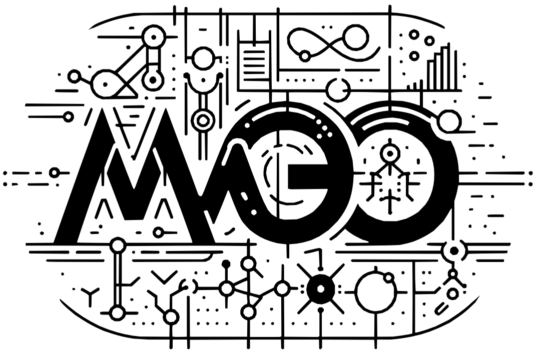
BOGDAN OKREŠA ĐURIĆ

Developing a Framework for Agent Gamification Based on Ontologies

MAGO

Part 2: MAGO-Ga Ontology and Framework



UNIZG Faculty of Organization and Informatics
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Part I

Phase 0: The GIVEn Ontology

Introduction

The development and engineering processes of the ontology described here follow the steps defined by the METHONTOLOGY ontology engineering methodology [1], [2]. This is the methodology of choice because it is very well defined, using clearly described steps to engineer the desired ontology. This and a dozen other ontology engineering methodologies were analysed more thoroughly in preparation for the author's doctoral thesis [2].

This chosen ontology engineering methodology is described as having a set number of steps, each described in detail by the authors of the methodology. In addition, steps related to the entire life cycle of an ontology are identified. An ontology life cycle is described by Iqbal, Murad, Mustapha *et al.* as '[. . .][a] set of stages through which the ontology moves during its life.' [3, p. 2997]

👁 see figure 2.1

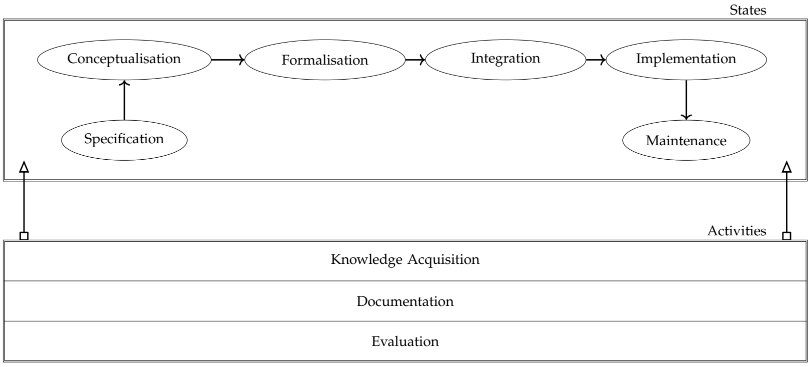

Figure 1: Basic steps of METHONTOLOGY ontology engineering methodology, reproduced from [2], adapted from [1]

The rest of this document is structured according to the defined METHONTOLOGY steps, representing the documentation process. First, the ontology specification document is described and given, followed by the description of knowledge acquisition as an ongoing process. Conceptualisation originates from the defined specification and is the input to formalisation. Once the ontology is formalised, it can be integrated with other ontologies of similar domains. Finally, the ontology is implemented and maintained. The ontology is evaluated in phase P1.2 of this part of this research. Each methodology step is briefly described at the beginning of the related chapter.

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1 Specification

The second part of this research is geared towards video games and the concept related to video games. The main objective of this is to combine the concepts of multiagent systems (MASs) and video games into a working system capable of modelling video games using the concepts applicable to MASs, with special emphasis on modelling systems of agents in intelligent virtual environments (IVEs). Furthermore, the modelled MAGO-Ga ontology aims to map gamification's techniques, mechanics, actions and behaviours to propose a way of introducing gamification to a system of reasoning agents. The result will be developed towards a system that can automatically adapt based on the set or emerging goals while keeping true to its initially (or planned for) gamified nature.

The GIVEn ontology is the first step towards creating the MAGO-Ga ontology that features gamification-specific concepts.

The main objective of the GIVEn ontology is to provide concepts necessary for describing video games as intelligent virtual environments (IVEs). An IVE is a concept used for describing 'a physical world inhabited by autonomous intelligent entities.' [4]–[6] When transferred to the domain of video games, the concept of an IVE can be considered as describing the game world inhabited by autonomous intelligent entities. Furthermore, one might consider the 'physical world' concept to map to the 'game world', the people of the physical world as the artificial intelligent agents playing the non-player characters (NPCs) in the game world, the 'autonomous intelligent entities' as additional artificial agents in the game world implementing all the other needed roles.

intended use

The GIVEn ontology will be used to model video games in the domain context of IVEs. Therefore, the GIVEn ontology builds upon the already-developed MAMbO5 ontology [4]. The MAMbO5 ontology features concepts for modelling IVEs enhanced with concepts for describing agent-based organisational features. The concepts featured in MAMbO5 ontology can be considered abstractions of the concepts that can be found in the GIVEn ontology. The foreseen benefit of this approach is to create a way of modelling the simulated world of a video game, like modelling the real world, thus potentially making it easier to translate simulations created for the real world into game-based environments. Such an approach is deemed useful since simulated environments are prone to many problems that occur in the real world, such as physical constraints.

scenario of use

The GIVEn ontology is planned to be used for describing video game worlds using the applicable concepts. Such models might be used in simulations or to provide the necessary context to intelligent artificial agents to enhance their reasoning capabilities. Furthermore, a model describing the main concepts of a video game as an IVE can be used to generate various types of content for the modelled game, e.g. to generate worlds based on their ontological models or to generate NPCs that can understand the world, or to automatically generate items that can have features that are aligned with the model of the video game world.

degree of formality

To achieve the described, the GIVEn ontology will be expressed using a high degree of formality, namely classified as rigorously formal by [7]. The formal structure of the ontology, along with its various constraints, guarantees clarity, unambiguity, and ease of use. Additionally, this structure facilitates the process of extending other ontologies or allowing other ontologies to extend it. Lastly, a highly formalized expression of an ontology enhances its compatibility with other digital systems.

scope

Based on the above description of the GIVEn ontology, the ontology is planned to comprise the concepts that specify the concepts that can be found in the MAMbO5 ontology. The specification is geared towards the domain of video games and the concepts necessary to model a video game as an IVE. The foreseen additions will be in terms of specialising the `Agent` concept of the MAMbO5 ontology, possibly the `Artefact` concept, and similar. The GIVEn ontology is not planned to be created to be able to provide concepts for extremely detailed modelling of a video game.

level of granularity

The level of granularity stemming from the description above is quite abstract. The ontology should include concepts that can be, for example, used to describe NPCs, monsters, places, and points of interest in the video game, but another layer of the specification is expected to be added where the specific genre of video games should be described and genre-specific entities defined. On top of this domain-specific layer is foreseen the individual-based layer. The GIVEn ontology provides generalised concepts that should be further specified.

2
Knowledge Acquisition

Several ontologies related to video games can be found in publications dating from 2008 or later [8]–[19]. The referenced selection of the available publications was consulted, and it was found that only two of the ontologies presented in those publications can be found as publicly available formalised ontologies [14], [16]. These two ontologies are considered in this document:

- Core Game Ontology [16],
- Video Game Ontology [20].

These above-mentioned two ontologies are the only ones that can be fully analysed. Completely available ontology files are an important prerequisite to using their concepts in further development since a concept can be fully analysed and understood only when their neighbourhood is available for analysis, too.

Honourable mention is the Game Ontology Project [19], an experienced framework for describing, analysing and studying games. The resulting hierarchy of concepts pertaining to video games is not formalised and is currently available only as a collection of related wiki pages. Another honourable mention is the Game Character Ontology, presented in detail by Sacco, Liapis and Yannakakis [17], yet the ontology implementation can no longer be found online.

What follows are the concepts identified as relevant to the domain of video games, and that can be found in the two of the above-mentioned ontologies:

- Core Game Ontology,
- Video Game Ontology.

👁 see tables 2.1 – 2.13

👁 see tables 2.14 – 2.23

These concepts are described based on their definitions in the mentioned two ontologies, although that definition can change in the further steps of developing the GIVEn ontology. Only a selection of the VGO concepts is given here since the ontology is richer than the CGO one.

In addition to the above ontologies related to the domain of video games, the glossary here contains a selection of concepts from the MAMbO5 ontology. These concepts are selected as potentially useful when considering video games in the context of IVEs. Their descriptions are cited from [2], [4].

👁 see tables 2.24 – 2.40

Concept name	Game
Definition	Specifies a video game.
Description	The Game class represents a video game entity within the ontology. It serves as the central hub that connects various facets of a game, such as visuals, audio, narrative, game design, level design, and gameplay. This class encapsulates the essence of a video game, providing a foundation for detailing all its integral components. Through properties like hasVisuals, hasAudio, and hasNarrative, the Game class links to other classes that define specific aspects of the game experience.

Table 2.1: *Game* glossary entry

Concept name	Visuals
Definition	Visuals contain any visual output of a game, ranging from photorealistic to caricaturized or abstract visuals.
Description	The Visuals class encompasses all the visual elements of a game, including graphics, animations, and visual effects. This class captures the aesthetic essence of the game, whether it portrays realistic landscapes, stylized characters, or abstract art forms. By connecting to the Game class via the hasVisuals property, it specifies the visual characteristics that define the game's appearance and visual storytelling.

Table 2.2: *Visuals* glossary entry

Concept name	Audio
Definition	Audio includes background music such as a fully orchestrated soundtrack, sound effects, rewarding sounds, and voice-acted dialogue.
Description	The Audio class covers all auditory components of a game. This includes the musical score that sets the mood, sound effects that provide feedback, and voice acting that brings characters to life. Linked to the Game class through the hasAudio property, it highlights how sound enhances the gaming experience by adding depth and immersion.

Table 2.3: *Audio* glossary entry

Concept name	Narrative
Definition	Narrative contains the interactive story of a game, which makes up the game's plot.
Description	The Narrative class represents the storyline and plot elements within a game. It includes the characters, events, and dialogues that engage the player in the game's universe. Through the hasNarrative property, it connects to the Game class, emphasizing the importance of storytelling in creating an immersive and emotionally compelling experience.

Table 2.4: *Narrative* glossary entry

Concept name	GameDesign
Definition	Game design contains all the game's mechanics that define the game's rules, providing structures and frames for play (e.g., winning and losing conditions) and actions available to the player.
Description	The GameDesign class focuses on the underlying mechanics and rules that govern gameplay. It outlines how players interact with the game world, the challenges they face, and the goals they strive to achieve. By linking to the Game class via the hasGameDesign property, it details the structural framework that shapes the player's experience and defines what makes the game engaging and challenging.

Table 2.5: *GameDesign* glossary entry

Concept name	LevelDesign
Definition	Level design includes the architecture of the spatial navigation of levels, determining how the player can progress from one point in the game to another.
Description	The LevelDesign class pertains to the creation of game environments and levels. It involves the layout of spaces, placement of obstacles, and pathways that guide player progression. Connected to the Game class through the hasLevelDesign property, it highlights how thoughtful level design enhances exploration, pacing, and the overall enjoyment of the game.

Table 2.6: *LevelDesign* glossary entry

Concept name	Gameplay
Definition	Gameplay consists of the player's strategies while playing a game.
Description	The Gameplay class represents the interactive experience from the player's perspective. It encompasses the strategies, decision-making processes, and play styles that players adopt. Through the hasGameplay property, it links to the Game class, illustrating how player interaction with game mechanics leads to a unique and personal experience for each individual.

Table 2.7: *Gameplay* glossary entry

Concept name	hasVisuals
Definition	Specifies the visuals of a game.
Description	The hasVisuals property connects a Game to its Visuals, indicating the visual content that defines the game's aesthetic. This relationship showcases how visuals contribute to the game's identity and player immersion, whether through stunning graphics or distinctive art styles.

Table 2.8: *hasVisuals* glossary entry

Concept name	hasAudio
Definition	Specifies the music and sound of a game.
Description	The hasAudio property links a Game to its Audio, detailing the auditory elements that enhance the gameplay experience. This includes everything from ambient sounds and musical scores to character voices, all of which contribute to the game's atmosphere and emotional impact.

Table 2.9: *hasAudio* glossary entry

Concept name	hasNarrative
Definition	Specifies the story and plot of a game.
Description	The hasNarrative property associates a Game with its Narrative, outlining the storylines, character arcs, and plot developments that engage players. This connection underscores the role of storytelling in creating meaningful and memorable gaming experiences.

Table 2.10: *hasNarrative* glossary entry

Concept name	hasGameDesign
Definition	Specifies the rules and mechanics of a game.
Description	The hasGameDesign property links a Game to its GameDesign, highlighting the mechanics that define how the game is played. This includes rules, controls, objectives, and other elements that shape the player's interaction with the game world.

Table 2.11: *hasGameDesign* glossary entry

Concept name	hasLevelDesign
Definition	Specifies the levels of a game.
Description	The hasLevelDesign property connects a Game to its LevelDesign, focusing on the spatial and environmental aspects of the game. This relationship emphasizes how level design affects gameplay dynamics, exploration, and the player's journey through the game.

Table 2.12: *hasLevelDesign* glossary entry

Concept name	hasGameplay
Definition	Specifies the gameplay of a game.
Description	The hasGameplay property links a Game to its Gameplay, emphasizing the player's experience and interaction with the game mechanics. It reflects how the game engages players, challenges them, and allows them to develop strategies and skills.

Table 2.13: *hasGameplay* glossary entry

Concept name	Achievement
Definition	An achievement is a reward gained in a game due to some event accomplished in the game.
Description	The Achievement class represents rewards that players earn by completing specific tasks, reaching milestones, or exhibiting particular skills within a game. These achievements serve as incentives and recognition for players, enhancing engagement and providing goals to strive for. Achievements are linked to Games through the hasAchievement property, indicating which rewards are available in each game. Players can own achievements `ownsAchievement`, and they can be earned during gameplay sessions `involvesAchievement`, enriching the player's gaming experience.

Table 2.14: *Achievement* glossary entry

Table 2.15: *Character* glossary entry

Concept name	Character
Definition	Any actor that can exist in a game.
Description	The Character class encompasses all entities that act within the game world, including player-controlled avatars and non-player characters `NPCs`. Characters can be humans, animals, vehicles, or even abstract representations like paddles in Pong. They are central to gameplay, influencing how players interact with the game. Characters are associated with Games via the hasCharacter property, and players can own characters `ownsCharacter`. During gameplay sessions, characters participate and may trigger events `isEventTriggeredByCharacter`, highlighting their dynamic role in the game.

Table 2.16: *Game* glossary entry

Concept name	Game
Definition	Describes a game product that can be played by a player.
Description	The Game class represents the game itself as a product and interactive experience. It serves as a hub linking to various components such as Achievements, Characters, Items, Genres, PlayingAreas, and Leaderboards. Through properties like hasAchievement and hasCharacter, it details the content and features that define the game. Players interact with games `playsGame`, and sessions `Session` represent periods during which the game is played, capturing the dynamic nature of gameplay.

Table 2.17: *Genre* glossary entry

Concept name	Genre
Definition	Describes the genre a game belongs to.
Description	The Genre class categorizes games based on their style, mechanics, and thematic elements, such as RPGs, simulators, or adventure games. By linking Games to their genres through the hasGameGenre property, it provides context and helps players understand what to expect from the game, aiding in discovery and classification.

Table 2.18: *Item* glossary entry

Concept name	Item
Definition	Portrays any item that exists in a game.
Description	The Item class includes all objects that can be found or used within a game, ranging from weapons and tools to collectibles and decorative objects. Items are integral to gameplay, often enhancing a character's abilities or serving as objectives. They are connected to Games via the hasItem property and can have specific features `hasFeature`. Characters can own items `ownsItem`, and items may be involved in events `isEventRelatedToItem`, illustrating their multifaceted role in the game.

Table 2.19: *Leaderboard* glossary entry

Concept name	Leaderboard
Definition	Describes a ranking system of the players.
Description	The Leaderboard class represents competitive ranking systems that track player performance, such as high scores, fastest times, or most victories. Leaderboards encourage competition and replayability, fostering a sense of community. They are linked to Games through the hasLeaderboard property, indicating where players can compete and compare achievements.

Table 2.20: *Player* glossary entry

Concept name	Player
Definition	The entity playing the game.
Description	The Player class represents individuals who engage with the game, whether human players or AI-controlled agents. Players are central to the gaming experience, bringing the game to life through interaction. They have profiles that may include usernames `username`, real-world locations `livesIn`, and relationships with other players `isFriendWithPlayer`. Players own characters `ownsCharacter` and achievements `ownsAchievement`, participate in sessions `involvesPlayer`, and their actions can trigger events `isEventAssociatedToPlayer`, capturing the richness of the player experience.

Concept name	Session
Definition	Describes a session of gameplay.
Description	The Session class captures specific instances of gameplay, such as a match, level, or any defined period during which the game is played. Sessions are linked to Games `isSessionInGame`, involve Players `involvesPlayer` and Characters `involvesCharacter`, and can include events and achievements earned during that time `involvesAchievement`. Sessions provide a framework for analyzing gameplay, understanding player behavior, and tracking progress over time.

Table 2.21: *Session* glossary entry

Concept name	PlayingArea
Definition	Describes the place where the gameplay takes place.
Description	The PlayingArea class defines the environments or settings within a game where the action unfolds. This could be a specific level, map, world, or any spatial context like a racetrack, battlefield, or fantasy realm. Through the hasPlayingArea property, Games are connected to their playing areas, emphasizing the importance of environment in shaping gameplay and player immersion.

Table 2.22: *PlayingArea* glossary entry

Concept name	InstantaneousEvent
Definition	An event that happens during gameplay at a certain moment in time.
Description	The InstantaneousEvent class encompasses events that occur at specific moments during gameplay, triggered by player actions, game mechanics, or other factors. These events can include earning an achievement `unlocksAchievement`, defeating an enemy, or making a purchase `InAppPurchaseEvent`. Instantaneous events are linked to Games `isEventInGame`, Sessions `isEventInSession`, Players `isEventAssociatedToPlayer`, Characters `isEventTriggeredByCharacter`, and Items `isEventRelatedToItem`, providing a detailed account of the dynamic occurrences within the game.

Table 2.23: *InstantaneousEvent* glossary entry

Concept name	Action
Definition	An action is the building block of agents' activities.
Description	An action is esentially an agent's response to tasks. Whereby tasks are created to be met or reached, an action is the atomic concept for achieving tasks. In the context of this document, an action is the building block of a process, and agents' ability to act towards its environment in general. Every action can be used to fulfill at least one task.

Table 2.24: *Action* glossary entry

Concept name	Agent
Definition	A piece of software that can act upon its environment and perceive it.
Description	An agent in the context of this document is a piece of software that can interact with its environment, act upon it, and, in case of an intelligent agent, reason upon their accessible knowledge. Indeed, an agent is *anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators.* [21] In the organisational context of this document, a software agent is essentially a model of a real-life person.

Table 2.25: *Agent* glossary entry

Concept name	Artefact
Definition	An artefact is an otherwise unclassified element of an organisation system.
Description	An artefact is, as of yet, a somewhat undefined concept, in the context of specifying its domain. Essentially, an artefact can be anything that is not classified using the other classes of this ontology. Furthermore, an artefact can be phisically representative (e.g. a chair), or an unphisical concept (e.g. knowledge). Artefacts therefore represent various concepts that the agents can interact with, or that affect the given environment or the given system, i.e. objects forming the environment.

Table 2.26: *Artefact* glossary entry

Concept name	Behaviour
Definition	A behaviour is an implemented action, or a part of one, that defines how an agent interacts with its environment or internal states.
Description	In the context of this document, a behaviour is a set of actions or operations that an agent can perform in response to its environment or internal states. Behaviours are essential components that define how an agent acts and reacts, allowing it to achieve its objectives and respond to changes. Moreover, a behaviour is, in this context, a way of implementing a specific action and is that which an agent can actually run in runtime.

Table 2.27: *Behaviour* glossary entry

Concept name	Role
Definition	A role is a set of norms with a common denominator.
Description	In the context of this document, a role is defined as a set of normative rules that are applicable to a particular part of the given organisation. Such normative rules are parts of the organisation's normative system, and can be grouped by specific criteria, thus forming roles. Roles are played by agents. When an agent plays a role, the role's constraints are applied to them, therefore constraining their possible actions, their perceivable goals, and their possibilities in general.

Table 2.28: *Role* glossary entry

Concept name	Workspace
Definition	A workspace is the union of all the elements of a system, including agents, artefacts, etc.
Description	A workspace is the complete environment of a given system, including all the agents, artefacts, etc. What sets the concept of a workspace apart from the concept of an environment is the extent of the involved concepts, i.e. a workspace contains all the elements of an organisation and the whole system, while environment comprises only the elements that are external to the given organisation. It is worth noting that elements of the environment are an integral part of the whole system, since the life and activities of the given organisation are influenced by them.

Table 2.29: *Workspace* glossary entry

Concept name	Intelligent Virtual Environment
Definition	An intelligent virtual environment is a virtual environment that simulates the real world, and is populated by autonomous intelligent entities. [5]
Description	Intelligent virtual environments are researched as an area on the intersection of two aspects pertaining to the concept of artificial intelligence, if only but marginally: intelligent tools and techniques that are embodied in autonomous agents (real-life and digital alike), and effective ways of representing them, along with various means of achieving different kinds of interaction amongst them [5], [6]. In other words, a IVE is a concepte that represents a virtual environment whose main goal is simulating a segment of the real world, populated by artificial autonomous entities (agents). [5]

Table 2.30: *Intelligent Virtual Environment* glossary entry

Concept name	IVE Law
Definition	A IVE law is a norm that is valid only within a specified physical space (a IVE workspace).
Description	A special kind of a norm, an IVE law is a norm that is constrained by its applicability to a specific physical space, i.e. a specific IVE workspace. Being applicable to only a restricted area means that every IVE law is valid only within the bounds of the given area (a IVE workspace), and never outside of that specified space. This kind of a norm is the key constraint of the concept of a situated organisational unit.

Table 2.31: *IVE Law* glossary entry

Concept name	IVE Workspace
Definition	
Description	Complimentary to the concept of a workspace, a IVE workspace represents a physical location, or a physically describable location.

Table 2.32: *IVE Workspace* glossary entry

Concept name	Objective
Definition	An objective is a high-level goal the be met, suitable for the context of strategic planning.
Description	An objective is more general than a goal, although their definitions are rather similar. Fulfilling several goals can lead an organisational unit towards fulfilling a set objective. Thus, an objective is more suitable in the context of strategic planning, while a goal is more suitably used in the context of short-term planning.

Table 2.33: *Objective* glossary entry

Concept name	Observable Property
Definition	An observable property is a peroperty of an artefact that can be observed by agents in the same IVE.
Description	This is a property of an artefact located in a IVE that is observable by other agents located within the same IVE. These are tighly connected to the concept of observable events, and can be influenced upon by an operation.

Table 2.34: *Observable Property* glossary entry

Concept name	Physical Artefact
Definition	Physical artefacts are all the concepts that can be physically represented and included in a IVE.
Description	Every concept that describes objects that can be physically represented (e.g. a top hat), i.e. embodied and positioned on a topological map, and as such included in a IVE are classified as physical artefacts. Such elements have their role to play in the given IVE and usually contain a defined interface that governs the process of interaction of an agent with the given physical artefact.

Table 2.35: *Physical Artefact* glossary entry

Concept name	Physical Property
Definition	
Description	Physical properties are key elements of physical artefacts, i.e. artefacts that can be visualised in a physical space. Usually when an artefact is used, a physical event is generated, and a physical property is modified.

Table 2.36: *Physical Property* glossary entry

Table 2.37: *Goal* glossary entry

Concept name	Goal
Definition	A goal is a result towards which effort is directed - an end to be met.
Description	A goal is broadly defined as a result or achievement towards which effort is directed[1]. In the context of this document, a goal is a form of an objective. A goal is an end to be met or reached, and can consist of several sub-goals.

Table 2.38: *Quest* glossary entry

Concept name	Quest
Definition	A quest is similar to a goal, but has a defined starting and ending situations.
Description	A quest is a similar to a goal, but it has a defined beginning and a defined end, i.e. a starting situation, and an ending situation[2]. In the context of massively multi-player on-line role-playing games (MMORPGs), a quest is what drives a story, and, in principle, motivates the player to continue playing the game. Furthermore, a quest is often given to the player by an in-game character. A quest usually has various stages, and represents a challenge for the given player, thus embarking them on an adventure.

Table 2.39: *Strategic Alliance* glossary entry

Concept name	Strategic Alliance
Definition	Strategic alliance is a form of a long-lasting partnership of organisations of various forms, formed around a shared strategy, or a strategic goal.
Description	An alliance that is aimed at forming long-lasting partnerships consisting of organisations of various forms is dubbed a strategic alliance. A strategic alliance is formed around a strategy as a long-term objective that is shared amongst the strategic alliance members. Norms and regulations governing the expected behaviour within the strategic alliance are expected to be accepted by all the members, old and new alike.

Table 2.40: *Task* glossary entry

Concept name	Task
Definition	A task is the building block of a quest.
Description	A task is the building block of a quest, i.e. its elementary part. A quest is built of atomic tasks that are easier to follow in execution phase, rather than the overview provided by the main definition of a quest. In MMORPGs a quest could demand an item to be retrieved, yet such a simple-sounding quest could consist of various tasks that have to be fulfilled in order for the main quest to be finished. The relation of quest and task concepts can be recursive[3].

Part II

Phase 1: The MAGO-Ga Ontology

Introduction

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see figure 2.1

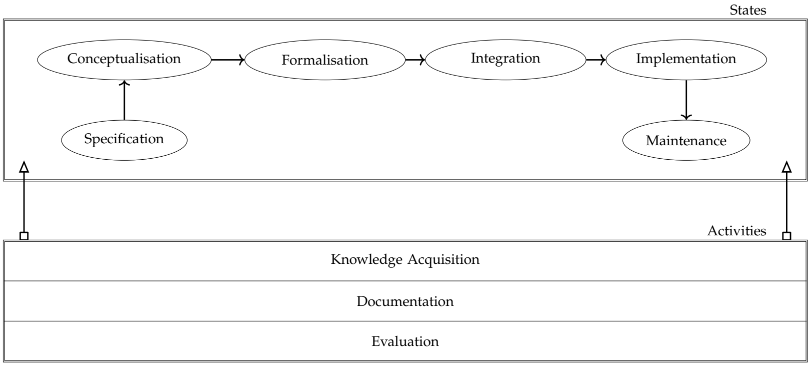

Figure 2.1: Basic steps of METHONTOLOGY ontology engineering methodology, reproduced from [2], adapted from [1]

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Part III

Phase 2: The MAGO-Ga Framework

Part IV

Appendices

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Notes

1. http://www.dictionary.com/browse/goal
2. https://medium.com/the-mission/why-you-should-change-your-goals-into-quests-2467bbef9867
3. define further, i.e. a main quest in a game can consist of several tasks, which can be quests themselves