Chapter 7
(Re-)Localization of Location-Based Games

Simon Scheider and Peter Kiefer

7.1 Introduction

Location-based games (LBGs) involve movement in and large-scale interaction with *environmental space* (Nicklas et al. 2001; Schlieder et al. 2006), which is the space larger than the body which cannot be comprehended without considerable locomotion (Montello 1993). They form an important subclass of *mixed reality games*, i.e., computer games played in a physical environment which add novel dimensions to the game experience, including seamless *immersion* of players, new kinds of *social interaction* with other players, as well as *physical interaction* with the environment (Hinske et al. 2007). The main advantage of such games is that physical and social experiences are most authentic in a concrete physical or social environment, while the virtual layer of mixed reality adds unprecedented forms of imagination to these environments. In *pervasive games*, the virtual, social, and physical environments are interconnected based on weaving computing power and sensors into the environmental fabric, and based on the fact that players constantly carry mobile devices (Hinske et al. 2007; Benford et al. 2005; Walther 2005). We regard LBGs as a particular subclass of *geogames*, i.e., games played in geographic space (Schlieder et al. 2006). The latter, however, include also online games that make use of geographical information without any physical interaction of players (Ahlqvist et al. 2012).

S. Scheider
Institute of Cartography and Geoinformation, ETH Zurich, Zurich, Switzerland

Department of Human Geography and Spatial Planning, University Utrecht, Utrecht, Netherlands

P. Kiefer (✉)
Institute of Cartography and Geoinformation, ETH Zurich, Zurich, Switzerland
e-mail: pekiefer@ethz.ch

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While LBGs have been around for some time (Nicklas et al. 2001), only few of them have succeeded in attracting a larger number of players. One reason is the difficulty of embedding game concepts in an environment. In order to reach players from different places and in order to allow for flexibility in taking gaming opportunities, LBG concepts need to be easily re-localized in a way which preserves the particular attractiveness of a game. Furthermore, turning successful virtual reality games played on a computer, or massive multiplayer online games (Ahlqvist et al. 2012), into a LBG requires localization, i.e., the suitable embedding of virtual game concepts into a physical environment. All these tasks still pose considerable conceptual and computational challenges, even though some effort has been made to tackle them (Schlieder et al. 2006; Kiefer et al. 2007; Hajarnis et al. 2011; Schlieder 2014). Furthermore, it recently has become popular to use game concepts in non-game contexts for persuasive computing (gamification) (Deterding et al. 2011; Scheider et al. 2015). Here, too, the successful embedding of elements of games and play into an environment constitutes a considerable challenge for designers (Hassenzahl and Laschke 2015).

In general, we can distinguish three research challenges on the way towards really flexible location-based gaming:

1. How can (arbitrary) games be localized?
   ($Game \rightarrow Game + Env$)
2. How can location-based games be re-localized?
   ($Game + Env_1 \rightarrow Game + Env_2$)
3. How can environments be gamified?
   ($Env \rightarrow Game + Env$)

In order to provide answers to these questions, and to facilitate corresponding game localization technology, it is necessary to develop *computational quality criteria for the embedding of games in an environment*. While this problem has partly been recognized in the literature (Schlieder 2014), a systematic derivation of criteria which take into account a game's ludic dimension, the game narrative, as well as the activity-based embedding into an environment, is still missing.

In this chapter, we discuss the problem of game localization in the light of recent game literature and environmental and psychological models of space (Sect. 7.2). Based on this, we propose a layered (3-tier) model of game localization (Sect. 7.3) which provides a way of addressing all three questions introduced above. We use this model to suggest some novel quality criteria (Sect. 7.4) for games which particularly reflect their environmental embedding and are based on state transition graphs. We illustrate our criteria with a hypothetical conquer game that has a very simple state transition graph (Sect. 7.5), and discuss its application to an existing LBG (Sect. 7.6). We conclude the chapter in Sect. 7.7 by discussing in how far our method provides answers to the research questions posed above, and what still needs to be done.

7.2 Location-Based Game Concepts and Related Work

Games consist of different conceptual elements which deploy a game in environmental space. These elements determine its quality, and thus need to be taken into account in game localization.

7.2.1 Games and Play

The element of *play* refers to a kind of embodied activity which is shared and involves social roles, and which is deeply rooted in human biology (Stenros 2015). Play ranges from foundational forms of hiding and chasing to sophisticated forms of role play in a theater. The main characteristic of play is that involved objects and agents can play roles different from what they are supposed to be (outside play), and that the rules which guide play are not explicit, fixed and shared (Stenros 2015), i.e., they are not institutionalized facts (Searle 1995). Games, in contrast, can be seen as an institutionalized (codified) form of play (Stenros 2015), where (collective) intentionality presupposes that players stick to certain rules and follow pre-defined goals. Play accounts to a large extent for the experience of *immersion* and *flow* in a game (Hinske et al. 2007), where large parts are probably not made explicit or happen on a subconscious level. The explicit restrictions and rules that come with a game sometimes can even destroy a *playful experience*, partly because breaking and redefining the rules is an intrinsic part of play (Stenros 2015). Still, a game retains an essential part of the play experience in the form of activities and roles which allow players to connect a game to meaningful places, scripts and narratives in the environment. We therefore hold that play is an intrinsic part of localizing games.

7.2.2 Scripts and Narratives in Games

In classic game research, there is a debate between ludologists, who investigate games in terms of game mechanics, referring primarily to their rules and winning strategies and sometimes denying the relevance of narratives in games, and narratologists, who see games primarily as a form of interactive story telling (Jenkins 2004). While games admittedly work in a different way than *plots* in cinema or fiction, in the sense that the story is not told linearly and is not (entirely) in the hands of the game designer, narratives do play an essential role in game localization (Paay et al. 2008). The reason is that in LBGs, players often understand the environment in terms of a narrative, and thereby project the game onto the environment. This narrative has *a non-linear spatial form* (Jenkins 2004), based on roles for things distributed in space that can be accessed by a player. In this way, games can evoke collectively known stories, such as pirate stories in a Disney amusement park.

Furthermore, players can push a story forward by movement in space (e.g., when a story unfolds through space, as in Bichard et al. (2006)), by revealing background stories (e.g., the murder in a classical detective game), or by constructing emergent stories on their own as in a game like **The Sims** (cf. Jenkins 2004), and through this they are able to break the linear narrative. For example, in backseat games (Bichard et al. 2006), where players move through an environment in the backseat of a car listening to a detective story that plays in their surroundings, the background story can be actively pushed forward at certain locations in that environment. Even though some games may not involve an elaborate linear plot, we suggest that game localization is always a matter of the design of a *spatial narrative* (Jenkins 2004), where either some roles or some points in the story are fixed to locations, objects or activities in environmental space. In some cases, stories may be reduced to a minimal form, such as a *script* (a stereotyped sequence of events) or a *frame* (a stereotyped situation) in cognitive linguistics (Petruck 1996). In these cases, roles may be almost unrecognizable and remain manifest only in the names of figures, such as the queen game piece in chess.

7.2.3 Places and the Meaningful Environment in Games

LBGs need to control the space in which players act (Lemos 2011). This was first discovered by researchers on pervasive gaming: Benford et al. (2003, 2005) raised the problems of uncertainty, spatial configuration, and temporal orchestration of a pervasive game, which are caused by its embedding in space. Walther (2005) distinguished tangibility space, information space, and accessibility space, where the first is the space of possible interactions with a physical environment, the second is a digital game representation of the first, and the third interfaces the former two. Several authors (de Souza e Silva 2008; Montola 2005) argued that LBGs are performed simultaneously on different virtual, social and physical spaces which extent the "magic circle" of a game to encompass "serious" social life activities, and thus extend cyberspace to *geographic places* and *objects* (Lemos 2011). Reid argued that all LBGs have a degree of place-related embedding, which corresponds to the extent to which their narratives specifically relate to existing places instead of only loosely overlapping space (Reid 2008).

In the age of digital information, space is often reduced to GPS coordinates. Place, in contrast, appears to be a more involved category of Geography (Cresswell 2013), which is closely related to daily activities (Seamon 1979), routine habits as well as narratives (Tuan 1977, 1991). Places shape possible actions (affordances) (Scheider and Janowicz 2014) by their spatial layout, by the people who live there, as well as by convention. In this, they are comparable to Gibson's meaningful environment (Scheider and Janowicz 2010; Gibson 2013), which is a way to regard an environment in terms of what it affords to animals or humans. For these reasons, mobile technology needs to take existing places into account (Dourish 2006). Designing games such that player interactions closely correspond to affordances of those places in which they are played increases a player's immersion and feeling of authenticity, and thus, gives meaning to ludic activities.

The latter seems, however, an ongoing challenge for game designers. Most pervasive games to date are rather "spatial" than "platial": they largely consist of chases and hunts (Lemos 2011), and the interaction between space and cyberspace is reduced to tracking unrestricted movement or to arbitrary space division. For example, a game like **Parallel Kingdom**[1] arbitrarily divides geographic space into territory claims, without taking into account the structure of existing places. Another example is **Zombies Run!**,[2] in which joggers can escape Zombies by running in any direction. In Google's successful contemporary LBG **Ingress**,[3] urban landmarks form "portals" which need to be "hacked" and "linked" to generate "control fields", i.e., spatial triangles under the control of a group of players. However, the choice of landmarks and triangles is arbitrary, and there is no dependency between player actions and geographic places, in particular since actions remain largely virtual.[4]

7.3 A Layered Model of Game Localization

While existing models of game localization mostly focus on a game's codified rules or technical infrastructure for ubiquitous computing, playing a game is always a fabric of roles, concepts and actions on different layers of conceptual abstraction embedded into an environment. Large parts of these layers are often not made explicit or represented in a computer. In fact, one may consider LBGs as primary examples for the mingling of digital and analog computation (MacLennan 2009), in which the human environment takes over important roles in activities not necessarily represented in a digital form.

7.3.1 Three Conceptual Game Layers

Following the suggestion of Schlieder (2014), we distinguish the *ludic*, *narrative* and *environmental* layer (see Table 7.1). The ordering of layers in Table 7.1 is important here, since lower ones are assumed to *deploy* or *implement* concepts of the upper layers. For example, a building in the environment may play the role of a castle on the narrative layer and be simply a place for resources on the ludic layer.

[1] http://www.parallelkingdom.com.

[2] https://zombiesrungame.com/.

[3] https://www.ingress.com/.

[4] This problem has recently led to serious ethical complaints of the German public. Ingress players had erected portals inside the former concentration camp Sachsenhausen in Berlin, cf. http://www.zeit.de/zeit-magazin/leben/2015-07/ingress-smartphone-spiel-google-niantic-labs-kz-gedenkstaette.

Table 7.1 The three conceptual layers of a LBG

Abstraction level		Actions	Constraints	Quality criteria
0	Ludic	Game actions (e.g. re-allocation)	Game rules and mechanics	Game balancing
1	Narrative	Play actions (e.g. conquer)	Scripts and story	Authenticity
2	Environmental (perception or simulation)	Environmental actions (e.g. movement)	Affordances	Playability, breakability

The action of walking somewhere on the environmental layer may correspond to an invasion on the narrative layer and an ownership change of a place on the ludic layer. To account for the dependency between layers, a *mapping* between layers becomes necessary, which is discussed later in this chapter (see Sect. 7.4.1).

We furthermore assume that layers on higher levels are not reducible to lower levels because each layer adds specific *constraints* to the game actions, which are not necessarily present on other layers. For example, the ludic layer adds constraints by codified game rules (such as, whether a player is allowed to go to a place), the narrative layer adds constraints concerning scripts and roles in a corresponding narrative (such as, kings need to travel in carriages), while the environmental layer adds constraints concerning what can be done (affordances) in an environment (e.g., reaching a place in a certain time). Each layer thus adds *quality criteria* for games associated with its constraints and concepts (see last column of Table 7.1).

In the following sub-sections, we suggest a *state transition model* for the layers in this hierarchy. This model is the basis for the localization criteria described in Sect. 7.4.

7.3.2 Ontology of Game States

During game play, all layers are in a *game state*. States are described by sets of facts present on a given layer. *Actions and other processes* can change this state from one to the next. Figure 7.1 gives an overview of a simple game state ontology expressed in OWL.[5] We suggest this game state ontology as a *pattern* (Gangemi and Presutti 2010), i.e., a minimal ontology required to describe a LBG on the ludic layer. Note that more specific classes can be introduced for a specific game, and that narrative and environmental layer will extend this ontology.

Among the *classes* of this OWL pattern, we have *Agent* which denotes the set of things that can act intentionally, and *Player* as a subclass of Agent which encompasses all agents that participate in a game. *Object* denotes the set of things that are neither agents, places nor locations. *Place* and *Location* localize games and need to be distinguished in order to cope with both discrete, cognitively meaningful space

[5] http://www.w3.org/TR/owl-features/. This is the "Web Ontology Language", a W3C recommendation for describing Web information with ontologies.

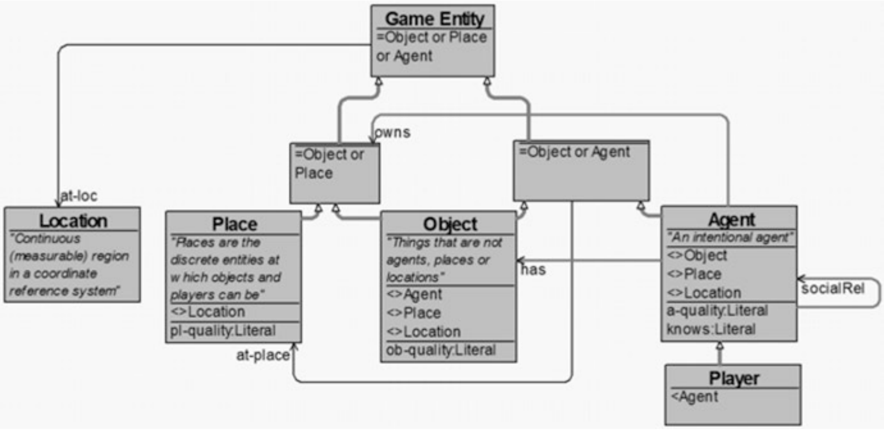


Fig. 7.1 An OWL ontology of the classes and properties used to describe the state of a LBG

(such as cities and market places), as well as continuously measurable space (e.g., in terms of GPS coordinates in a spatial reference system).

Among the *properties* (denoting binary relations), we distinguish *owns*, which denotes an agent's ownership of some object or place, *has*, which denotes that an agent carries some object, *at-place*, which denotes that agents or objects are located at some place, and *at-loc*, which denotes that agents, objects or places are located in some coordinate region (which may also be a single point). The union of the latter two properties is simply called *at*. The distinction of ownership and possession can be important but may be irrelevant for a particular game. We also introduce properties which assign attribute values (*qualities*) to objects, places, and players. These can be used to model all kinds of unary states, including also states denoting events. For example, the fact that an agent knows something relevant for the game can be modeled as a quality[6]. Furthermore, we distinguish a single property *socialrel* among players which denotes possibly diverse social relations between them, such as that they belong to the same group, are at war, or that one player is superior to another player.

7.3.3 Game Processes as State Transitions

Game processes are modelled as state transitions, i.e., operations which trigger *changes of the sets* denoted by the properties and classes of the state ontology on the respective layer. Note that game states may change with and without player actions involved. In principle, one can therefore distinguish two kinds of processes which

[6] Knowledge is modeled here simply as a particular state, without taking into account any more sophisticated (modal) logic.

can change the state of a game: a *game simulation* and a *game sensing*. A game simulation is a player-independent computer simulated process. For example, at a certain point in the game, a sequence of changes can be triggered to enforce a linear storyline, or there may be a random generator that enforces changes to a game's state, similar to throwing a dice. Game sensors, in contrast, detect changes in qualities or states of the perceived environment which cannot be influenced by the computer, such as whether some object moves around, detected by positioning technology. In the following, we do not further distinguish between these two kinds of processes.

We use another ontological hierarchy for describing kinds of state transitions. In the following notation, the subsumption operator $\sqsubseteq$ denotes the "*subClassOf*" relation between *state transition classes*. Note that *individual* state transitions form the *edges* of a state transition graph, whereas state transition classes form the *labels* of these edges (see Sect. 7.4.2). Actions, whether performed by players or not, are the most important kinds of state transitions in games:

$$action \sqsubseteq stateTransition$$

When an agent decides to perform an action, this—in essence—changes at least one of the sets which describe a game's state. We can specify an action type therefore by the sets it is supposed to modify, using the symbol $::\rightarrow$[7]:

$$(changeowner ::\rightarrow owns) \sqsubseteq action$$

$$(take ::\rightarrow has,\ at) \sqsubseteq action$$

$$(put ::\rightarrow has,\ at) \sqsubseteq action$$

$$(move ::\rightarrow at) \sqsubseteq action$$

$$(changesocial ::\rightarrow socialrel) \sqsubseteq action$$

$$(learn ::\rightarrow knows) \sqsubseteq action$$

We distinguish ownership change from reallocation (take, put), since ownership change is possible without any location change. Movement, in contrast to reallocation, denotes only movement of players. Learning something means that some agent gets to know something.

[7]This is an informal notation, which illustrates the usage. A formal notation would make use of corresponding transition rules, see below.

7.3.4 Ludic Layer

On the ludic layer, a game has a set of codified (shared and institutionalized) rules, i.e., the *rules of a game*, which constrain player actions that modify a game's state. Ludic game states are modelled therefore in the simplest possible form sufficient to describe such ludic constraints.

The rules of a game are specific to a game, and thus cannot be specified in general. Codifying a game's ludic rules can be done in terms of *inference rules*, denoted by ⇒, specifying the conditions for actions (in the rule body) as well as their outcomes (in the rule head). For example, the action type *take* can be defined as follows:

$$take : Object(x),\ Agent(a),\ at(x,p),\ at(a,p), \Re has(a,x)$$

$$\Rightarrow has(a,x),\ \neg at(x,p)$$

We assume that all ludic player actions are made explicit, since otherwise, it is not possible to compute a *state transition graph* on the ludic layer, i.e., a graph which explores action possibilities in an exhaustive form.

Besides the rules of a game, the ludic layer also qualifies particular states of a game, namely *starts* and *goals*, based on corresponding *start and win conditions*. For each player, game states are evaluated according to a win condition. For example, the goals of some games are based on a score of ownership, such as Monopoly, while others are based on a geometric state condition, such as checkmate in chess.

7.3.5 Game Narrative

On the narrative layer, *classes* and *properties* are added to the ontology which embed a game state into a certain narrative or script. For example, a fantasy game may add the following subclasses and properties to the game state ontology:

$$Wizard \sqsubseteq Agent$$

$$Dwarf \sqsubseteq Agent$$

$$Witch \sqsubseteq Agent$$

$$superior \sqsubseteq socialrel$$

This specifies that, in this example, three different kinds of agents participate in the game, and that there is a particular type of social relation *superior*, which denotes whether somebody was superior in a fight.

Also new state transitions (including player actions) can be added which are specific to this narrative, e.g.

$$walk \sqsubseteq move$$

$$ask \sqsubseteq learn$$

$$(attack ::\rightarrow superior) \sqsubseteq changesocial$$

$$conquer \sqsubseteq changeowner$$

Similar to the ludic rules above, on the narrative layer these actions may be further constrained. For example, in our fantasy play, players may be able to ask somebody only if the other Agent is spatially present. Furthermore, one may only be able to conquer something from somebody if the superior relation holds, e.g., as a result of an attack action. Note that narrative constraints may not be necessary for playing the game on the ludic layer, but still add a sense of authenticity and can account for large parts of the play aspect of a game. In this chapter, we treat narrative constraints as (non-codified) rules in a similar way as ludic constraints.[8]

In a classical computer game, almost all game actions and states on higher layers map into virtual actions and states in an environmental simulation of the game, including virtual layouts visible on the computer screen. The only kind of physical action involved may be joystick manipulation and screen interaction. In a LBG, many actions translate into physical movement or manipulation of objects in the perceived human environment. The degree to which this is the case determines the degree to which a game is a *location-based*, and thus determines its spatial scope.

The constraints on the layer of environmental perception are usually not made explicit on a computer. Actually, they are given by *environmental affordances*, and thus are implicit in the relation between objects and environment (Gibson 2013).

7.3.6 Environmental Perception and Simulation

The environmental layer is the level of direct *player interaction* with a game, i.e., of interactions between physical and virtual entities through appropriate sensory interfaces. The *perceived environment grounds* the upper layers (c.f. Scheider 2012), i.e., it serves as spatial anchor for the game abstraction hierarchy. It contains objects and layouts as well as corresponding affordances and actions, as proposed by Gibson (2013).[9] *Environmental simulation*, in addition, denotes the computer simulation of the environment in a game. It can contain exactly the same kinds of things as the

[8] Whether this strategy is always applicable seems an open question of research: can narratives always be formalized in terms of rules?

[9] Environmental perception, as a matter of fact, can be considered a kind of simulation performed by our brains (cf. Hawkins and Blakeslee 2007; Scheider 2012).

perceived environment or further ones, such as ghosts or monsters. Just as the perceived environment, it displays game affordances and thus serves as a gaming interface for player actions. If the two environments are blended over each other, they constitute an augmented reality.

7.4 Game Localization Criteria

In essence, game localization criteria are a function of the *particular embedding* of a layer into lower layers, taking into account the *constraints*, which exist on each layer. In the following, we discuss localization as embedding and the preservation of consistency under state transitions, define a number of novel criteria based on embeddings, and discuss how these criteria may be measured and computed.

7.4.1 Game Localization as Embedding

Localizing a game means to establish mappings between the narrative and the environmental layer, as well as between the narrative and the ludic layer—both, for kinds of state transitions, as well as for those entities, classes and properties (represented as unary and binary relations, respectively) that describe the state of a game (see Fig. 7.2).

Mappings need to establish identity between layers in a way that still allows for layer-specific modifications of facts. For example, the fact that a knight is located at some forest on the narrative layer may translate into the fact that some player is located at some park on the environmental layer, or the action class horse riding may be translated as tram riding. Furthermore, we require that every fact describing the state of a game on higher layers and every state transition class is translated into lower layers, and thus into the environmental layer. That is, the mapping needs to be *total*. This is because a game's state needs to be fully controlled bottom-up by environmental processes, regardless of whether they are triggered by player actions, non-player processes or simulations. We leave open whether mappings are established ad-hoc, i.e., during the playing of a game, or a-priori.

The main purpose of the mapping is to pinpoint those entities in an environment (or in a narrative) which are supposed to play a role in the game. As depicted in Fig. 7.2, we can identify game-relevant things on each layer in terms of the respective *images* of the mappings. There may be other things on each layer that do not play a role in a game (e.g., smoking as an action on the environmental layer). Furthermore, we do not require mappings to be *injective* (one-to-one), because there may be objects of the environment playing several roles in the game, and because there may be several ludic/narrative processes that map to a single process in the environment. For example, both swimming and riding in the narrative might be mapped to walking in the environment, whereas a ruin in the environment could be

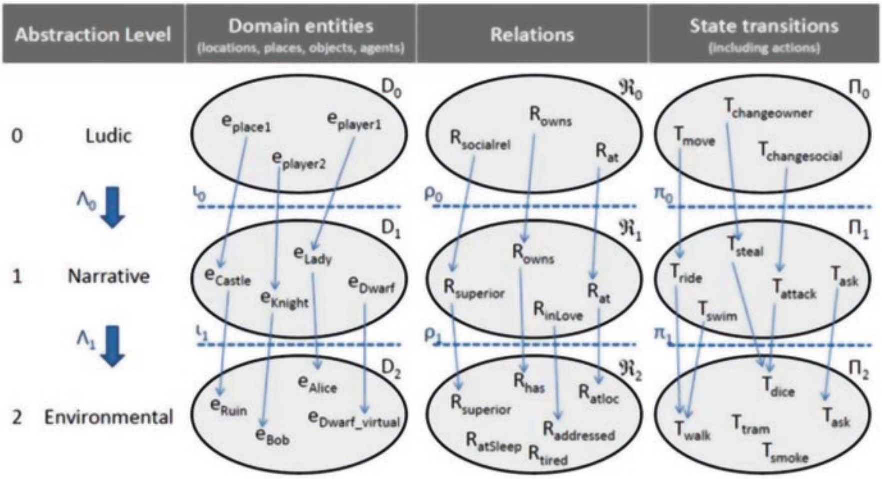


Fig. 7.2 The principle of game localization as a mapping of the three sets of game elements: domain entities (D), relations (R), and state transitions (Π) between the three layers

used for two different castles on the narrative layer. We thus propose to map game elements *top-down*, i.e., from ludic to narrative and from narrative to the environmental layer.

In summary, we propose that game localization consists of a mapping (refer also to Fig. 7.2):

$$\Lambda = \{\Lambda_0, \Lambda_1\}, \text{ where}$$

$$\Lambda_i = \{\iota_i, \rho_i, \pi_i\}, \text{ with}$$

$$\iota_i : D_i \mapsto D_{i+1} \text{ and } \rho_i : \mathfrak{R}_i \mapsto \mathfrak{R}_{i+1} (\text{total})$$

$$\pi_i : \Pi_i \mapsto \Pi_{i+1} (\text{total})$$

Here, the index $i \in \{0, 1\}$, with 0 = ludic, 1 = narrative, 2 = environmental layer, which means that the mapping stops precisely when mapping from the narrative into the environmental layer. The domain and range symbols of these mappings have the following meaning

$$D_i := \text{set of entities (domain) on layer } i$$

$$\mathfrak{R}_i = \{R_{i1}, \ldots, R_{in}\} := \text{ set of relations on layer } i$$

$$\Pi_i = \{T_{i1}, \ldots, T_{im}\} := \text{ set of state transition classes on layer } i$$

with i ranging this time over all three layers, and n and m denoting the sizes of corresponding sets.

7.4.2 Consistency Preservation of Game States Under a Given Localization

A mapping of a certain game state into lower layers can be *consistent* or not. We define a consistent mapping as one that preserves states of affairs between layers. This is also called a *homomorphism*. If the mapping of game states is homomorphic, then it is the case that:

$$R_{ij}(a,\ldots,z) = \rho_i(R_{ij})(\iota_i(a),\ldots,\iota_i(z)) \text{ for all } R_{ij} \in \Re_i \text{ (homomorphism)},$$

where a to z denote individual things and R_{ij} the j - th relation on layer i, and ρ_i, ι_i denote mappings as defined above. This *propagates states of affairs* upwards from the environmental layer to higher layers. For example, if ownership change on the narrative layer is translated as taking some object on the environmental layer, then whenever I have taken an object, a homomorphic mapping would cause me to own that object (Fig. 7.2).

Since we do not require a localization to be homomorphic, and since state transitions are bounded by *independent constraints* on each layer, a game state can become inconsistent. Figure 7.3 illustrates two inconsistent states in a state transition graph. The only consistent state is the start (state 1), while the two depicted follower states (states 2 and 2′) are inconsistent: if we map the relation *owns* on the narrative layer to the spatial relation *at* on the environmental layer (Fig. 7.3), and if it was excluded by narrative rules that two people can own a castle at the same time, then every time two people move to the ruin which denotes that castle (such as Peter and Bob in Fig. 7.3), the game state becomes inconsistent (state 2). More precisely, players can move on the environmental layer in a way which enforces a state transition on the narrative layer that *breaks the rules*. We call this possibility of generating an inconsistency in a game *breakability*. And vice versa, suppose that based on narrative constraints, we compute possible moves of a player, and that one of these possible moves leads a player straight across a wall (such as Bob in Fig. 7.3). Since this move is excluded by affordances on the environmental layer, it leads to a state inconsistent with environmental constraints (state 2′), and thus to a state which is not playable. The non-playable subset of the narrative graph therefore consists of edge 1 and state 2′, and the breakable subset of the environmental graph consists of edge 2 and state 2.

It is important to understand that these possibilities of independently pushing a game into inconsistent states on different game layers under a given localization is exactly what causes *state transition graphs* to become *incompatible* between layers, and thus games to become either increasingly *non-playable* or *breakable*. The *non-playable subset* of the ludic state transition graph can now be precisely defined: it

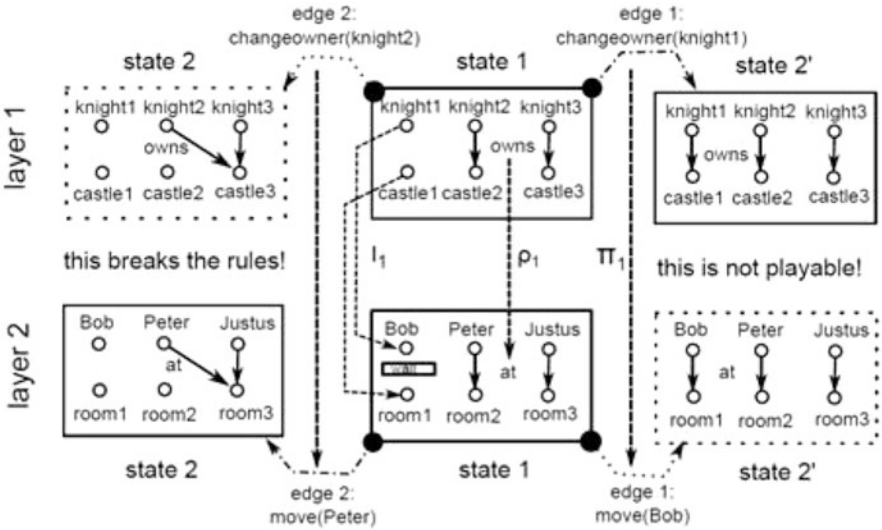


Fig. 7.3 Illustration of inconsistent state transition graphs on the narrative (*upper*) and environmental (*lower*) layer, given the rule that no two persons can own a single place

consists of exactly those edges which do not have a corresponding edge in the environmental state transition graph, and the *breakable subset* of the environmental state transition graph are exactly those transitions that do not have a corresponding edge in the ludic state transition graph.

In order to formally capture this idea, we define a couple of functions which homomorphically translate between state transition graphs on different layers:

$$f^i_{fact} = (a,\ R_{ij},\ b) := (\iota_i(a),\ \rho_i(R_{ij}),\ \iota_i(b))(\text{translate facts between layers})$$

$$fset(\{x,\ldots,z\}) := \{f(x),\ldots,f(z)\}(\text{apply a function to a set})$$

$$f^i_{edge}(s_1,\ T_{ij},\ s_2) := (f^i_{fact}\ set(s_1),\ \pi_i(T_{ij}), f^i_{fact}\ set(s_2))(\text{translate transition edges})$$

Here, π_i is a mapping between state transition classes on different levels as defined above. State transition graphs have states s_{ij} as nodes (compare the squares in Fig. 7.3) and transitions between states as edges (compare edges between squares in Fig. 7.3) which are labelled by a state transition class T_{ij}. An example for such an edge would be "move(Peter)" in Fig. 7.3. f^i_{edge} translates such transition edges of a state transition graph into edges on another game level. An edge $e_0 = (s_{01}, T_{01}, s_{02})$ of a ludic state transition graph G_0 homomorphically translates to edge $e_2 = (s_{21}, T_{21}, s_{22})$ of an environmental state transition graph G_2 if states are mapped *homomorphically* and $T_{21} = \pi_1(\pi_0 T_{01})$ is a result of translating state transition classes by the mapping. A homomorphic translation of a state transition graph $G_i = (N_i, E_i,)$ therefore can be expressed by:

$$v_i(G_i) = (f^i_{fact}\ set(N_i), f^i_{edge}\mathrm{set}(G_i))$$

Note that each node from N_i in this graph denotes a whole game state on layer i, and thus the graph cannot be easily visualized. In order to make state transition graphs more illustrative, we refer to the simple example given in Sect. 7.5, which contains a state transition graph on the ludic level together with possible translations (embeddings) into lower levels. We use these abstract ideas in the following to suggest novel quality criteria for breakability and playability of LBGs.

7.4.3 Quality Criteria

How can the constraints on each layer together with a mapping be used to determine quality criteria for localization?

7.4.3.1 Playability and Breakability

Ideally, an embedding is such that higher layer constraints (ludic and narrative) are precisely reflected in lower layer constraints (environment). If this is not the case, then either actions foreseen on the ludic and narrative layers are not possible in an environment (non-playability), or it becomes easy in an environment to break the rules of the game (breakability), because actions are possible which are against the rules of the game.

In order to capture these two qualities, we assume that *the space of state transitions* can be computed on each layer *independently*, based on the particular constraints of that layer. We capture these state transitions on each layer with state transition graphs $G(N, E)$, where N is the set of graph nodes and E the set of (transition-class labeled) edges between nodes:

$$G_0 = (N_0,\ E_0), \text{where } N_0 \subseteq \text{possible states on ludic layer, and } E_0 \subseteq N_0 \times \Pi_0 \times N_0$$

$$G_1 = (N_1,\ E_1), \text{where } N_1 \subseteq \text{possible states on narr. layer, and } E_1 \subseteq N_1 \times \Pi_1 \times N_1$$

$$G_2 = (N_2, E_2), \text{where } N_2 \subseteq \text{possible states on env. layer, and } E_2 \subseteq N_2 \times \Pi_2 \times N_2$$

The set difference[10] between independently determined graphs on a given layer and graphs translated from higher layers is a measure for the quality of an embed-

[10] The operator for subtracting a set from another one is \. The set difference of two graphs $G_1 = (N_1, E_1)\backslash G_2 = (N_2, E_2)$ is defined as $N_1\backslash N_2$, $E_1\backslash E_2$.

ding, because it captures all transition possibilities caused by non-compatible constraints. Degrees of *playability* and *breakability* with respect to different layers may therefore be defined most easily in terms of the relative size[11] of the following intersections:

$$Q^{0}_{breakability} = \frac{|G_2 \setminus v_1(v_0(G_0))|}{|G_2|} = 1 - \frac{|G_2 \cap v_1(v_0(G_0))|}{|G_2|}$$

$$Q^{0}_{playability} = \frac{|G_2 \cap v_1(v_0(G_0))|}{|v_1(v_0(G_2))|}$$

$$Q^{1}_{breakability} = \frac{|G_2 \setminus v_1(G_1)|}{|G_2|} = 1 - \frac{|G_2 \cap v_1(G_1)|}{|G_2|}$$

$$Q^{1}_{playability} = \frac{|G_2 \cap v_1(G_1)|}{|v_1(G_1)|}$$

However, since graph sizes only insufficiently capture the effect on possible game strategies, it may be more adequate to measure these qualities in terms of *possible paths* from start to goal in the corresponding state transition graphs. This captures in how far possible *win strategies* are affected by constraint propagation. Suppose we denote the set of possible paths through a graph G from a start to a goal in G by the function $paths_{goal}(G)$, then:

$$Q'^{0}_{breakability} = 1 - \frac{|paths_{goal}(G_2 \cap v_1(v_0(G_0)))|}{|paths_{goal}(G_2)|}$$

$$Q'^{0}_{playability} = \frac{|paths_{goal}(G_2 \cap v_1(v_0(G_0)))|}{|paths_{goal}(v_1(v_0(G_0)))|}$$

$$Q'^{1}_{breakability} = 1 - \frac{|paths_{goal}(G_2 \cap v_1(G_1))|}{|paths_{goal}(G_2)|}$$

$$Q'^{1}_{playability} = \frac{|paths_{goal}(G_2 \cap v_1(G_1))|}{|paths_{goal}(v_1(G_1))|}$$

---

[11] Denoted by dashes around sets. The size of a graph is defined as its number of edges.

7.4.3.2 Authenticity

Authenticity describes in how far entities conceptually resemble the entities into which they are mapped. A non-authentic localization, e.g., would map places of a narrative to arbitrary places in an environment, without taking into account whether the place experience fits to the place in the narrative. For example, a medieval game may be playable in New York but the specific localization may not give rise to a very authentic experience. Even in a medieval city center, there may be more or less authentic localizations of a particular game.

In order to capture authenticity, we need to capture relevant aspects of *place experience*, such as perceptual similarity (visual, auditory, haptic qualities) and conceptual similarity (such as historical relatedness or taxonomic distance). If we can express these aspects in terms of concepts in our game ontology, then we can use existing *semantic similarity measures* in order to measure authenticity. For example, Rodriguez and Egenhofer (2004) and Janowicz (2006) proposed elaborated similarity measures for geospatial object classes. A simple kind of similarity (*sim*) between two different entities e_1 e_2 (e.g. two places or two objects) would be to measure the maximum-standardized shortest distance (*dist*) between their classes in the graph of the game ontology (*O*):

$$sim(e_1, e_2) = 1 - \left(\frac{dist(O, e_1, e_2)}{\max_{i,j} dist(O, e_i, e_j)}\right)$$

Based on such a simple measure or a more elaborate one, authenticity could be defined as an aggregated similarity value:

$$Q^0_{Authenticity} = agg_{i=1}^{|D_0|} sim(e_i, \iota_1(\iota_0(e_i)))$$

$$Q^1_{Authenticity} = agg_{i=1}^{|D_1|} sim(e_i, \iota_1(e_i))$$

The aggregation function *agg* could be, e.g., a weighted sum with weights specific to the kinds of entities. Furthermore, one could also take into account similarities between ontology classes and properties as well as between corresponding state transitions into account.

7.4.3.3 Game Balancing

Another relevant but more ludic quality of any (also non-location-based) multiplayer game is determined by its balancing. An unbalanced game, i.e., a game in which one player has a dominant winning strategy, will be conceived as disappointing for the loosing player, and as not very challenging for the winning player. Previous work by Schlieder et al. on Geogames has pointed out that, due to the temporal duration of the *move* action, the balancing of a LBG is particularly challenging, since running as fast as possible may easily become a dominant strategy (Schlieder et al. 2006). Though race games (e.g., **Zombies Run!** or **Can You See Me Now** (Benford et al. 2003)) may have their particular charm and motivate their players to go running, they miss the intellectual challenge of reasoning over a state space (Schlieder et al. 2006).

The spatialization of a LBG, together with the means of transportation available, influences how long it takes to locomote between places. The duration of a *move* action can only be determined after mapping it down to the environmental layer. Consequently, we identify *game balancing* as an important criterion of game localization. Tool-supported state-space analyses (Kiefer and Matyas 2005) can help simulate the spatiotemporal dynamics of a game for a given localization, yielding a numeric value that quantifies the degree of balancing. The most likely outcome of the game, as well as the number of actions each player will likely perform until that outcome is reached (given both act rationally), are two possible measures (Schlieder et al. 2006). Note that in games featuring moving (non-player) agents, the spatiotemporal balancing of a game is also influenced (and can be regulated) by the agents' speed (refer to Kiefer et al. (2005)). In general, it seems that a good balancing strategy in designing LBGs is to prevent action types which require speed from dominating the state space, e.g., by sprinkling strategic thinking actions inside a game via the game rules. We end our discussion on game balancing of LBGs here, because this problem has been extensively treated in previous work. For a game example in which balancing is of particular importance, see Sect. 7.6.

7.5 Relocalizing a Simple Conquer Game

To illustrate our quality measures, take, for example, the following simple game. Suppose there is a single player and states are described by the following vocabulary (abbreviations in brackets are used in Fig. 7.4).

$$D_0^{Places} = \{Info,\ Depot,\ Target,\ Home(H)\}$$

$$D_0^{Objects} = \{Object(O)\}$$

$$D_0^{Agents} = \{Player,\ Informant(I),\ Enemy(E)\}$$

$$\mathfrak{R}_0 = \{at(@), knows, has\}$$

$$\Pi_0 = \{move,\ ask,\ take,\ attack\}$$

The idea of this conquer game on the *ludic layer* is illustrated by 15 states (generated by according rules) in the state transition graph in Fig. 7.4: in this game, players need to find local information/equipment in an environment in order to conquer a target. At the beginning (dotted arrow on the bottom left), the player is located at

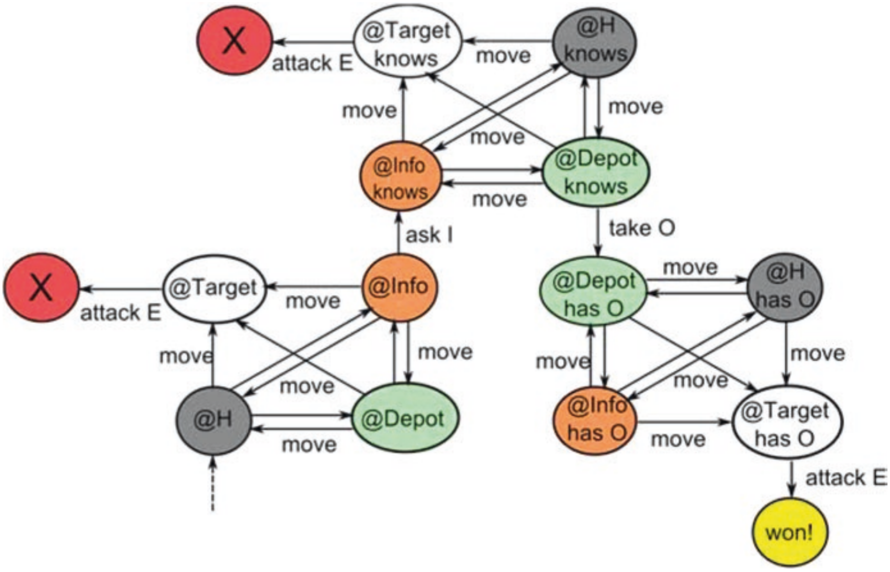


Fig. 7.4 State transition graph of a simple (single player) conquer game (ludic layer). Nodes denote states, labels in nodes denote facts about the player that are true in this state. Labels of edges denote state transition classes. Players in crossed states lose the game, and there is a single winning state

home(*H*) and can move to three other places. One of these places is the *target* that needs to be conquered to win the game. The player can directly *move* to the target, however, then lacks a resource (an object) necessary to win an *attack* of an *enemy* located at that target place, and thus will immediately loose the game (denoted by state *X*). The player thus first needs to find out where this object is located by asking a person in another place (*Info*), and once she *knows* where that object is, she can move to the *Depot* place, *take* the object *O*, move to the target, and win the attack of the enemy with the help of this object.

7.5.1 Medieval Fantasy Embedding at "Schloss Burg"

In a medieval fantasy narrative of this game, the roles may be distributed as follows (where the embedding from the ludic level is into notions at equal positions in the following listing):

$$D_1^{Places} = \{Forest,\ Cave,\ Castle,\ Village\}$$

$$D_1^{Objects} = \{Wand\}$$

$$D_1^{Agents} = \{Wizard, Dwarf, Witch\}$$

$$\mathfrak{R}_1 = \{at(@), knows, has\}$$

$$\Pi_1 = \{walk,\ ask,\ take,\ attack\}$$

Now the game tells the story (see Fig. 7.6a) of a wizard who wanders through a village and learns that an evil witch in the nearby castle has enslaved its inhabitants. The wizard promises to free the village from the reign of the witch. The way to the castle inevitably leads through a forest, where the wizard can ask a dwarf, who tells him that the witch put a spell on the castle that prevents people from escaping, and therefore can only be defeated using a magic wand, which is hidden in a cave. The wizard needs to find the wand and enter the castle to keep his promise. Note that under this embedding, all states of the game reappear homomorphically (see Fig. 7.6a), however, some state transitions were removed to streamline the story (e.g., there is no possibility to return to the village after a certain point in the story).

Suppose we furthermore embed this narrative into the environment of a real castle, such as "Schloss Burg"[12] in Germany (see Fig. 7.5). The role of the village could be played by "*Unterburg*", which is part of a small town (Burg an der Wupper) located directly at the foot of the hill on top of which the castle is located, the forest could be played by "*Schlossberg*", the woody hill slope through which a footpath leads to the top, and the cave could be embodied by a *playground* beneath the castle. The sphere of influence of the castle could involve a narrow buffer or boundary surrounding the castle (compare Fig. 7.5):

$$D_2^{Places} = \{Schlossberg,\ Playground,\ SchlossBurg,\ Unterburg\}$$

$$D_2^{Objects} = \{Wand_{virt}\}$$

$$D_2^{Agents} = \{Player,\ Dwarf_{virt},\ Witch_{virt}\}$$

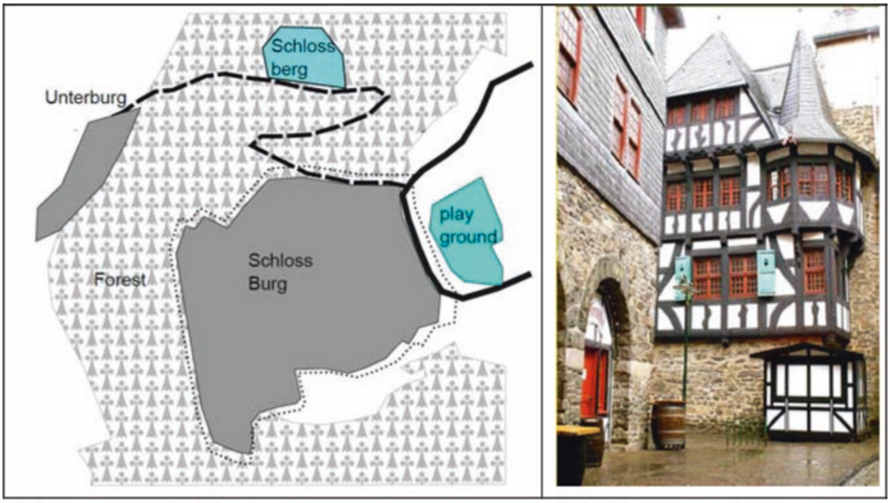
$$\mathfrak{R}_2 = \{at(@),\ knows,\ has\}$$

$$\Pi_2 = \{walk,\ ask,\ take_{virt},\ attack_{virt}\}$$

Note how some of the entities and actions are *virtual* (the witch, the dwarf and the wand), while others correspond to things in physical reality.

Note furthermore the state transition differences imposed by *environmental affordances* (compare Figs. 7.6b and 7.5a): under this embedding, certain direct walks, namely the ones between the "forest" (Schlossberg) and the "cave" (Playground) are not possible anymore, because the footpath (black dotted line in Fig. 7.5a) through the forest inevitably leads to the castle first. Furthermore, a player

[12] https://en.wikipedia.org/wiki/Burg_Castle_(Solingen).



(a) Places around Schloss Burg.

(b) Schloss Burg a.d. Wupper, Germany (CC BY-SA 2.0[12] courtesy by Plybert 49 on Flickr)

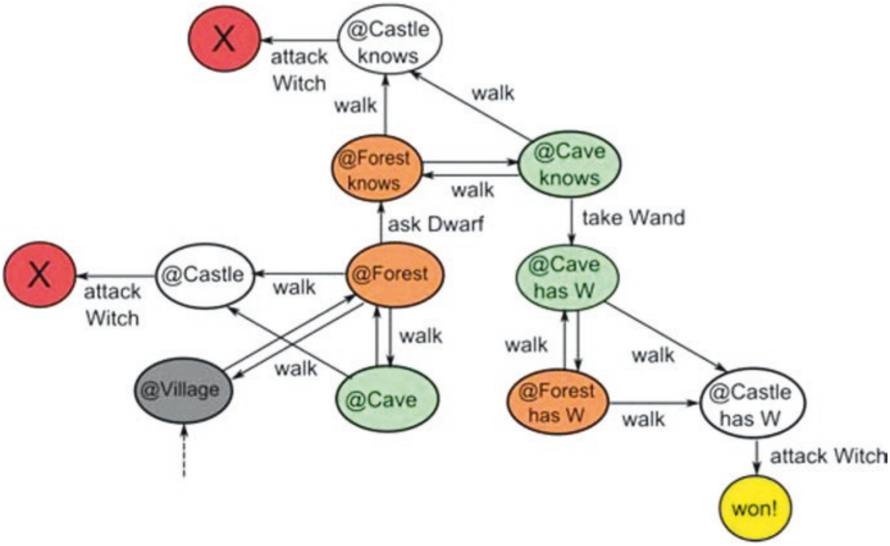
Fig. 7.5 The environment for embedding the medieval narrative. (**a**) Places around Schloss Burg. (**b**) Schloss Burg a.d. Wupper, Germany (CC BY-SA 2.0 (`https://creativecommons.org/licenses/by-sa/2.0/`) courtesy by "Polybert49" on Flickr)

can leave the castle and get to the playground by taking the footpath leading past the castle's exterior wall. The latter breaks the rules of the game, whereas the former renders the game unplayable under this embedding. To be more precise, Table 7.2 shows the exact numbers for playability and breakability as defined in this chapter together with the underlying graph-based measures regarding the medieval embedding.

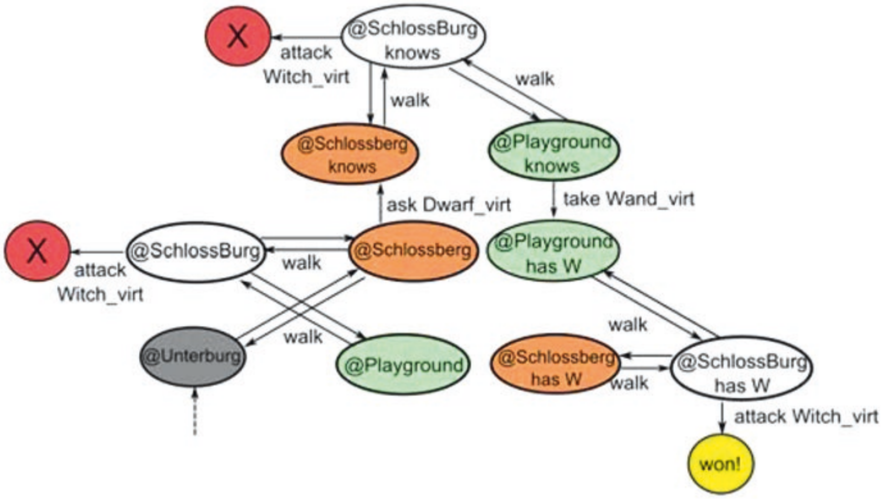
Note that only the path-based measures (Q') actually reveal that the game is practically unplayable under this embedding (*playability* = 0), and that every possible strategy will break the ludic as well as narrative rules of the game (*breakability* = 1). Note also that playability and breakability are not simply $(1 - x)$ of each other.

7.5.2 Crime Story Embedding in "Little Italy"

Suppose we embed the medieval fantasy narrative (*n*1 in Table 7.3) into an urban environment, such as the Little Italy district in New York (*e*2 in Table 7.3). For instance, the narrative "Village" would map to "Angelo's" (an Italian restaurant), the medieval "Forest" to "Ravenite Social Club", etc. (refer to Table 7.3). The authenticity of this embedding, taking into account ontological differences between classes and properties, should be rather low.



(a) State transition graph of the medieval fantasy narrative.



(b) State transition graph of the game environment of Schloss Burg.

Fig. 7.6 State transition graphs on narrative (**a**) and environmental (**b**) layers for the medieval fantasy embedding. (**a**) State transition graph of the medieval fantasy narrative. (**b**) State transition graph of the game environment of Schloss Burg

Table 7.2 Playability and breakability measures for the medieval embedding

	$\|G_2\|$	$\|vG\|$	$\|G_2 \cap vG\|$	Breakability	Playability
Q^0	19	31	11	0.421	0.355
Q^1	19	19	13	0.316	0.684
Q^{I0}	1	20	0	1	0
Q^{I1}	1	2	0	1	0

$|G_2|$ = cardinality of state transition graph on environmental layer, $|vG|$ = cardinality of translation from 0/1 layer to environmental layer, $|G_2 \cap vG|$ cardinality of intersection. Cardinalities are either of edge sets (Q) or of sets of start-goal paths (Q')

Table 7.3 Authenticity for two narrative and two environmental embeddings

Ludic	Narrative 1 (n1)	Narrative 2 (n2)	Environment 1 (e1)	Environment 2 (e2)	Similarities		
					n1,e1	n1,e2	n2,e2
Home	Village	Restaurant	Unterburg	Angelo's	0.75	0.25	1
Info	Forest	Nightclub	Schlossberg	Ravenite Social Club	1	0.25	1
Depot	Cave	Rifle Store	Playground	John Jovino Gun Shop	0.5	0.25	1
Target	Castle	Bank	Schloss Burg	City Bank	1	0.5	1
$Q^1_{Authenticity}$					0.8125	0.3125	1

Figure 7.7 displays a simple ontology of the different types of places, which we can use to measure authenticity. And in fact, based on this ontology, it turns out that the averaged similarity (as defined in Sect. 7.4.3) over all places is 0.31 (see Table 7.3).

For the New York environment, a different narrative would provide better authenticity values, and thus a better gaming experience. Consider a narrative playing in the times of the Mafia of the 1920s (*n*2 in Table 7.3): the player is member of a Mafia family, seated at some restaurant, and has the goal of robbing a Bank. For this, he needs to move to a nightclub to find out how to get a gun. Some other Mafioso in the nightclub tells him to rob a specific gun shop. This embedding yields an averaged similarity of 1, since all places match places of identical classes (Table 7.3). Note that the original medieval fantasy embedding at Schloss Burg yields also a high authenticity value of 0.81, which is a bit lower than 1 because the playground is not an ideal place for the role of the cave.

7.6 Localization of an Existing Multi-player Game: CityPoker

Here we demonstrate how relocalization can be applied to an existing game: **CityPoker**, a multi-player LBG introduced in (Kiefer et al. 2005; Kremer et al. 2013). As for any serious game, its state transition graph is too complex to be

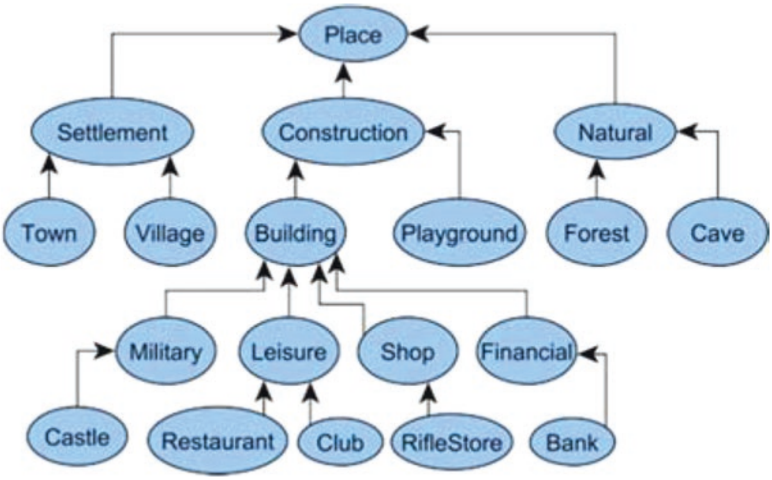


Fig. 7.7 A hierarchy of place types used for measuring authenticity based on semantic similarity

visualized. We provide a simplified rule description here; the extended rule set can be found in Kiefer et al. (2005).

In **CityPoker**, two players each aim at improving their hand of five cards by exchanging these with cards hidden in the environment. There are 20 cards in the game ({♣, ♦, ♥, ♠} × {10, J, Q, K, A}), 10 of which are on the players' hands, and 10 hidden in five caches. Players can exchange at most once at each cache, which means they drop one card and pick another. Figure 7.8 (left) illustrates a possible initial card distribution for Bamberg, Germany, as well as the players' starting positions. The end evaluation follows that of the traditional Poker game (Royal Flush > Four of a kind > … > One Pair).

The ludic level contains the following things:

$$D_0^{Places} = \{place_1, \ldots, place_5,\ start_1,\ start_2\}$$

$$D_0^{Objects} = \{item_1, \ldots,\ item_{20}\}$$

$$D_0^{Agents} = \{player_1, player_2\}$$

$$\Re_0 = \{at(@), has\}$$

$$\Pi_0 = \{move, exchange\}$$

where the mechanics of the game are modeled with a large state graph describing all possible sequences of moving and exchanging cards. There is a trivial bijective mapping from the ludic to the narrative level (similar for state graphs):

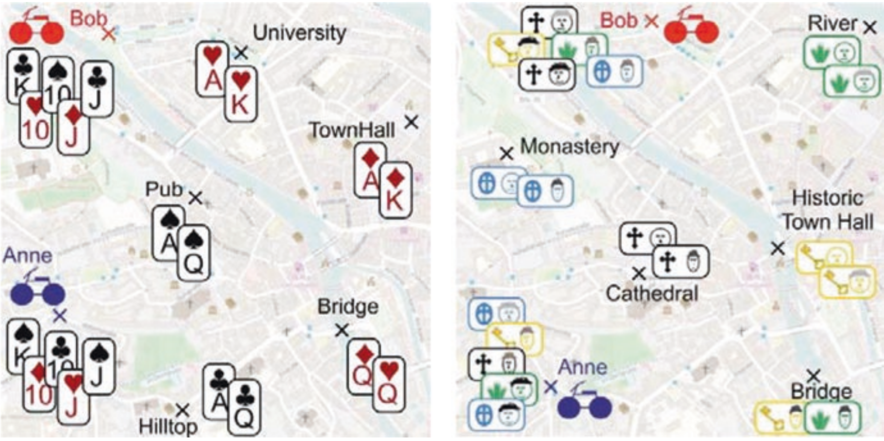


Fig. 7.8 CityPoker with two different narrative and environmental embeddings in Bamberg, Germany (*left*: original, *right*: medieval version; basemap: OpenStreetMap)

$$D_1^{Places} = \{cache_1, \ldots, \ cache_5, \ start_1, \ start_2\}$$

$$D_1^{Objects} = \{heart10, \ heartJ, \ldots, \ spadesA\}$$

$$D_1^{Agents} = \{pokerplayer_1, pokerplayer_2\}$$

$$\Re_1 = \{hasSelectedCache, \ hasOnHand\}$$

$$\Pi_1 = \{selectCache, \ swapCard\}$$

The localization displayed in Fig. 7.8 (left) yields in the following sets of game elements on the environmental level:

$$D_2^{Places} = \{TownHall, Bridge, start_1, start_2\}$$

$$D_2^{Objects} = \{heart10_{virt}, heartJ_{virt}, \ldots, spadesA_{virt}\}$$

$$D_2^{Agents} = \{Bob, Anne\}$$

$$\Re_2 = \{at(@), has_{virt}\}$$

$$\Pi_2 = \{bicycle, keyPress\}$$

Let us assume our localization allows for locomotion by bicycle between each pair of caches, and the game software ensures that cards can only be exchanged following the ludic rules. In that case, the localization is perfectly playable and not at all breakable. Authenticity, however, is rather weak (none of the selected places is associated with Poker), and a relocalization within Bamberg would not help either: the historical center of Bamberg is characterized by medieval buildings and tourist attractions, not with a single gambling place.

This can be solved by changing the narrative to a medieval setting, while keeping the ludic rules fixed: the four colors ({♣, ♦, ♥, ♠}) could be replaced by four competing parties that were relevant in medieval times: {*CatholicChurch, Benedictines, Citizens, Peasants*}. For each party, we could select five professions replacing the Poker numbers, such as {*Abbot, Vice-Abbot, Treasurer, Cellarer, Monk*} for Benedictines, and {*Major, Vice-Major, Merchant, Blacksmith, Worker*} for Citizens:

$$D_{1'}^{Places} = \{cathedral, \ldots, monastery, start_1, start_2\}$$

$$D_{1'}^{Objects} = \{BenedictineAbbot, BenedictineViceAbbot, \ldots, CitizenWorker\}$$

$$D_{1'}^{Agents} = \{delegate_1, delegate_2\}$$

$$\Re_{1'} = \{at(@), hasAsFollower\}$$

$$\Pi_{1'} = \{horseRiding, convinceFollower\}$$

In this narrative, players are delegates on some diplomatic mission with the goal of convincing influential people (which are considered items here, not agents). The winning condition is defined in a way consistent with Poker: all from one party > four of the same level > … > two of the same level. It is now possible to find a localization in Bamberg which ensures high authenticity (e.g., Bamberg Cathedral, Michaelsberg monastery, etc.; see Fig. 7.8). Finally, it will most likely be necessary to change the two start positions to keep the game dynamics balanced, which is out of the scope of this chapter.

7.7 Discussion and Conclusion

Based on a layered model of game localization, we have suggested novel measures for playability, breakability and authenticity of possible environmental embeddings of a game. Since our approach involves game narratives, it takes into account some of the "play" aspect of games. It also contributes to the challenge of "deep" localization of games, which goes beyond superficial spatialization to consider embedding of games into places and possible actions (affordances).

Now, one game embedding can be compared with another one in order to determine the optimal one given an environment. This provides a way to answer research questions 1 and 2 of section 1 about localization and re-localization, as it gives us novel and relevant criteria to evaluate possible localizations with respect to narratives, roles and environmental affordances. However, in this chapter, we have not yet addressed the problem of *searching* for good or optimal localizations. Based on future research, it might also become possible to search for a game that has the highest quality of embedding into some given environment, addressing question 3 (gamification) of section 1.

Here are a number of open research questions that need to be addressed in order to reach these goals.

First, to what extent does our approach really capture meaningfulness and the play aspect of games? In how far could it be used for *meaningful gamification* of environments? The existing research on meaningful gamification is in a very early stage (Nicholson 2012; Hassenzahl and Laschke 2015), which means it is open what aspects of gaming activity really need to be taken into account. We think our chapter gives some suggestions on what criteria might be relevant.

Second, our approach requires that state formalizations and state transition graphs are present on all game layers. Which sensors/observations are needed in order to generate state transitions on the environmental layer? How can we formalize state transition constraints on ludic as well as narrative layers? How can we compute state transition graphs given constraints? This can be of different complexity, depending on the nature of these constraints.

Third, and most importantly, the computation of the localization quality of a given embedding, as well as the search for an optimal embedding given an environment are both computationally complex. Computing playability and breakability in a strategic manner requires computing all start to goal paths in transition graphs on all three layers. Computing authenticity requires similarity computations for each mapped symbol. Searching over the set of possible game localizations given states on two layers is a combinatoric problem $\binom{n}{m}$ where n is the size of the union of domain, relation and state transition symbols on one layer and m on the other. However, the latter problem can always be simplified by certain practical considerations, such as a fixed start location of a user, and a restricted relation or state transition mapping.

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