Preface

In a nutshell, this book treats the methods, structures, and cases on the representation(s) of the environment in multi-agent systems. The individual agents in the systems are based on the Interactivist-Expectative Theory of Agency and Learning (IETAL). During their sojourn in the environment, the agents interact with it and build their intrinsic representation of it. The interagent communication is solved via imitation conventions of the homogenous agents. Due to the specific interrelation of the drives, motivations, and actions, a multitude of fuzzy structures is used as a base for the formalization of the theory. Original results in the Theory of Fuzzy Graphs, and Fuzzy Algebraic Structures, valued by lattices, posets, and relational structures are also given. Algorithms for detection of the learnability of the environment are given, as well as a discussion on the concept of context within this theory. The phenomenology of the drives and percepts as well as of the imitation is surveyed in detail. Solution of the interagent communication and of the emergence of language in the system is also discussed. The original experiments with humans investigate the status of some key notions of our theories in human subjects. We also present a variety of hardware and software solutions that have served us in our research and that are flexible enough to serve other researchers in similar experiments, whether they are of simulation nature, emulations on robotic agents, or based on harvesting data from human individuals or groups. In our discussions we focus on important biological concepts from humans that our theories are based on. We discuss actions, motivations, and drives in human subjects, explore the concept formation in related literature, and give our own take on it, as that serves as the base of our discussion on emergence of language in our artificial societies.

There are four key notions that we observe in this volume: agent, environment, imitation, and multi-agent systems.

In existing literature, there have been numerous attempts to define the term *agent*. The existing definitions span from laconic definitions of software online agents to those that define the term so that it serves a specific goal in the context it is being discussed in. So, authors use it as broadly or as narrowly as needed within the context of the topic they have been discussing. We are adopting a fairly general — in our opinion — axiomatic definition of an agent. For an artifact (biological or man-made) to be considered an agent, we require for it to be in possession of the following three properties: (1) *autonomy*, as the ability of the agent to function on its own with no outside help; (2) *proactivity*, as the ability of the agent to undertake actions to satisfy its goals; and (3) *purpose*, as the ability to attribute goals, beliefs, and/or desires.

The agents inhabit a given *environment* that they interact with. Through interaction with the environment they are in, they learn what to expect from it (but sometimes they end up being surprised or experiencing pain when bumping into obstacles). If more than one agent inhabits the same environment, we talk of a *multi-agent system* inhabiting that environment. Actually, if the agents only view the other agents as a part of the environment, without communicating with each other, it would not make sense to talk about systems, as the term itself from the perspective of the science of cybernetics assumes that the parts of a collection work together. Without the agents working together, we would be observing a collection of agents that only notice the other ones as a part of a changing, dynamic environment, and most of the time they would mess up the expectations of the agent of the environment.

When many agents that are built the same, have the same abilities, and can communicate between themselves, are put together in the same environment we can sit back and observe emergent phenomena in a society of *homogenous* agents. We live in such an environment, indeed, for example, with so many other fellow humans. But we do not communicate with other humans only. If we look deeper into our environment, we might identify agents that are not human but with still some kind of an interaction and communication going between us. For example, although my pets are not human, I can still communicate with them. Systems where the agents are not necessarily homogenous will be referred to as *heterogeneous*.

This book will concentrate on the uniagent environments and then extend the theory to multi-agent systems (the term multi-agent societies is — after all — an oxymoron) that consist of *homogenous* agents. The discussions may lead to possible generalizations into the area of heterogeneous systems, though. Systems with one agent in the environment that we observe will be referred to as *uniagent environments*.

Why this interest in multi-agent systems? Well, in the past few years we witnessed an increase in their importance in many of the computer sciences (artificial intelligence [AI], theory of distributed systems, robotics, artificial life, etc.). The main reason for this appeal — I think — is the fact that they introduce the problem of collective intelligence and emergence of patterns and structures through interaction. Classical AI has attempted to study a lot of relevant phenomena. Despite the limited success in several isolated fields, this discipline seems to have always been chocked into its own unsuccessful, full of vicious traps, formalisms…

The research in multi-agent systems requires an integrated, not analytical approach. The majority of research work in this domain is toward two main goals. First, carrying out a theoretical and experimental analysis of the self-organizing mechanisms during the interaction of two (or more) agents. The second is creation of distributed artifacts able to cope with complex tasks via collaboration and interaction amongst themselves.

Several years ago, when we were investigating interagent communication, the imitation phenomena found its natural place in our multi-agent theory. After being put aside as nonintelligent learning (if learning at all), with the 1996 discovery of mirror neurons by Rizzolatti, we ended up convinced that — after all — *imitation* is far from a trivial phenomenon but rather a creative mapping of one's actions and their consequences onto self. The mirror neurons, located in the frontal cortex, fire when the subject is executing motor actions while watching somebody else doing them. It seems that, after all, we are wired for imitation. We believe that is *how* we learn at very early age.

In this book, we give an attempt to establish a mechanism of interagent communication in the multi-agent environment, thus expanding IETAL to multi-agent systems with linguistic competence; formalizing the said methods via the means of the classical algebraic theories and the fuzzy algebraic structures; studying the emerging structures when interacting with the environment, and studying the emerging social phenomena in the system.

What we discuss in this book would not be classified as mainstream AI by most researchers. We rather offer solutions for some problems that AI was either not successful in solving or did not consider at all. This is a contribution towards the sciences that emerged more than a decade ago from the classical AI, more specifically the cognitive sciences and especially developmental and cognitive robotics and multi-agent systems.

The book is organized in three main sections followed by two appendices: Theory (Chapters I-IX), Cases (Chapters X-XIII), and Alternatives (Chapters XIV-XV). In the sequel of this introduction we briefly summarize the contents of the chapters, thus painting the big picture. The details are in the respective chapters. The appendices have been added to supplement the chapters; they have been placed at the end of the book.

Section I: Theory

In this section we give an overview of our theories and views of agency, learning in agents, multi-agency, and emergent phenomena in multi-agent systems.

In **Chapter I**, *On Our Four Foci*, we introduce the most important basic concepts for this book. We give an overview of the notion of an agent; a multi-agent society; interaction between the agent and the environment and the interaction between agents; and put it in the relevant historic and theoretical framework. We focus here on the four foci of our theories: agent, environment, imitation, and multi-agent system.

The **Chapter II**, *On Agency*, overviews the IETAL theory developed from the need to offer solutions to well-known problems in autonomous agent design. As the name of the theory indicates, the key concepts in the uniagent theory are those of *expectation* and *interaction*. With the expectancies we emphasize the notion of being in the world. They are defined as the ability of the autonomous agent to expect (anticipate) the effects of its actions in the world. The second key notion in the theory is the interaction with the environment. The expectancies are being built through the interaction with the environment the agents inhabit.

Chapter III, *On Drives*, we give the relation between the drives, motivations, and actions, as well as a short overview of some key interagent and social concepts in multi-agent systems. We often distinguish between consummatory acts and appetitive behaviors. The first ones refer to the intention for satisfaction of a tendency, and the latter ones are being applied in the active phase of the purposeful behavior. The taxings are on the very border between the two. They are the behaviors that orient and align the agents towards (or from) the source of simulation. The agent gains information of the world via its precepts and readies action to meet its goal. The perception system is the gate between the world and the agent. The standard categorization of the motivations is as follows: personal motivations, the object of which is the agent itself, aiming at satisfying its needs or relieving itself from obligations imposed on it; motivations from the environment, produced by perceptions of elements of the environment; social motivations, imposed by the meta-motivations of the designer;

and relational motivations, that depend on the tendencies of the other agents. A separate class of motivations (according to other classification criterion) would be the motivations of agreement as a result of the agreement of the agent to undertake a given responsibility.

Appendix B complements this chapter, as it focuses on what motivates humans. It raises questions researched well in psychological literature. What motivates people? Why do they behave as they do? For that matter, why do people do anything at all? Questions like these have persisted over 100 years of psychology despite decades upon decades of research to answer them. Waves of academic thinking have addressed these issues, with each new school of thought providing different answers, at least in form if not in function.

When the agents are more complex, the relationship between the drives and tendencies become more complex as well. In more simple agents where we include Petitagé, the tendencies are results of the combinations of the inner stimuli and the stimuli of the environment. As the complexity rises, the systems are able to combine the tendencies into higher-order tendencies.

The main problems that this theory deals with are learning about the environment and using the intrinsic representation of the environment that helps guide the agent towards the satisfaction of its drives. The second problem is the one of the human-agent interaction, which is typically not being discussed within the research in the area. Unlike the *traditional* approaches in the so-called behavior-based design, we emphasize the importance of the interaction between the agent and the environment. During this interaction, the agent becomes aware of the effects of its actions via learning the expectations.

Accurate spatial representations are imperative for good performances in autonomous agents. We give the algebraic framework for spatial representations in mobile agents, which is used as a formal frame for our experiments. For successful performance of the mobile agents, accurate spatial representations are crucial. The agent should learn the environment through the interaction with it. In more recent studies, this approach is referred to as navigational map learning. These maps are planar connected graphs whose vertices are locally distinct places, and edges are the agent's actions. More problems emerge in a more realistic situation when two or more places in the environment look the same to the agent, due to sensor limitations. This problem is referred to as *perceptual aliasing*. **Chapter IV** (*On IETAL, Algebraically*) presents the algebraic framework for modeling our agents, whereas **Chapter V** (*On Learning*) discusses how these agents build their intrinsic representation of their environment through interacting with it.

Appendix B fills in the theoretical gap between Chapter V and Chapter VI and should be read by those unfamiliar with the fuzzy algebraic structures before reading Chapter VI. In this appendix, three approaches in defining fuzzy graphs (*Fuzzy graphs*: graphs with fuzzy vertices; graphs with fuzzy edges;

and graphs with fuzzy vertices and fuzzy edge [• ostak graph]). They are further discussed in the context of the term random graph, and • ostak graphs are also defined. In **Appendix A**, we also present the theories of L-fuzzy lattices, as a specification on one hand, and generalization, on the other, of the fuzzy graph, and we give directions for further generalizations in the sense of poset and relational structure-valued lattices. As lattices are being considered as algebraic and as relational structures, we discuss two types of two kinds of fuzzy lattices: L^M, where the membership function of the structure carrier is fuzzified, and L^O, where the ordering relation of the carrier is being fuzzified. The link between these two kinds of lattices is given via algorithms for rerepresentations. This approach is outlining a more general approach that can be adopted in the fuzzification of algebraic and relational structures via their level cuts. As we believe — and our beliefs are supported from previous research — the drives in humans are hierarchically ordered. As the behavior of our agents depends on the active drives, the drive structure becomes crucial in the modeling of our societies because most structures are valued by the drive hierarchies.

Abraham Maslow has developed a hierarchical system of drives that influence human behavior. On a low level, the psychological and physical needs are on the bottom of the hierarchy. They need to be at least partially satisfied in order for the human to be motivated by higher-order motivations. Maslow's hierarchy levels (bottom to top) are as follows: biological motivations (food, sleep, water, and oxygen), safety, belonging, and love (participation in sexual and nonsexual relationships, belonging to given social groups), respect (as an individual), and self-actualization (being everything that the individual is able to be). In such a strict hierarchy, the drives are ordered in a chain, a special case of a lattice. The motivations, though, do not need to be always comparable, and the hierarchy does not always imply linear order. **Chapter VI**, *On IETAL, Fuzzy Algebraically*, which is based on the theories in Appendix A, gives an alternative to the algebraic environment representation. The notion of intrinsic representation is formally defined as a fuzzy relation valued by the agent's drives lattice. The understanding of the term context is also discussed.

In **Chapter VII**, *On Agent Societies*, we describe the multi-agent environment inhabited with homogenous agents that have the ability to imitate their cohabitants. Every agent in the multi-agent system has a special sensor for the other agents close to it in the environment. The drive to communicate is the top of its drive structure. This multi-agent extension of IETAL is called Multi-Agent Simulated Interactive Virtual Environments (MASIVE). As soon as one agent in the society senses another, the agent switches to the *imitation mode*, where it stays as long as the interchange of the contingency tables lasts. The contingency tables grow as the intrinsic representations are being exchanged. The drive to find akin agents in the environments is at the top of the drive structures in MASIVE. We now observe some emerging structures in the multi-agent system.

Hardware constraints of the associative memory are a more complex problem than the temporal constraints. Solutions need to be provided when the memory is full. Normally, rows with low emotional context would be discarded and replaced with more actual ones. The knowledge structure of agents in those cases would have a bottom but not a unique top, and therefore, would not be a lattice. As an alternative to the whole intrinsic representations exchange during the *imitation conventions*, agents could only exchange rows relevant to only and active drive. In the tradition of generation-to-generation knowledge propagation in human societies, agents could unidirectionally exchange knowledge from the older to the younger individuals. A problem of importance in the context of this discussion is when to conclude if two rows are contradictory to each other. In our simulations we were randomly choosing one of the candidates for expectations. Another biologically inspired solution to this problem would be in cases like this one, to go with the personal experience and discard in consideration those rows that were acquired in conventions. Instead of random choice when contradictory rows are in question, each row can be attributed a context, in the sense of evidence, from the theory of evidence, or more generally, the theory of fuzzy measures.

The phenomenon of imitation is the one that we strongly believe is responsible for learning from other agents (at least at an early age). In Chapter VII (*On Agent Societies*) we also overview relevant literature from developmental psychology, infant behavior, and neuroscience that both through indirect results (various experiments) and direct wiring (brain regions in monkeys' and human brains) motivated us to adopt imitation conventions as a method in information interchange between agents.

Chapter VIII, *On Concepts and Emergence of Language*, gives a critical take on the theories on concept formation and concept development. The popular theories of concept formation involve categorization based upon the physical features that differentiate the concept. Physical features do not provide the understanding of objects, entities, events, or words, and so cannot be used to form a concept. We have come to believe that the affect the object, entity, event, or word has on the environment is what needs to be evaluated for true concept formation. Following our argument for a change in the direction of research, our views on some of the other aspects of concept formation are presented. The second section of the chapter discusses language as a key element for communication in multi-agent systems. In this chapter we discuss the phenomena of emergence of language, amongst the other issues. Communication is expressed via the interactions in which the dynamic relation between the agents is being carried via mediators, called signals that once interpreted, influence the agents. In the sense of the complexity of the communications, the autonomous agents can be classified in four basic categories (ordered by intensity of the communication): homogenous, which do not communicate; heterogeneous, without communication; heterogeneous, which communicate; and centralized agent (uni-agent environment). Normally, we assume that there are six ways of communication in two major functional categories (paralinguistic and metaconceptual): *expressive* functions, that is being characterized by information interchange of and about the intensions of the agent: "This is me, what I believe and what I think"; *conative* function, with which one of the agents asks another to answer a question or to do something for it: "Do this, answer me this question"; *reference* function that refers to the context of discourse: "This is the state of the matters"; *fatic* function that is being used to establish, prolong, or cut a given process of communication: "I want to communicate with you and can clearly read your messages"; *poetic* function, that beautifies the message, and the *meta-linguistic* function: "When I say 'X', I mean 'Y'."

In the uniagent version of IETAL the term perceptual category refers to a row in the contingency table. These categories are being built based on the inborn scheme. The agent builds perceptual categories during its sojourn in the environment and also depends on the active drive of the agent. During its interaction with the environment, an internal classification/similarities engine classifies the contents of the *mind* of the agent and builds categories/concepts. We can assume the other agents to be understood as a part of the environment in this context, and they help build the contingency table of a given agent. They normally need to be named, and the name stamp should also be a part of the table. The naming of the agents is a separate problem that can be solved via special percepts for each individual agent. Perceptual aliasing is also another phenomenon that can be observed. All perceptual categories that refer to a given drive compose the conceptual category for the drive. They model the trip to the satisfaction of a given drive, as well the object that satisfies it. From the perspective of agent's introspection, the concept makes the agent aware of the places where a certain drive can be satisfied. From the social perspective, when the concept is being fortified during the imitation conventions, the agent serves the environment it is in, and disseminates to the other agents information about the satisfaction of the drives of the fellow agents. If we introduce a system for attributing similarity measure to two lexemes, then the classes of equivalence will be indeed the concepts in the agents. Categorization is needed, because generally, we have a limited number of behaviors. In the modeling of our agents, we can introduce a module for computing similarities, that is, the categorizing module. Based on the protolexemes and their emotional context, the similarity-measuring engine decides whether two lexemes are similar or not. That can further be used for the reduction of the contingency tables after the imitation convention of two agents. Then, there would be no need for spending any associative memory for keeping similar protosentences. Another aspect of the categorization is the so-called *categorical perception*, when the agent distinguishes between physical and functional perception. The functional perception refers to objects in the environment that are perceived differently but serve a similar function. In our theory the functional perception was solved by assuming that the agent has a special sensor for the object that satisfies its appetitive drives. From the mathematical perspective, the similarity relation is a fuzzy equivalence relation. Every equivalence class in that context is a concept. When the agent enters the environment it starts building its conceptualization of the environment, while sharing information with the other agents through its personal experience and the information of the other agents. The conceptualization module builds the conceptual scheme of the agent. During the imitation conventions, the agents cannot share concepts, but they can exchange representatives from the equivalence classes. This comment is biologically inspired because in humans we explain one notion via others until the other individual conceptualize that notion.

The first section of the book ends with **Chapter IX**, *On Emergent Phenomena: If I'm Not in Control, Then Who Is? The Politics of Emergence in Multi-Agent Systems*. There, we give an overview and critique on emergent phenomena in multi-agent societies. Part of the popularity of multi-agent systems-as-generative-metaphor, however, lies in the synergy between multi-agent systems in computer science and the *sciences of complexity* in biology, where the beauty is seen in the emergence of higher levels of collective behavior from the interactions of relatively simple agents.

Section II: Cases

In this section of the book we overview a series of software and hardware solutions that we have been using in the process of simulation studies, robotic emulations, and gathering information from human subjects. The emphasis is given on the technical solutions that we have implemented, thus making them replicable and customizable for researchers doing similar research. We end this section with an overview of our Patterns in Orientation: Pattern-Aided Simulation Interactive Context Learning Experiment (POPSICLE).

The Multi-agent Systems Simulations (MASim) simulator is overviewed in **Chapter X**, *On MASim: A Gallery of Behaviors in Small Societies*. This simulator has been developed in order to facilitate the user with an environment in which to observe behavior of one to four agents in a randomly generated environment with wall-like obstacle. The chapter focuses on the particularities of the use of MASim and presents some simulation results generated by a modification of this software. Note that the metrics in this gallery are different than the metrics used in the study of IETAL. A step here refers to a single action application, whereas, in the IETAL statistics generation we used the application of a row of the contingency table as one congregate action (transitions). This chapter goes into detail on the implementation of the emotional context function that has been discussed scarcely up to this point. The emotional context depends on the active drive, it is attributed to the rows of the contingency tables, and it is a measure of the *usefulness* of that particular row in the quest of drive satisfaction in previous experiences. The emotional context changes in time diminishes for entries in the contingency table that have not been contributing recently, so the agent tends to forget them. Although we have experimented with exponential approach in the description of the emotional concept previously, in the original IETAL simulations, here we simplified the approach and use integers. The larger the integer, the further the row of the contingency table is from the drive satisfier. We also use an alternative (oversimplified) parameter in the approach shown in this chapter: **confidence**. The importance of MASim lies in the lessons learned, and identifies the points of improvement.

Historically, MASim evolved in a more general environment presented in **Chapter XI**, *On a Software Platform for MASIVE Simulations*. We present a software library providing tools for IETAL and MASIVE simulations. This chapter overviews the technical solutions in the development of the project and gives details on integrations of the modules developed for other IETAL or MASIVE-like experiments. The system simulates the behavior of autonomous agents in a two-dimensional world (grid) of cells, which may include cells the agent is free to move into or walls that block movement. The goal of an agent is to satisfy specific user-defined drives, such as hunger, thirst, and so forth. An agent may have any number of drives, but only one is active at any given point in time. Additionally, the user populates select world cells with drive satisfiers that are used to satisfy the active drive of any agent entering the cell. In other words, when an agent moves into a cell containing a drive satisfier, the drive is only satisfied if it is the agent's active drive. In the beginning, the agents navigate around the world using a user defined inherent scheme, which is a short series of moves the agent will make by default. Gradually, an agent builds up an internal associative memory table as it explores the environment in search of drive satisfiers. As the agent moves in search of a drive satisfier, observations are made and recorded in the emotional context of the active drive. Once a drive has been satisfied, the recorded observations (leading to drive satisfaction) are recoded in the agent's associative memory table. As the agent continues to explore the world, other drives may become active, leading to new observations in new contexts. As the agent continues to build a model of the world in relationship to its drives, the agent will begin to use its associative memory to plan a route to the drive satisfier. The agent uses current observations to derive expectations from the associative memory table. When a matching observation is found in the table, the agent temporarily abandons its inborn scheme and uses the expectation to execute the next series of moves. If the observations made during this next series of moves match another observation in the table, the process continues until the drive satisfier is reached. If at any time a subsequent observation does not match the expectation, the agent records a surprise and returns to its inherent scheme to continue exploration — all the while, continuing to make new observations. Additionally, if the agent cannot make a move because a path is blocked by a wall or world boundary, the agent registers this as pain, skips the move, and continues execution of scheme or expectation. Unlike MASim, this environment is much more general and can be used and integrated in a variety of simulations. It contains a library of functions for customized implementations when designing a broad range of experimental setups.

For realistic real-world experiments of IETAL/MASIVE we have developed our own robotic agents. In **Chapter XII**, *On a Robotic Platform for MASIVE-Like Experiments,* we overview some of the technical details on the hardware solution and the low-level programming details of projects implemented. As a control unit for the robot we have chosen the BrainStem® unit. Not only was this unit inexpensive (as are all the other parts of the robot) but we can easily boost its computational powers by using a Palm® Pilot. When a Bluetooth™ card is inserted in the Palm Pilot the agents can communicate between themselves. This chapter gives the recipe for building such agent(s), as they are easily replicable.

The POPSICLE experiment chapter (**Chapter XIII**: *On the POPSICLE Experiments*) looks at the setup and some of the results of our experiments with human subjects that are emulating abstract agents. POPSICLE is a study of learning in human agents, where we investigate parameters and patterns of learning. We study the use of inborn schemes in environments and phenomena that emerge in the environments via the imitation conventions of the subjects. In this chapter we describe the environment, give its importance in the context of IETAL and MASIVE, and give the results collected from 60 participants as subjects of the study, who emulated abstract agents in a uni- and multi-agent environment. The parameters that were measured were the interaction times, the parameters in the success of finding food, as well as the amount of pain (hitting an obstacle) encountered in the quest for food. From the data collected, we were able to extract data on the sequences used while in the environment to attempt a study in the inborn schemes area. The lessons learned from POPSICLE help us calibrate our simulations of the agents in the IETAL and MASIVE theories. The subjects' reactions are indications of a limited (for such a small environment) but valuable variety of inborn schemes in the sense of Piaget.

In addition to the simulation solutions, we have also developed an online data harvesting engine to facilitate POPSICLE-like studies in human agents online, called e-POPSICLE. This tool is rather general and enables the designer to set up his/her own scenario of POPSICLE-like modules. Instead of tiles with colors, as in the original experiments, the designer might choose to work with more general environments (not only direct perception-action systems). For example, what the subject sees might be numbers, and a pattern consisting of prime numbers might lead from the start position to the goal directly.

Having studied the phenomenon of stress in the human agents in the POPSICLE environment, we have developed a 3D testing environment with methodologies from game design that are expected to keep the motivation of the subject high during any configuration of a POPSICLE experiment. Both qualitative data and interview remarks indicate that to the subjects it is hard to maintain concentration past the first 15-20 minutes of the POPSICLE experience. We have taken the experimental environment one dimension up, made it 3D and implemented common objects from video games — counters, prizes, and so forth to keep the motivation up while we are gathering interactions data and data on pain and surprises in subjects.

Section III: Alternatives

In this section of the book we give results from our related research in the area, and we pave the ground for our future investigations.

In **Chapter XIV**, *On an Evolutionary Approach to Language*, we use the genetic algorithms approach in the study of language emergence in an artificial society. The inborn scheme evolves through the generations of the agents inhabiting the environment. The inborn schemes of any two agents can cross over or they can self-mutate (within an agent, internally).

Chapter XV, *On Future Work*, concludes the theory discussed in the book and gives directions for further research. Some of the topics we discuss here are the human-computer interaction (HCI), interactions in heterogeneous environments, and the use of the alternative theories and tools for environment modeling in multi-agent systems, as a continuous counterpart of our discrete theory. In environments with heterogeneous agents, the problem of interagent communication is important, and not many solutions have been proposed for it. Due to the differences in the construction and the perceptual abilities, there would be no similarities in the construction of the protolanguage. In this area, we are aware of research in the domain of polyglot agents that serve as translators. The phenomenon of bilingualism itself creates a plethora of questions and has been studied at large. But, is it possible to construct a translating function between heterogeneous agents? What preconditions should be met for such communication to be possible? How does language emerge from protolanguage? What is the reason for bilingualism? Another aspect of the before mentioned questions is the communication between the agents and the designers. How does the designer tell the agents what he/she wants them to figure out about the environment? The problem of interaction then becomes a problem in HCI. What is then the interface? How to design an interface between two homogenous agents? How to do the same for two heterogeneous agents?

Online interactions have usually been structured through metaphors drawn from physical spaces (e.g., multi-user dungeons, chat rooms, distance learning, and home pages) and through certain assumptions about the user derived from pre-existing, physical relationships (e.g., the distance learner in the virtual classroom, online shopping). Not only do these assumptions ignore the heterogeneity of our social and cultural lives, but also to the extent to which all of these differences might mean different outcomes, that is, the possibility that there are different ways of conceptualizing computer-mediated interaction applicable online interactions of all kinds. We are now developing a dynamic, online, *0-context* environment-agent that will allow us to study online interaction as a simultaneously, cognitive, social, and cultural event. Our online instrument, *Izbushka*, changes with the inputs from users and the patterns that emerge are the co-production of each agent — human and nonhuman. During the experiences, different teams will interact with the online environment and with each other, generating *emergent* forms of learning, communicating, and behaving.

In the proposed research, we proceed from the insight that our interactions with online environments and agents have been usually structured through metaphors drawn from physical spaces (information superhighways, chat rooms, home pages) and through extant, social interactions (querying, directing, sending). While this is to a certain degree unavoidable (*cyberspace* is, after all a notional space), this way of understanding does not take into account (1) the social and cultural differences structuring different online practices, and (2) the ways in which humans themselves have cognitively, socially, and culturally changed as they have accommodated their lives to the information networks interpenetrating their lives. Taking ideas of distributed cognition and *enaction* associated with multi-agent systems and third-generation cybernetics, we propose to develop online tools that we believe will be generative of new understandings of online interactions by presenting users with a *0-context* environment-agent *Izbushka* that is in many ways inexplicable and unfamiliar, that is, without evident goals, familiar *spaces,* or language.

* * *

So, this is the big picture. Let us zoom in now and look into the chapters.