Atomic Actions – Molecular Experience: Theory of Pervasive Gaming

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ABSTRACT
The attempt of this paper is to describe and analyze the formalisms of pervasive games and pervasive gaming (PG). As the title indicates, PG consists of atomic entities that nevertheless merge into molecular structure exhibiting emergent features during the actual gameplay. The paper introduces four axes of PG (mobility, distribution, persistence, and transmediality). Further, it describes and analyses three key units of PG (rules, entities, and mechanics) as well as discusses the role of space in PG by differentiating between tangible space, information embedded space, and accessibility space. The paper is generally concerned with classifying the indispensable components of pervasive games and, in addition, it lists the invariant features of pervasive gameplay meaning the epistemology that is tied to this new kind of gaming situated on the borderline between corporeal and immaterial space. Of particular interest are game rules in pervasive gaming since they seem to touch upon both the underlying, formal structure of the game (i.e. the ontology of PG) and the actual play vis-à-vis physical and/or virtual constraints (i.e. the PG epistemology).

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: Artificial, augmented, and virtual realities.

General Terms
Performance, Human Factors, Theory.

Keywords
Pervasive gaming, game rules, gameplay, game theory, ludology, game space.

1. INTRODUCTION
A mounting number of games already run on mobile devices such as cellular phones or handhelds, but only few of these can sense their physical environment. Massively Multi Player On-Line Roleplaying Games (MMPORPG's) such as *Majestic*, *Everquest*, and *The Matrix Online* clearly aim at being pervasive in the sense of incorporating a vide spectrum of information and communication technology. However, they do not fully exploit the potentials of combining physical and virtual space. In addition, we witness a growth in the design of game systems that use ubiquitous computing techniques so as to propel forward player experiences that interconnect objects within the real world and objects of the virtual world. The Swedish game company It's Alive Mobile Games AB and their *SuperFly* is a great example (see Figure 1). The projects *Can You See Me Now?* And *Uncle Roy All Around You*, both created by the UK performance group Blast Theory, use handheld, digital devices, GPS location tracking, and on-line agent technology in the attempt to use location and mobility as game features of the real world (Figure 2). These systems do not, however, entirely integrate adaptronics – i.e. the production technological amalgamation of robotics, artificial life, and adaptive systems – in the game design as well as in the game design process. Similarly, the preponderance of hardware and software presently made for the game market is restricted to the field of e.g. graphics, game and AI engines, 3D rendering techniques, and real time motion control all of which relate more or less to either interfaces (visual presentation of game worlds) or game mechanics, i.e. any part of the rule system of a game that covers possible modes of interaction during gameplay. In order to reach a strong attentiveness towards game machinery that range beyond the 'static' convention of immobile users and/or stagnant, screen-based interfaces it is vital to observe the interactions between human and computers and the computer mediation of human communication through naturally established interfaces which are, in turn, supported by embedded technology. This new awareness of dynamic games and the complex, augmented locations and topographies they rely on must be aided by ubiquitous computing, design of tangible interfaces, and 'adaptation by electronics'.

New technology and new methods for networking digital systems are thus essential for the development, implementation, and conceptual understanding of complex adaptation in computer mediated games and play. At the same time, we must identify and rethink the social interactions that are deployed in PG activities. An interesting aspect of gaming in pervasive milieus is that ‘rules’ seem to become the emergent result of negotiations between participating agents and the various, digital pieces of equipment that facilitate the amplified playing environment. A consequence of this is that concepts such as *probability*, *uncertainty*, and *contingency* gain importance in the design and understanding of PG.

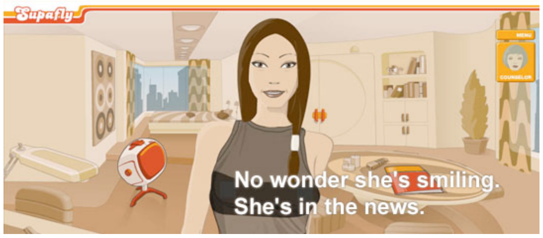

Figure 1. SuperFly (www.itsalive.com).

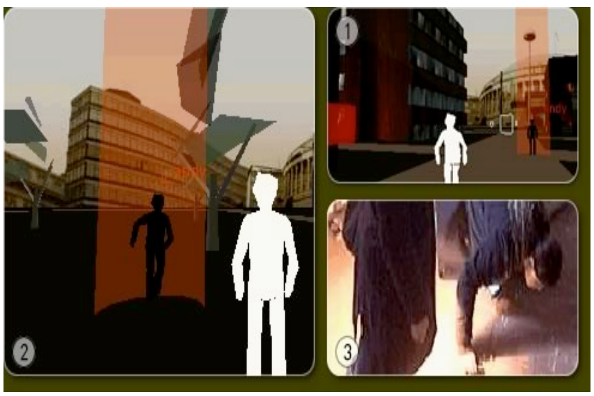

Figure 2. Uncle Roy All Around You (Blast Theory, http://www.uncleroyallaroundyou.co.uk/online.php).

In this paper I shall look more carefully into the ontology of pervasive games. I shall cross-examine the fabric of PG atoms and the way in which atomic game structures or potentials for game actions coalesce and change themselves into molecular experience, i.e. gameplay. How do we explicate the relation between fixed game rules and emergent player behavior and strategies? First, I will depict the four axes of pervasive games: the mobility axis, the distribution axis, the persistence (or temporality) axis, and the transmediality (or convergence) axis. In the second part of the paper we shall look deeper into the three key units of PG, i.e. game rules, game entities, and game mechanics. The fascinating and demanding aspect of PG in relation to traditional, non-ubiquitous games is the triadic attribute of game entity: a PG game entity can be a game object, a human agent or a physical object. Third, we shall concern ourselves with the renewed focus on space or spatiality in relation to PG. Here, for the sake of (hopeful) clarity, I shall distinguish between tangibility space, information embedded space, and accessibility space.

2. PG FORMALISMS

In order to track down the invariant ‘atoms’ of PG it is important to get an overview of the genres and sub-genres involved. I define ‘pervasive game’ as an over-arching concept or activity subsuming the following post-screen gaming sub-genres [9]:

- A *mobile game* is a game that takes changing relative or absolute position/location into account in the game rules. Strictly speaking this excludes games for which mobile devices merely provide a delivery channel where key features of mobility are not relevant to the game mechanics. Hence, one could distinguish between *mobile interfaced games* and *mobile embedded games*.
- A *location-based game* is a game that includes relative or absolute but static position/location in the game rules.
- A *ubiquitous game* uses the computational and communications infrastructure embedded within our everyday lives. This is related to the conception of ubiquitous computing, which is concerned with embedding intelligence within everyday environments (e.g. smart appliances, buildings and surroundings). Ubiquitous games are games that benefit from ubiquitous computing environments.
- *Virtual realities games* are games generated by computer systems. The goal is to construct is to construct wholly autonomous and completely surrounding game worlds. Hence the game worlds of commercial computer games are in a sense form of virtual realities. VR research has had a strong focus upon closing the perceptual gaps between virtual worlds and physical worlds, incorporating, for example, stereoscopic viewing and haptic technologies. The commercial success of computer games has demonstrated that closing the perceptual gap is not crucial for highly engaged and immersed game play. Why else explain the new fandom related to the mobility version of good old *Pacman* or *Snake*?
- *Augmented reality games* and *mixed reality games* are an interesting approach to the creation of game spaces that seek to integrate virtual and physical elements within a comprehensibly experienced perceptual game world.

In addition, one more sub-genre needs to be mentioned:

- *Adaptronic games* are games consisting of applications and information systems that simulate life processes observed in nature. These games are embedded, flexible, and usually made up of ‘tangible bits’ that oscillate between virtual and real space. The goal is to position game entities (or clusters of game objects) that can change their configuration in real time relative to changes in the environment and relative to the behavioral patterns of gameplay.

Two essential qualities of the pervasive computing evolution stand out that relate strongly to pervasive games; namely 1) the explicitness of *computational tasks*, and 2) the all-importance of *physical space*. The former implies that actions are carried out in ways that transcend the traditional screen-facilitated environment; embedded computing shifts our attention from metaphorical data manipulation to simulated and natural interactions with things and physical objects. This interweaves with the second aspect of pervasive computing as objects obeying the laws of natural physics are open to (digital) manipulation and thus take on a double meaning: they are objects within the outside (non-game) world; yet they can also be objects within a game world.

Following this I will propose a general or 'classic' definition of PG:

Pervasive gaming implies the construction and enacting of augmented and/or embedded game worlds that reside on the threshold between tangible and immaterial space, which may further include adaptronics, embedded software, and information systems in order to facilitate a 'natural' environment for gameplay that ensures the explicitness of computational procedures in a post-screen setting.

2.1 The four axes of PG

In order to further progress the broad spectrum of the general definition listed above we will zero in on four axes that together mark the possible domains of PG. The four axes can be illustrated like this:

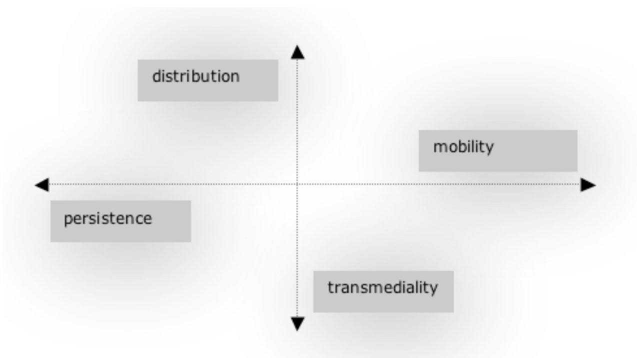

Figure 3. Four axes of PG

- *Distribution*. Pervasive computing is the junction of information technologies into a networked digital environment that is always on, always available, and unobtrusive. Pervasive computing devices are frequently mobile or embedded in the environment and linked to an increasingly ubiquitous network infrastructure composed of a wired core and wireless edges. This combination of embedded computing, dynamic networking, and discrete information sharing clearly affects and strengthens the distribution paradigm of IT. One example of a distribution system designed to work in huge networks is the so-called Twine resource discovery system. It uses a set of resolvers Twine nodes that organize themselves into an overlay network to route resource descriptions to each other for storage, and to collaboratively resolve client queries [1].
- *Mobility*. New challenges of pervasive computing further include mobility, i.e. computing mobility, network mobility, and user mobility, context aware (smartness), and cross-platform service. Particular interesting to the field of PG is the growth in mobile 3G technologies, Bluetooth, and LAN-LAN Bridging.
- *Persistence*. The idea of creating an online world in a mobile phone is the driving force behind the Danish company Watagame and their game *Era of Eidolon*. The persistence factor here touches upon the notion of temporality. Persistence means total availability all the time, i.e. a kind of omni-temporality.
- *Transmediality* challenges the relation between sender, text, and receiver as it emphasizes the active role of the user. Patterns of media consumption have been profoundly altered by a succession of new media technologies, which enable average citizens to participate in the archiving, annotation, appropriation, transformation, and re-circulation of media content [7]. Transmediality works as an unspoken support for the erection of bits and pieces of media material that create the 'aura' of user oriented amusement. It further indicates that no medium in the present day can be defined as a self-sufficient application based on partial groupings. On the contrary, the junction of multiple media spread out over huge networks and accessible through a range of devices is rather a nice instance of how media commune in circular, not linear, forms. They carry information, entertainment, games, role portraying, and character sketches in a non-stop circuit of jointly coupled citations and codes of utilization that can be promptly attuned and functionally altered.[1]

2.1.1 The PG possibility space

Combining distribution, mobility, persistence, and transmediality we embark upon what could be called the 'PG possibility space'. This space entails the field of potentials for developing, consuming and thinking about gaming in the years to come. It is a space that deals in *networking* given the focus on non-locality, non-metric systems, and constant accessibility. It is a space that celebrates the *freedom of device* – games can be played on anything; and game devices may trigger anything, anywhere, anytime. It is further a space that favors *non-closure*; although pervasive games still cling to the law of goal-orientation (closure) they nevertheless open up new ways of collaborative world building as well as invite continuous structural expansion. Finally, the PG possibility space naturally embraces transmediality and *circular* storytelling as *the* norm of mediated entertainment. Stories produced and consumed in bits or fragments may very well be the future standard of (visual) narration.

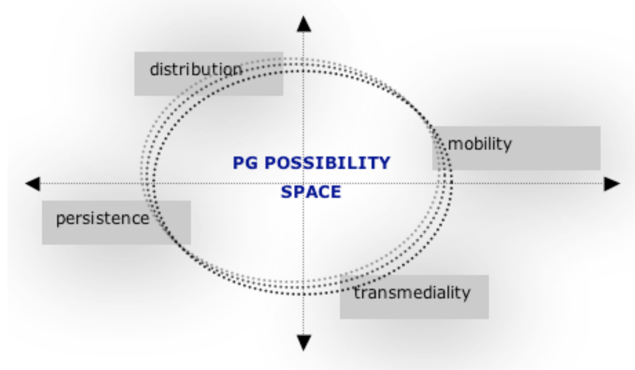

Figure 4. Four axes and the PG possibility space: networking, freedom of device, non-closure, and circular storytelling.

[1] A nice example of this circular and self-reflexive media ecology is the TV series *24*; it is a TV show, an action game, a website, a news forum, mobile content, and much more [15].

2.2 The three key units of PG

In traditional computer games the player has a double role; he is both observer of and an actor within the observed representation. Pervasive gaming goes even further in this complexification of identity constitution and structural coupling; the game reflects directly into the player's reality and constitutes a second 'world' within the world.[2] A wide consequence of this structural coupling is that real objects become pervasive. They are 'real' due to their tangible and physical quality, and they are real in the sense of information embedded devices open for manipulation, cybernetic control, and input output feedback – i.e. they can be played with.

Games can be divided into three key units that are, however, strongly interlaced: 1) Game *rules*, 2) game *entities*, and 3) game *mechanics*. How can we typify them? And how are they tested by the 'pervasiveness' of pervasive games? In the subsequent section I shall briefly list the basic characteristics of the three game units followed by some reflections on their eventual shortcomings vis-à-vis the PG ontology and PG epistemology.

2.2.1 Game rules

A number of game rule definitions have been suggested. In this context I will stick to Jesper Juul's generalized model in which there are six invariant parameters of game rules:

> **1) Rules:** Games are rule-based. **2) Variable, quantifiable outcome:** Games have variable, quantifiable outcomes. **3) Value assigned to possible outcomes:** That the different potential outcomes of the game are assigned different values, some being positive, some being negative. **4) Player effort**: That the player invests effort in order to influence the outcome. (I.e. games are challenging.) **5) Player attached to outcome**: That the players are attached to the outcomes of the game in the sense that a player will be the winner and "happy" if a positive outcome happens, and loser and "unhappy" if a negative outcome happens. **6) Negotiable consequences**: The same game [set of rules] can be played with or without real-life consequences [8].

It is evident that some of these rule parameters are altered with respect to PG. Let me narrow this alteration down to two issues:

1) Take, for instance, the vital concept of variable, quantifiable outcome. To Juul, this means, among other things, that the outcome of a game is designed to be beyond discussion, and that this trait is an instinctive token of game rules. This fits perfectly well with practically all computer games. However, when moving the logic structure of the digital computer into the tangible world the quantifiability of a rule system seems to shift into a more fuzzy type of interaction between constitutive and regulative rules. In *The Construction of Social Reality* Searle explains that social rules may be regulative or constitutive [12]. *Regulative* rules legalize an activity whereas *constitutive* rules may create the possibility of an activity. It is the constitutive rules that provide a structure for institutional facts. In the context of explaining the (extended) rule system of PG, computation can be regarded as a conceptual framework or underlying norm system that, in turn, constitutes the possibility space for regulative behavior. Constitutive rules belong then to the set of quantifiable norms while the regulative rules govern the ad hoc player interference with the game world. Another way of distinguishing the computational rule logic from the real-time interaction pattern of gameplay would be to differentiate between *global regulations* (provided by the computer's state machine) and *local operatives* (controlled by the player's behavior with the physical as well as information embedded game world; see Figure 5).

2) Next, we should consider the term 'negotiable consequences'. In pervasive gaming 'real-life consequences' is exactly that which drives the play experience forward. The entire teleology of gameplay in fact rests on these outcomes that transpire and are enacted on the physical arena. A game of chess might have ferocious consequences if played out in real life. However, since the movement of pieces across the board merely *represents* physical structures it follows that the rules of chess apply to the discrete topology of pieces and plane of play and not the phenomenological experiences that this topology may cause. In the domain of pervasive gaming it is precisely the 'negotiability' signifying the toggling back and forth between real-life consequences and discrete representations that pushes gameplay forward. Thus, the 'tangibility consequence' of PG brings forth a level of uncertainty to the gaming phenomenology; and this uncertainty becomes part of the rule structure, i.e. it must be inscribed in the computational representation.

2.2.2 Game entities

In line with the Object Oriented Programming paradigm I define a game entity as an *abstract class of an object that can be moved and drawn over a game map*. There can be an enormous amount of entities in a game; inventory objects in an adventure game; Non Playing Characters (NPC's) in a FPS (First Person Shooter); or a text message in a strategy game. Since a game has more entities, the ways that they can react together increases geometrically.

Pervasive gaming further adds to the complexity of game entities. A PG entity can take the shape of a) *game object*, i.e. any object that can be encountered, seen, or interacted with during gameplay; b) the entity can be a *human agent*, since an essential part of a pervasive game is to collaborate and engage in conflict with 'flesh polygons'; and finally c) the entity may simply be a *physical object* (see Figure 5).

Again, it is the negotiability or uncertainty principle that do the trick. Pervasive gameplay implies *contingency handling* – are the passing people on the street NPC's; is the elevator a token of the game's passage from one level to the next connected to a network of sensor technology; or is it simply an element of the building's non-pervasive construction?

2.2.3 Game mechanics

Lundgren & Björk define game mechanics, as simply *any part of the rule system of a game that covers one, and only one, possible kind of interaction that takes place during the game, be it general or specific*. A game may consist of several mechanics, and a mechanic may be a part of many games [10].

Thus, one can generally define game mechanics as an *input-output engine*. The task of this engine is to ensure a dynamic relation between game state and player interference. Furthermore, the engine is responsible for simulating a direct connection between the I/O system of computational, discrete logic and the continuous

[2] Thanks to my colleague Lars Qvortrup for this insight.

flow from initial to final state in a physical setting. In a certain sense, then, game mechanics postulates a deep transport from the laws of computation to the natural laws of physics. Note, however, that the latter laws must be implemented in the algorithmic system of the computer.[3]

In relation to PG the following issues of game mechanics are specifically noteworthy:

- *Physically embedded game mechanics*. Frontrunner in pervasive gaming, German-based Fraunhofer FIT, has designed *NetAttack*.[4] The game is presented as a new type of indoor/outdoor Augmented Reality game that makes the actual physical environment an inherent part of the game itself. The mechanics apply to the outdoor environment where players equipped with a backpack full of technology rushes around a predefined game field trying to collect items as well as to the indoor setting where a player sits in front of a desktop computer and supports the outdoor player with valuable information. In order to control the information flow linking physical and virtual space the various components communicate via events and a TCP/IP-based high-level protocol. A central component guarantees consistency and allows the configuration of the game. Before starting to play the game, the outdoor game area must be modeled and the game levels configured. In other words: modeling the game means embedding the necessary mechanics into physical space. The configuration is done with XML.
- *Input-output engine with dual purpose*. Since interaction with tangible objects in PG implies, as noted above, a level of contingency handling the input-output engine must be constructed in such a fashion so that it provides a probability algorithm for the actual interaction as part of the rules and dictates a global, discrete and binary rule (state) to the interaction. That is why PG mechanics may serve a dual purpose; on the one hand maintaining and stimulating the contingency of interaction with real-life objects, and on the other hand structuring the controlled set of actions embedded in the state rules. Hence, the input-output engine becomes a machine that frames both contingency and necessity.

One of the most promising descriptions of games and dynamic complexity is Holland [5]. Here, Holland distinguishes between

- The *state* of the game, i.e. the arrangement of pieces on the board at any point in the play.
- The *state space* of a game, meaning a collection of all arrangements of the pieces on the board that is allowed under the rules of the game.
- The *root* of the tree of moves, which is the game's initial state.
- The *leaves* of the tree of moves, which are the ending states.
- A game *strategy* that serves as a prescription of right decisions as the game unfolds.

In the design of computer games a *finite state machine* (FSM) is frequently used to manage threads of execution and if-then-else statements in the course of gameplay, i.e. as the tree of moves unfold. One example of how a FSM function is the operation of *damage* (particular relevant to FPS's).[5] When a damage trigger is transmitted to another entity, its pain function pointer is called, thus triggering a state transition of the effected entity into possibly a death or attack state. The damage inflicted in the game is an input to the FSM, which may act as a trigger for a state transition.

In pervasive game universes possible states and state functions are exponentially multiplied. Each FSM can be considered an autonomous agent in a multi-agent system involving trigger mechanisms from both the real and the modeled world.

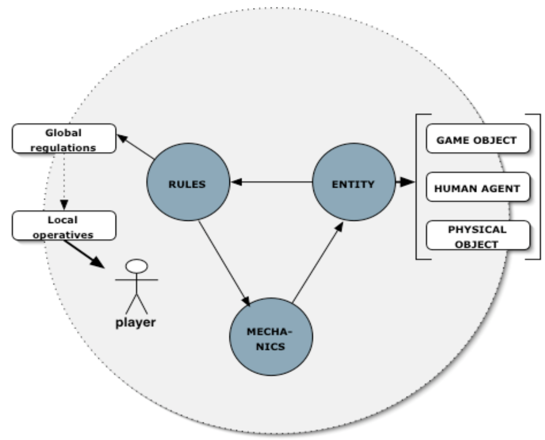

Figure 5. Rules, entities, and mechanics.

3. PG SPACE

Perhaps space is not a pure concept at all, since it is connected with time. This interweaving of categories can be registered in common physics as well as in everyday language: we utilize temporal metaphors with the intention of describing spatial topics. Temporalisation is that which donates a certain dynamics to space; time is space dimensioned; time is that which ensures a trajectory through space; time is precisely that which enables navigation. Time provides space with depth, relations, and maybe – some would assert – it assigns narratives to space. Whenever there is space there is a story, since – and this would be the argument – space needs to be perceived not only as an available abstract plane of coordinates but also as a set-up for lines and trails that precisely move in time. Space tells stories; and space facilitates the act of storytelling. Einstein challenged this view in which space is primarily conceived as synchronized representation. In his special theory of relativity, Einstein delivers a precise report of contingency that numerous painters and authors have portrayed during the 20th Century. In fact, it was one of Einstein's contemporaries, Henri Poincaré, which similarly launched an assessment of rigid space conceptualization that apparently turned Marcel Duchamp away from painting and into functionalism. Space that was earlier rationalized as a coordinated medium of continuity and endlessness is now, in the hands of Einstein and modern physics, a secondary facility that is

[3] In fact, one could claim that the 'success' of game mechanics rests on the idea that it is possible to simulate 'computational physics'.

[4] See www.fit.fraunhofer.de/projekte/netattack/index_en.xml.

[5] http://ai-depot.com/FiniteStateMachines/FSM-Framework.html.

inevitably attached to the system – i.e. the point – of observation, whereas the speed of light is the constant of the universe.

Furthermore, space differs when we look at it from a human and a strictly mathematical angle [14]. The mundane space that a human subject inhabits is not by nature geometrically; rather, it is structured in accordance with matter-of-fact actions. In such a spatial environment various orientations are related to directions – practical vectorizations – and places, ranges of space, and things, in contrast to dimensions, points, lines, and absolute objects. The space of action is a praxis-architecture – a phenomenological space, one might call it – that does not entail length, height, and width, but instead possesses territory, proximity, and distance [11]. A personal space zeroes in on equipments and relations that are required to institute qualities of meaning, whereas a geometrical space is incessant and unbounded. The space of every day life is *heterotrophic* in its design of multiple layers by which it constantly confronts its user with a surplus of potential strategies of spatial couplings. The space of mathematics is *isotropic* in which all matter and every coordinates are evenly spread in all directions. Thus, when a human subject navigates through space it becomes *contingent* – where to go next? – and *intentional*: the use of space through motives and affects.

The point here is that the space of pervasive gaming mixes the isotropic and heterotrophic space. The teleological goal structure of a game necessitates a certain amount of *accessibility* by which the user can obtain information about space and proceed from e.g. one level to the next [13]. A PG space must amalgamate the physical *metric* space and the informational and networked *non-metric* space and, finally, merge these into the accessibility space [4]. A metric space consists of a non-empty universe of points together with a family of distance relations satisfying the axioms of distance [3]. A non-metric space may be defined as a topological or nodal connected space. 'Real life' as such would not alone be interesting in a gaming sense. We need to organize and structure the non-teleological and open meaning of the mundane space in order to make it playable (or, actually, 'gameable'). Therefore, accessibility is the portal to the information embedded spatial game world. This is illustrated in Figure 6 below.

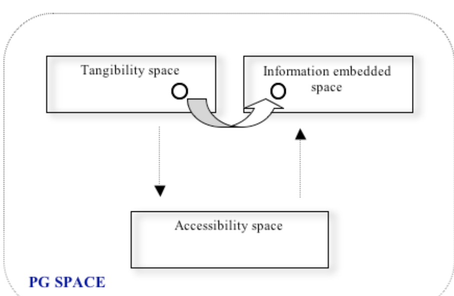

Figure 6. The accessibility space provides a passage to the tangibility space through the information embedded space, which, in turn, is represented in the tangibility space.

3.1 Tangibility space

An important aspect of PG – the whole idea of 'playability' – is evidently the player's interaction with the physical reality. The tangibility space, however, is not just the sum total of this available, real-time world and the vast amount of objects it possesses. Rather, it must be understood as the *heterotrophic organization of potential spatial patterns of behavior*. This organization or vectorization of space facilitates a 'playground' and is often aided by multiple information units located in material objects as 'tangible bits' [6].

Figure 7. Tangibility space – 'runner' interacting with real-life scenario (Blast Theory: *Can You See Me Now* [2]).

3.2 Distributed information space

To a large extent, the epistemology of PG involves the blending of physical and virtual space. In spatial terms this means that the tangibility space is facilitated by and projected onto information embedded space. This kind of space is the digital representation of the tangibility space. Yet, besides serving as a map of the game-world, it may also function as a phenomenological space in its own right, i.e. it is 'experience embedded' due to real-time changes, tracking of real player motion, etc.

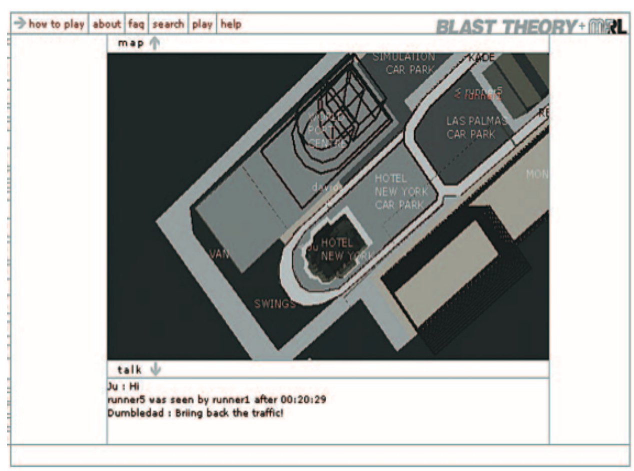

Figure 8. Information embedded space; 'runner' represented in a digital environment [2].

3.3 Accessibility space

Finally, we have the accessibility space that, as noted earlier, is the key to the oscillation between embedded information and tangibility in the pervasive game universe. One way of explaining the delicate relation between the triadic space structures is to say that accessibility space *maps* the information embedded space system that is in turn *mapped* onto the tangible reality.

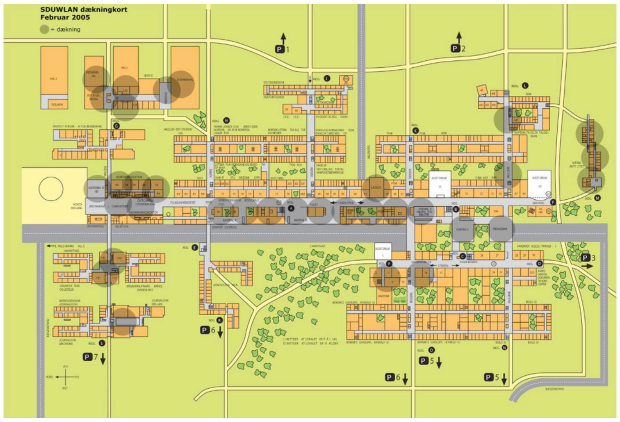

Figure 9. Accessibility space: a map showing wireless connectivity at The University of Southern Denmark indicated by circles. Through the wi-fi network accessibility information is embedded in the tangible space.

4. CONCLUSION

In this paper I have tried to construct a conceptual framework that will assist the design and interpretation of pervasive games and pervasive gaming. In many ways PG transcends 'traditional' computer games. The epistemology or molecular experience must be build into the ontology or atomic structure of the game map itself; a certain sense of openness, fuzziness, and uncertainty clings to PG; and the complexity of game states and state functions dramatically increases once a system of tangibility and random interaction with physical objects is tied to the virtual control apparatus.

A great many challenges thus await us in the field of post-screen gaming. On the analytical side it may be rewarding to think PG in terms of axes, key units, and space modalities, as I have suggested in this context; and regarding the continuous innovation of production schemes and technology enhancement it might prove equally gratifying to integrate the rising world of adaptronics in tomorrow's pervasive games.

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