Chapter 2
A Unified Framework

In this section, firstly an overview of the proposed framework is presented. Next the framework is described from two different perspectives firstly in terms of study objectives of conducting a CAS research case study and the expected level of commitment. Secondly, the framework is described in correlation with the availability and access to specific data types.

2.1 Overview of the Proposed Framework

For the sake of practicality, the framework guidelines have been developed in the form of levels of abstraction. Thus, CAS researchers can opt for modeling at a particular level depending on factors such as availability of data, meta-data as well as the level of interest and how much time CAS researchers can invest in pursuing a research project. In addition, example case studies are presented to demonstrate the usage of various framework levels. Based on the proposed framework, research in CAS can be conducted by choosing and subsequently following one of the following four proposed levels for developing CAS models:

- The complex network modeling level of the framework is useful if interaction data is readily available. In this level, complex network models of CAS can be developed using this interaction data and subsequently Complex Network Analysis (CNA) can be performed for network classification as well as determination of various global and local quantitative measures from the network for the extraction of useful information. Such information can give details of emergent behavior and patterns which would otherwise have not been evident using statistical or other more traditional mathematical methods. Numerous software tools are available which allow for an analysis of complex network models.

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- The exploratory agent-based modeling level of the framework extends existing ideas of agent-based modeling prevalent in multidisciplinary literature which focus on the development of exploratory agent-based models of CAS to examine and extricate possible emergent trends in the CAS. Building exploratory models allows CAS researchers to develop experimental models which help lay foundation for further research. These proof-of-concept models also assist researchers in determining the feasibility of future research in the domain using the selected model design.
- While text-based descriptions of models exist, such as the ODD protocol, these descriptions have primarily been designed for the human user. There is need to develop discipline-independent numerical and formal descriptions of models. While the previous framework models reflected existing research in ABM and CNs, this framework level combines both ABMs with a non-textual description to give a descriptive model of a CAS. Developing models at the descriptive agent-based modeling level of the framework entails developing concrete Descriptive Agent-based Models (DREAM) by using a combination of pseudocode-based specification, a complex network model and a quantitative model "fingerprint" based on centrality measures of the agent-based model which are all associated closely with the ABM. The pseudocode-based specification is developed in the form of non-code template schemas and has several benefits; firstly it is close to an executable specification but is not tied with any single programming language thus allowing use by CAS researchers for developing agent-based models based on the specification using tools of their own liking. Secondly, this specific type of specification allows a one-to-one correspondence of ABM concepts with the descriptive model. Thirdly this specification allows communication and comparison of models in multidisciplinary studies by using visual as well as quantitative methods.
- In addition to developing descriptions of models, an important feature needed for a framework would be a scheme of validation which would also encompass previous validation techniques such as empirical validation while allowing for specifying validation specific to CAS. The validated agent-based modeling level of the proposed framework is concerned with developing verified and validated agent-based models. This level allows performing in-simulation verification and validation of the agent-based models using a Virtual Overlay Multiagent System (VOMAS) based on a cooperative set of agents inside the simulation allowing the verification and validation of the CAS model by means of design-by-contract invariants. These invariants are developed as a result of collaboration of the Subject Matter Expert (SME) and the Simulation Specialist (SS). In this level, concepts originating from software engineering, multiagent Systems and social sciences are all used in tandem to propose a systematic methodology for ABM verification and validation.

2.2 Proposed Framework Levels Formulated in Terms of CAS Study Objectives

In Fig. 2.1, it can be noted how different framework levels can be used by multidisciplinary CAS researchers to develop models based on their particular study objectives and expected outcomes.

If there is sufficient interaction data available then the CAS research study can proceed by using the complex network modeling level of the proposed framework. In this level, researchers first analyze the data columns, extract suitable data, develop complex network models and subsequently perform network manipulation and complex network analysis for the discovery of emergent patterns.

However, as is often the case, if such data is unavailable and the goal of the research study is to determine the feasibility of future research, then it might be possible to feasible to proceed in their research study by using the exploratory ABM level of the proposed framework.

These two framework levels essentially can also be used to encompass existing CAS research studies which have primarily used either complex network modeling and analysis or else agent-based modeling or both in their analyses.

If however, the goal of the research is to perform an inter-disciplinary comparative case study then the descriptive agent-based modeling level of the proposed framework allowing for developing a DREAM model can be chosen. This particular framework level has the benefit of allowing for inter-disciplinary model comparison, knowledge transfer and learning.

Finally, if the goal of the study is develop simulations with a high degree of correlation with real-world systems such as in the development of decision support systems, then the appropriate framework level for usage would be the validated agent-based modeling level based on the development of an in-simulation validation scheme using the VOMAS approach. This framework level is also more suitable for large-scale team oriented projects and requires adherence to team-oriented protocols with the goal of a verified and validated agent-based model of the CAS system under study.

2.3 Proposed Framework Levels Formulated in Relation to Available Data Types

In the previous section, an overview of the different framework levels in relation to the CAS research study objectives was presented. In this section, we shall describe the framework in terms of available data or knowledge related to the CAS. Thus while the previous figure allows CAS researchers to choose a suitable modeling level, here we discuss the specific type of knowledge and data needed to pursue specific types of studies. As we can note from Fig. 2.2, a descriptive specification of the CAS model can be developed based on the metadata or knowledge about the CAS.

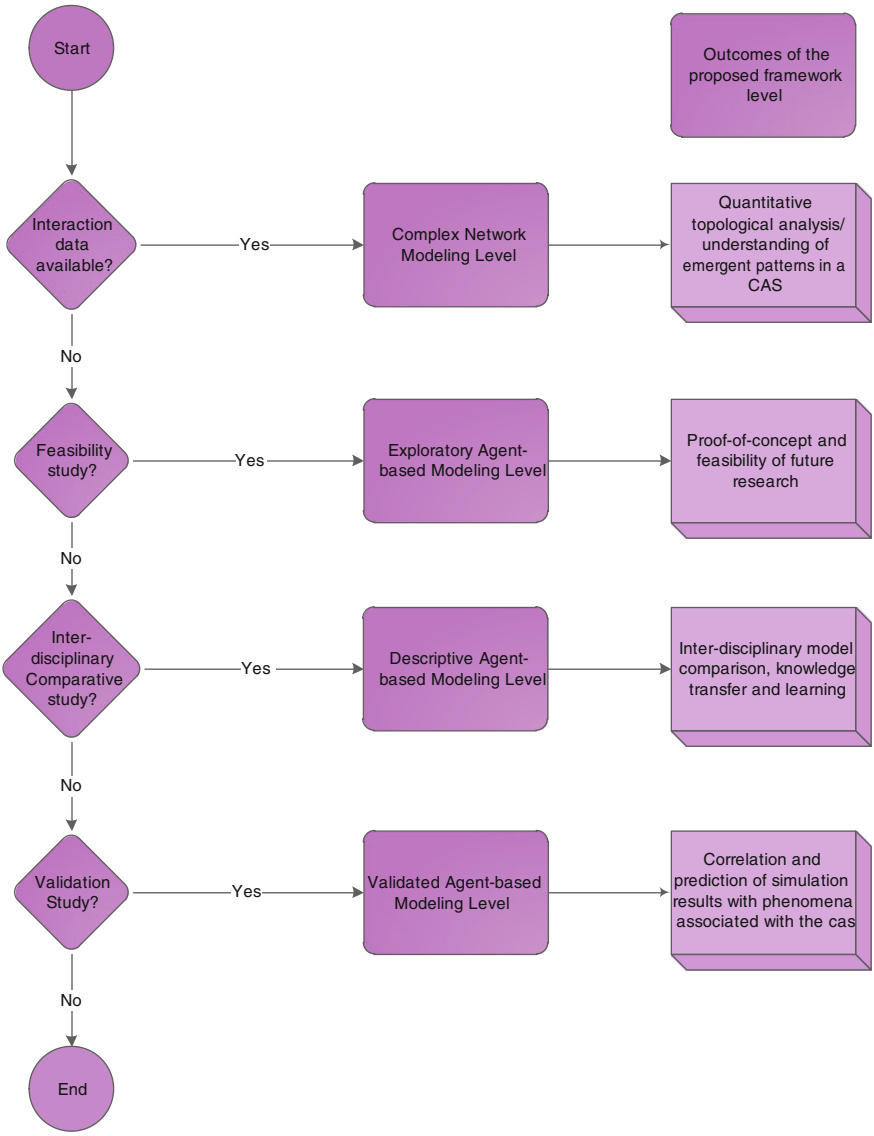

Fig. 2.1 An overview of the decision-making process for choosing framework levels in relation to CAS research study objectives

An ABM can be developed either from this specification or directly from the knowledge of CAS. The ABM can be verified and validated using in-simulation validation (which has been developed as a result of extensive meetings between SMEs and SSs) that is performed by building a VOMAS model. By the help of invariant constraints enforced by the cooperative agents forming the VOMAS, the simulation

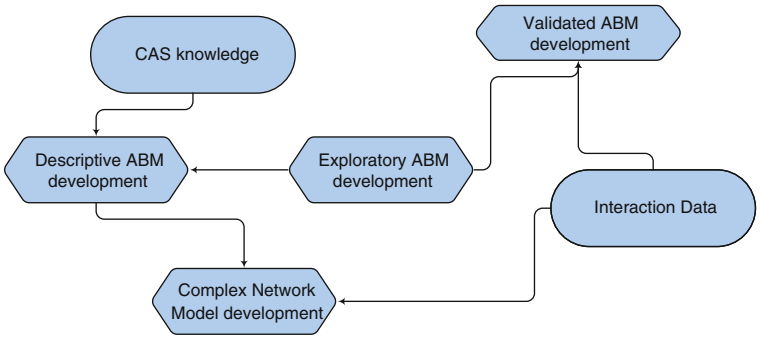

Fig. 2.2 A detailed overview of the framework

can be verified and validated using in-simulation methods. In addition, if interaction data is available for the development of network models, complex network models can be developed and CNA can be used to manipulate and analyze various structural topological features of the interactions using various information visualization-based and mathematical tools.

2.4 Overview of the Rest of the Parts

Here, first an overview of the different explored case studies is provided. This is followed by an overview of the chapters.

2.4.1 Overview of Case Studies

To ensure that the research was in line with the norms of various CAS, we have worked in tandem with teams of CAS researchers and domain experts from life sciences, social sciences and telecommunications. The following list gives details of some of the case studies discussed in this set of SpringerBriefs as a means of examples of the application of the proposed methods associated with various levels of framework along in correlation with the Briefs:

- The proposed framework level is applied on two different case studies in the domain of Scientometric data of agent-based computing and consumer electronics domains.
- A comprehensive case study on the use of unstructured search algorithms from the domain of P2P networks in the domain of "Cyber-physical systems" (Wayne 2009) by the development of an "Internet of things" (Ashton 2009) has been presented.
- A case study on the development of a heterogeneous ABM of sensing single-hop Wireless Sensor Network for sensing complex behaviors of flocking "boids" is presented.

- Three different case studies are presented. The first case study is in the domain of ecological modeling and models forest fire simulations. The second is in the domain of multi-hop Wireless Sensor Networks modeled in the form of a Quasi Unit Disk Graph (QUDG). The third case study is in the domain of simulation of the evolution of researchers on the basis of their Hirsch index.

2.4.2 Outline of the Briefs

Here we give an outline of the set of Springer Briefs:

- Part-1. This part presents background and related work. In addition an overview of the entire framework is presented.
- Part-2. This part presents complex network modeling level of the proposed framework. These methods are further applied to different domains such as Agent-based Computing and Consumer Electronics.
- Part-3. This part presents exploratory Agent-based modeling level of the proposed framework. As a demonstration of the proposed methods, a comprehensive exploratory agent-based model in the domain of Cyber-Physical Systems is developed demonstrating a combination of unstructured P2P search methods to locate content in static and mobile physical computing devices.
- Part-4. In this part, descriptive agent-based modeling level of the proposed framework is presented. Descriptive modeling entails the development of a DescRiptivE Agent-Based Modeling (DREAM) model by using a combination of a complex network model, a quantitative centrality-based fingerprint and a pseudocode-based specification model with a high degree of fidelity with the actual agent-based model. As a means of demonstration of the proposed framework level, the DREAM approach is applied in a comprehensive case study of a heterogeneous CAS ABM of a WSN observing a set of flocking "boids".
- Part-5. In this part, the validated agent-based modeling level of the proposed framework is proposed. The proposed methodology based a team-oriented approach of in-simulation validation is demonstrated using three different application case studies from three different scientific disciplines of ecology, telecommunications and social simulation allowing for a proof of concept of the generalized and broad applicability of the proposed methods.

References

Ashton K (2009) That internet of things thing. RFID J
Wayne W (2009) Cyber-physical Systems. IEEE Computer 42:88–89

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