obliterate the advantages of smart interaction.

A solution for problems that occur can provide a Social Smart Environment (SSE) that maintains Embodied Conversational Agents (ECAs). An SSE is a software environment installed in a physical place, for example, a city, a building, or a large room populated by intelligent technical artifacts such as smart robots. In the context of globalization, SSEs maintain many interacting ECAs that comprehensibly represent humans from different countries.

An SSE has many applications, in both normal and extreme situations for which humans need guidance. For instance, an SSE installed in a public place such as an airport, a metro station or a shopping mall can save human lives or help to avoid panic in cases such as earthquakes [29]. An SSE can help to design safer theaters or stadiums [20]. An SSE can assist international persons in resolving cultural misunderstandings between hosts and sojourners [33]. An SSE can intelligently guide museum's visitors [38]. An SSE can increase tourist flow by integrating tourism, cultural heritage and mobility [2]. Fig. 1 shows groups of international tourists (international networkers, shoppers, students, etc.) and reasons for their (virtual) trips.

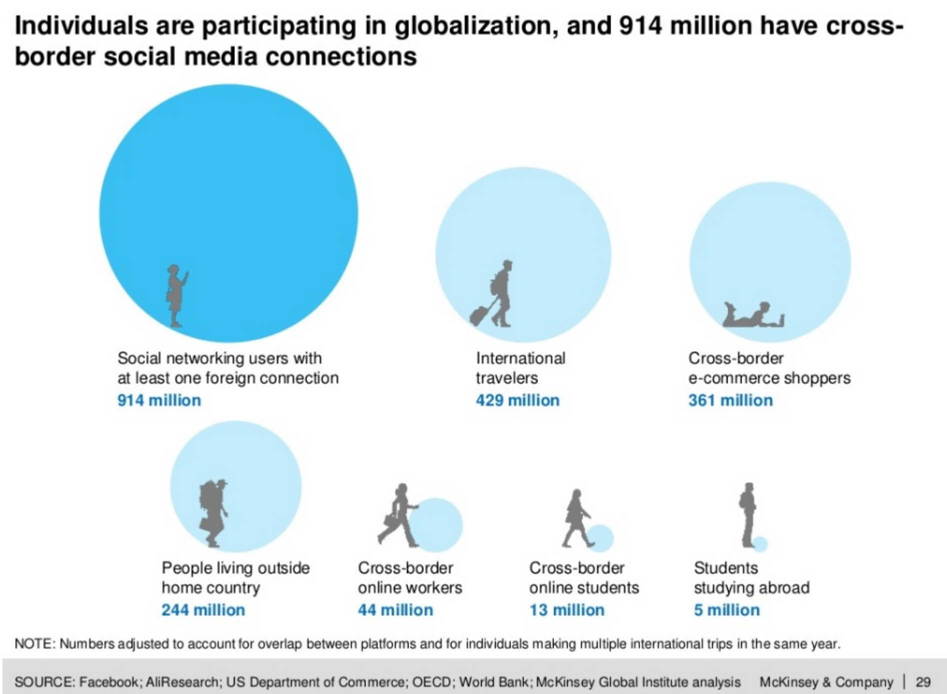

Fig. 1. Groups of international guests and reasons for their (virtual) trips.

The high numbers in Fig. 1 demonstrate the necessity of handling situations by, for example, using SSEs. Addressing the problem, this chapter describes an approach for the rapid prototyping of SSEs that can maintain a large number of believable ECAs. Moreover, this contribution answers the following questions concerning SSE scalability [44, p. 10], such as:

1. Size – can proposed SSEs scale up well to meet increased numbers of ECAs?
2. Geography – what is the geographical distance between the ECAs maintained by the proposed SSEs?
3. Administration – can administration of the proposed SSEs take place remotely?

Additionally, the current chapter addresses the following issues of SSE development:

1. Steps necessary for the rapid prototyping of SSEs with a large number of believable ECAs;
2. Architecture and implementation of SSEs with a large number of believable ECAs;
3. Determinants and implementation of believable ECAs.

2 Recent work

Different scholars have studied development of SSEs and discussed particular issues regarding their implementation.

Nakashima and colleagues [30] present a comprehensive study of Smart Environments (SEs). The authors describe intelligent agents, their implementation and interaction on the basis of Multi-Agent Systems.

Butz [9] examines SEs by giving special attention to the interaction between SEs and humans through displays that maintain personal information. The scholar claims that interaction takes part using human senses and through physical actions.

Bosse and colleagues [6] examine human aspects in SEs, abstaining from a pure examination of sensor data, but taking into account the human-directed sciences such as psychology and sociology. They focus on the human knowledge in ambient intelligence and describe an SE assessing the behavior of a human.

Cai and Kaufer [10] study SEs and state that simple communication among humans requires explicit computer-aided means. They define an image-word two-way mapping process that describes a mapping between image features and words for human facial features and introduce the computational implementation of human descriptions in the form of the visual and verbal interaction between them.

Aehnelt and colleagues [1] describe a situation-aware interaction in an SE. In their approach, user intentions deduced from sensory inputs are used to provide situation-aware informational assistance. For their purposes, the SE in their approach is a smart meeting room that proactively anticipates future goals. As a scenario, they study smart business applications in manufacturing industries, where they see a vital demand for facilitating decision-making at all company levels.

Fu and Zhang [16] explore virtual worlds in the context of urbanization and address corresponding social aspects. The scholars show a framework that considers social communication and personal opinions and describe a case study that distinguishes interpersonal interaction, behavior patterns, Social Interaction (SI) and communication contexts. Moreover, they study an approach to visualization of a virtual world that presents the info-structure of the virtual city under consideration of particular emotional and cultural aspects [21].

Spadavecchia and Giovannella [43] present a project that includes online monitoring and evaluation of learning processes accompanied by SI. SI between interactants proceeds through the exchange of Natural-Language (NL) emails or chatting. The project distinguishes 8 macrophases that collect data about the underlying social network and the social relationships among the learners. To assess the quality of an exchange, the emails or chat posts are scrutinized automatically according to their emotional content. Since the results revealed were encouraging, the authors plan to develop additional tools and methods for monitoring in future work. Moreover, they are considering implementing a real-time learning system that can be utilized on a daily basis.

Trovato and colleagues [45] discuss implementation of a culturally-dependent social robot that communicates with humans by showing particular emotions and altering facial expressions correspondingly. The approach acknowledges differences of emotional expression between the Japanese culture and Western culture in general, as well as the difficulty of substantiating corresponding differences. The approach uses six statistical classifiers, one for each part of the face, that regulate the expression of emotions and calculate a vector of motor angles.

3 Modeling and Implementation of Determinants

ECAs in an SSE interact with each other in a human manner. To identify determinants (significant issues) of believable SI between intercultural ECAs, we analyzed 35 scenarios of interaction among humans in the context of globalization and detected 10 agent-specific and 8 environment-wide determinants. We call some aspects 'agent-specific', emphasizing that the particular determinant is only valid in an ECA; we say 'environment-wide' so as to indicate that the particular determinant is valid for the whole SSE. To implement particular determinants, our approach uses the JADE platform, a development framework for multi-agent systems [3] .

3.1 Agent-specific determinants

Emotions Emotions should be considered in a believable SSE, as the many scenarios of intercultural communication show [5,7,24,36,41,45–47,50]. Emotion-related data is acquired in our approach from the audio-visual Sensitive Artificial

Listener (SAL) corpus [14]. The SAL corpus is a set of affective NL dialogues in which a wizard representing four psychologically different characters (optimistic and outgoing Poppy, confrontational and argumentative Spike, pragmatic and practical Prudence, depressing and gloomy Obadiah) tries to draw users into their own emotional state. The corpus consists of 27 NL dialogues.

SAL was transcribed and annotated by four labelers with FEELTRACE data [40], which identifies the emotions occurring in the the Evaluation/Activation (E/A) space [35]. Affect annotation of a turn in FEELTRACE contains numeric E/A data that is supplied continuously. For simplicity, the FEELTRACE annotations of turns are mapped onto 5 emotion segments in the E/A space (Fig. 2).

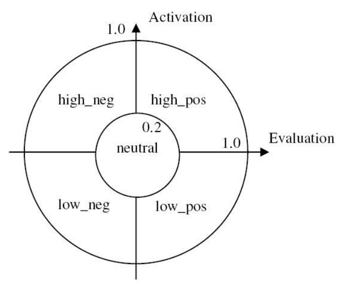

Fig. 2. Affect segmentation in the E/A space

Fig. 2 shows 5 emotional segments – high activation/negative evaluation (*high_neg*), high activation/positive evaluation (*high_pos*), low activation/negative evaluation (*low_neg*), low activation/positive evaluation (*low_pos*), and neutral – that represent affect segments of turns with different emotional loads. The value 0.2 is chosen empirically. The chosen affect segment of a turn corresponds to the vote of the majority of the annotators at the turn of a end; emotionally contradictory long turns are not considered in further experiments. Thus, 98 out of 672 turns are discarded due to the missing agreement between annotators or contradictory FEELTRACE data. The inter-annotator agreement is thus 85.42%. We adopt a model of emotions for affective behavior [34] that relies on a probabilistic Hidden Markov Model (HMM) and transfers it in a generic form containing more emotion states that, in our opinion, can be used in more realistic scenarios of processing (Fig. 3).

Fig. 3 shows a generic HMM for affective behavior with 5 emotion states, and question marks representing uninitialized transition and observation probabilities. To implement HMMs for affective behavior, JAHMM [15] a Java implementation of HMMs is used. To train the HMMs for affective behavior and assess initial probabilities of emotion states and transition probabilities, different algorithms can be utilized, for example, the k-means algorithm [23]. Initialization of the transition and observation probabilities is based on training sequences that can be composed, for instance, from adjacent dialogue turns with Spike, such as

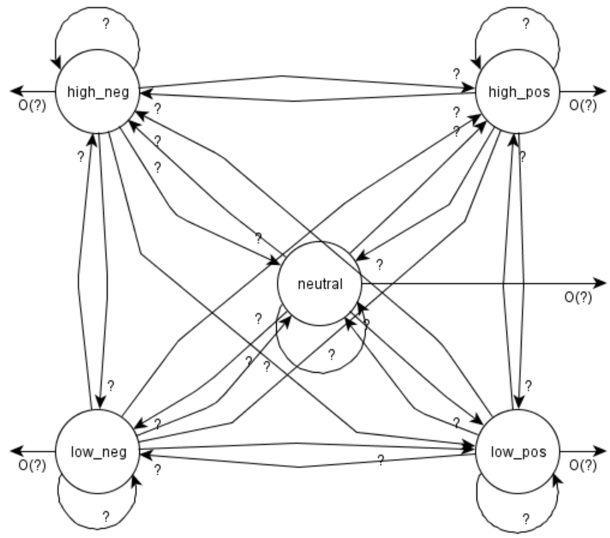

Fig. 3. A generic HMM for affective behavior.

low_pos neutral low_neg neutral low_pos neutral, which results from the first, second, . . . sixth dialogue turns (Fig. 4).

Fig. 4 represents an HMM for affective behavior for the Spike character with initialized transition and observation probabilities.

Personality To anticipate the general disposition of an inhabitant in an SSE, a personality dimension is necessary [27]. A personality model in our approach relies on the Big-Five model that defines 5 personality traits, *Extroversion*, *Neuroticism*, *Openness to experience*, *Agreeableness*, and *Conscientiousness*, and can be assessed using the NEO questionnaire [12].

To populate the personality model of ECAs numerically, we use our own heuristics [33, pp. 102-104], which use the transition probabilities from Fig. 4. For example, we calculate personality trait extroversion PT_E as follows:

$$PT_E = \frac{\sum P(X \to high\_pos) + \sum P(X \to low\_pos)}{|\{X \to high\_pos\}| + |\{X \to low\_pos\}|}, \tag{1}$$

where $\sum P(X \to Y)$ is the sum of transition probabilities from the affect state X into the positive affect states $Y = \{high\_pos, low\_pos\}$. Values of PT_E are normalized by the number of corresponding transitions $- 10 = |\{X \to high\_pos\}| + |\{X \to low\_pos\}|$.

Table 1 presents the values of the personality traits calculated using the threshold value 20%, where PT_E represents the value of the *Extroversion* trait, PT_N the value of the *Neuroticism* trait, PT_A the value of the *Agreeableness*

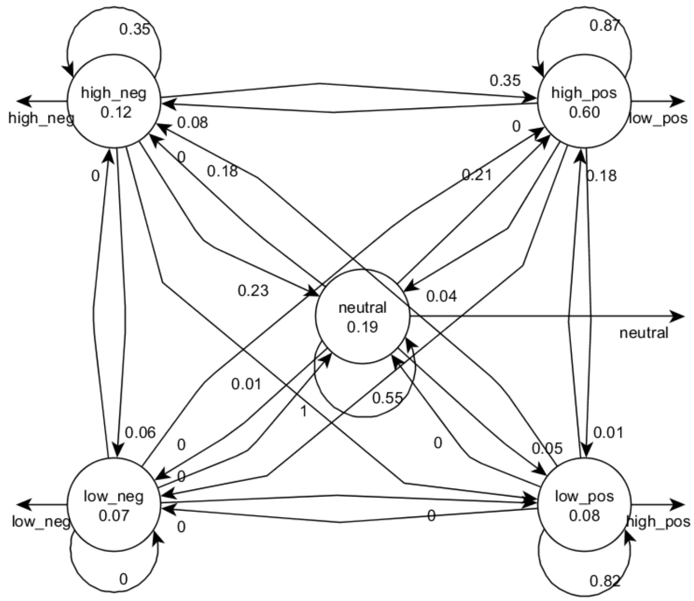

Fig. 4. A HMM for affective behavior for the Spike character.

Table 1. Values of personality traits for the Spike character

Character	PT_E	PT_N	PT_A	PT_O	PT_C
Spike (confront.)	25.0%	12.46%	5.23%	78.85%	9.13%

trait, PT_O the value of the *Openness to experience* trait, and PT_C the value of the *Conscientiousness* trait.

Culture Since particular aspects of an SSE are defined by the inhabitant's culture, the culture model is indispensable [42, 45]. As a culture model, we use synthetic cultures [22]. A synthetic culture is an artificial structure that distinguishes 5 dimensions:

1. The low vs. high power distance dimension describes the degree to which differences in power, status, and privileges are considered by representatives of the culture;
2. The collectivism vs. individualism dimension distinguishes the primary unit of the culture (I vs. we);
3. The masculinity vs. femininity dimension defines the orientation of the culture towards achievement and cooperation;
4. The uncertainty avoidance dimension defines the measure of tolerance to ambiguity;
5. The short-term vs. long-term orientation dimension indicates the extent to which the future has more importance than the past or present.

To populate the culture model of ECAs, we use empirical data in [21]. Hence, we extracted cultural values for the Irish SAL corpus in Table 2.

Table 2. Acquired cultural values from the Irish corpus

Country	Power distance	Uncertainty avoidance	Individualism/collectivism	Masculinity/Femininity	Long-/Short-Term Orientation
Ireland	49	47-48	12	7-8	13

Statistical engines Statistical processing is indispensable in SSEs [45]. In our approach, we use the WEKA statistical toolkit for data processing [48].

Natural-Language Processing Many SSE approaches maintain believable ECAs that perform SI using Natural-Language (NL) utterances [43]. In our approach, we use NL approaches in [32] to analyze NL communication.

Social relationships Comprehensible interaction in an SSE considers social relationships between ECAs [38, 47]. In our approach, ECAs hold a list of relationships defined by particular IP addresses of JADE neighbor agents.

Context (agent-specific) The agent-specific context defines the race, age, education, marital status, social class, religion, etc., and should be considered in an SSE [25]. The agent-specific context can be specified in an ECA as a dictionary of values, for example, {*"age": 35, "education": "higher"*}.

Knowledge (agent-specific) The agent-specific knowledge refers to the facts held by a particular ECA. The agent-specific knowledge can be specified in an ECA as a dictionary of values, for instance, *"name":joinery.*

Time (agent-specific) Some scenarios, for example, in an SSE that considers jet lag, take the temporal component into account. The agent-specific time can be specified in an ECA as the local time, realized using the system clock from the local computer. Alternatively, the ECA can install the JADE *onTick* behavior to measure time locally (more on the JADE platform in [3]).

3.2 Environment-wide Determinants

Explicit specifications In our approach, SI in SSEs is specified by Interaction Specifications (ISs). ISs are structured texts that define participating ECAs and their behaviors. ISs resemble sequence diagrams known from the Unified Modeling Language (UML) implemented using a sequence diagram package [28] (Fig. 5).

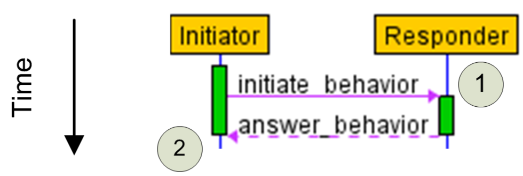

Fig. 5. Interpreting an interaction specification

The IS in Fig. 5 defines two agents that interact with each other, agent *Initiator* and agent *Responder*. Using this IS, our approach composes two JADE behaviors, the names of which contain the name of the initiator, the name of the responder, the name of the transaction, and the number of the initiator-responder combination: 1) *Initiator_Responder_initiate_behavior_*0 and 2) *Responder_Initiator_answer_beha* (more on the JADE behaviors in [3]).

The textual form of the IS represents Algorithm 1.

Algorithm 1 defines IS describing an SSE with 3 interacting ECAs *(agent0, agent1, agent2)* that receive the ping message and respond with the pong message.

Algorithm 1 IS defining SI in a population.

```
SSE
{
agent0.ping -> pong;
agent1.ping -> pong;
agent2.ping -> pong;
}
```

History Some scenarios in an SSE consider the history of SI. In our approach, an environment-wide JADE agent holds a list of previous states of the environment that can be accessed by particular ECAs.

Space Some scenarios in SSE consider a physical space that can be realized as the RoboCup soccer field [4] (Fig. 6).

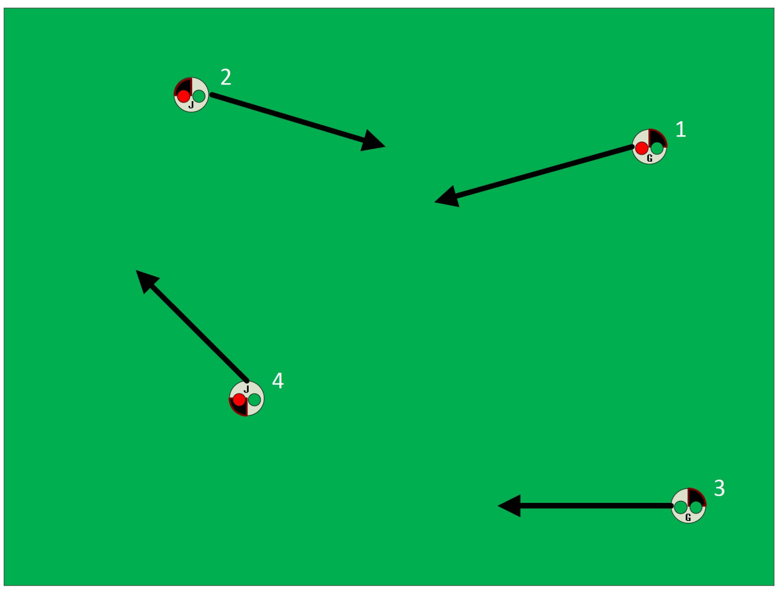

Fig. 6. An approach to spatial model based on the RoboCup representation

Fig. 6 shows a virtual space where numbered players (circles) move in directions specified by the arrows. The letters G and J respectively correspond to the German or Japanese culture of ECAs.

Context (Environment-wide) The environment-wide context defines circumstances in which SI in an SSE takes place. For example, the context can be defined by common real-world facts, such as *People find ghosts scary* [26]. To specify the environment-wide context, an SSE can hold particular rules such as *tango (culture : Argentina; value : high)* to define the high cultural value of tango in Argentina.

Knowledge (environment-wide) Environment-wide knowledge in an SSE defines the intentions of an inhabitant, for example, knowledge about the behavior or the attended action strategy. To maintain environment-wide knowledge, an environment-wide JADE agent holds a list of facts that can be accessed by particular ECAs.

Time (environment-wide) Some scenarios of intercultural SI, for example, the jet lag scenario, consider the temporal component. To maintain environment-wide time, the SSE in our approach installs an environment-wide timeserver agent that maintains the global time within the environment.

Social network, topological issues In our approach, an SSE maintains interconnected ECAs [41, 50] according to a specific topology. Social network is realized in an environment-wide JADE agent that maintains an implementation of the social network as a list of neighboring ECAs for each ECA in the SSE (more on the JADE platform in [3]).

Alerts An alert is issued if some requirements of the SSE are violated, for example, if a social network in the SSE must be reorganized. An alert is realized in our approach by means of the JADE platform.

4 Prototype

In our approach, the SSE is prototyped as a Multi-Agent System (MAS) with ECAs based on the server-based JADE environment [3]. To develop the prototype, we use our own framework for experimentation and rapid prototyping, called SocioFramework, which creates a Java prototype of an SSE [33] that has an interface to the WEKA toolkit [48] to analyze data statistically.

Agents in JADE communicate with each other using messages and maintain behaviors that handle particular events. JADE agents can be grouped in containers; these containers can have subcontainers. To administer or debug SSEs, standard administration JADE agents, such as the Agent Management System (AMS), the Directory Facilitator (DF), the Remote Monitoring Agent (RMA), or standard tools of JADE, as the *Sniffer* or the *Introspector* can be used (Fig. 7).

Fig. 7 shows an SSE with two ECAs (*ECA1* and *ECA2*) that communicate with each other using a remotely installed JADE server.

To evaluate our approach, we composed SSE prototypes with specific interaction behavior. For instance, we prototyped an SSE realizing the interaction

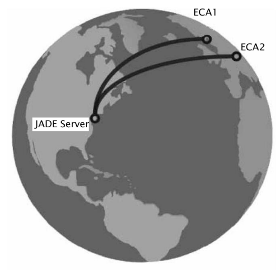

Fig. 7. Integration of JADE in building SSEs.

scenario with a higher status individual [37], for example, to simulate a meeting in an international corporation. The scenario considers specific emotional and personal properties of superior A and employee B that influence such categories of behavior as proxemics, vocalic, and symbolically intrusive (Algorithm 2).

Algorithm 2 Interacting with a higher status individual.

```
1: for all person in {A, B} do
2:    culture ← get_culture(person)
3:    for all category in {proxemics, vocalic, symbolically_intrusive} do
4:       behavior ← get_behavior(person, culture, category)
5:    end for
6: end for
```

5 Governing Scalability

One significant task of distributed systems such as SSEs stems from issues of scalability. According to Tanenbaum and Steen [44, p. 10], scalability can be measured along at least three dimensions with respect to:

1. Size;
2. Geography;
3. Administration.

Size In our approach, SSEs maintain many ECAs. To scale up an SSE according to a higher number of ECAs, additional agents with a corresponding service interface must be logged into the JADE server. Hence, the *size* scalability of the proposed approach relies on the JADE *size* scalability that depends on the DF storing agents' access catalogue. Consequently, the DF can cause scalability problems through increased memory consumption [3, pp. 176-179].

Nevertheless, to give an idea of what the empiric size of agents in existing systems is, this chapter describes the number of agents in our and other JADE systems. It must be said that other approaches do not mainly focus on the number of agents in the system, which is a significant measure in this chapter, but rather on measuring the speed of communication.

In our approach, it was possible to build an SSE with 10,000 ECAs that exchange 20,000 interaction messages. It was possible to run the SSE with 1,000 JADE agents maintaining 2,000 interaction messages. Burbeck et al. [8] studied a JADE system with 150 pairs of agents. Cortese [11] describes a JADE system with 1,000 agents.

Consequently, we assume that SSEs are highly scalable according to the number of agents, since this measure does not appear to be critical in JADE systems.

Geography Believable ECAs of SSEs can reside at significant geographical distances from each other. Hence, we used JADE means to resolve this issue:

```
java -cp jade.jar jade.Boot -host <IP address>
        -agents <agent name><agent class> -container
```

The command starts an instance <agent name> of agent <agent class>, where the text <IP address> specifies the IP address numerically (for example, 93.135.248.211) or as a name (for instance, localhost). Option -container specifies creation of a subordinate container within the main container.

Administration In our approach, SSEs can span significant territory. For administration of SSEs, a remote copy of the AMS, the DF, or the RMA can be started. For example, the following command starts the AMS agent in its own container, the remote location of which is defined by the IP address 93.135.248.211:

```
java -cp jade.jar jade.Boot -host 93.135.248.211
        -agents ams1:jade.domain.ams -container
```

6 Discussion and Future Work

This chapter described development of SSEs in the context of globalization and presented means to implement believable ECAs. This chapter also addressed scalability questions concerning size, geography and administration.

Addressing the implementation of SSEs, this chapter presented:

1. Steps necessary for rapid prototyping of SSEs on the basis of ISs;
2. Architecture and implementation of SSEs maintaining up to 1,000 believable ECAs exchanging 2,000 interaction messages;
3. A thorough study and implementation of 10 agent-specific and 8 environment-wide determinants of believable ECAs on the basis of 35 scenarios of intercultural interaction.

In future work, we will consider improvement and extension of the determinants' set. For this purpose, we will study the applicability of the identified determinants to implement further scenarios of SSEs, for example, SSEs implementing SI influenced by neurobiological signals [17]. Assuming that the JADE framework is sufficiently size-scalable and in line with [49], we will implement SSEs representing real-life societies with tens of thousands of ECAs and investigate how innovation alters the lives of the human members. Moreover, we will work on integration of identified determinants in robotic ECAs using our previous experience in implementing MASs that perform cooperative tasks [31].

Acknowledgments

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