



A Model-based Approach for Designing Location-based Games

Cristiane Ferreira, Luis Santos, Carlos Salles, Fernando Trinta, **Windson Viana**



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Introduction



Pervasive Games

A pervasive game "**blurs**" the line between the **virtual world** of the game and the **player's real world**, so the game become part of the player's reality



Magic Leap Game

Pervasive Games

A pervasive game "**blurs**" the line between the **virtual world** of the game and the **player's real world**, so the game become part of the player's reality

- Ubiquitous Games
- Augmented Reality Games
- Location-Based Games
- Live Actions Role Play Games
- Smart toys
- Computer-based tabletop games



Magic Leap Game

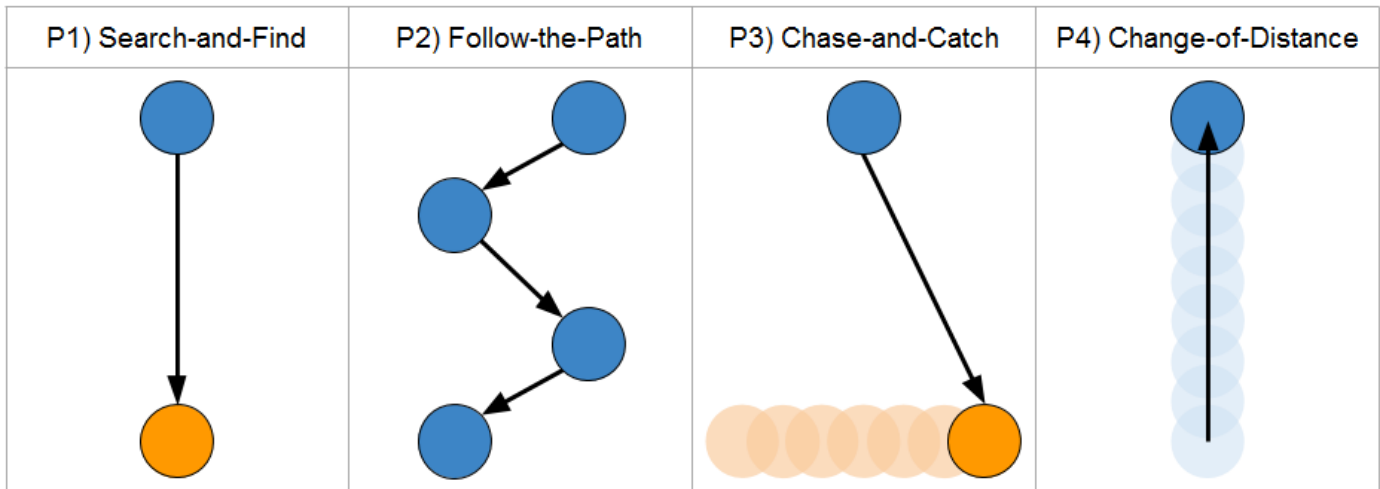
Location-Based Games (LBGs)

An **LBG** considers the players' **physical location** in its gameplay

- GPS
- Marker-based



LBG Design Patterns



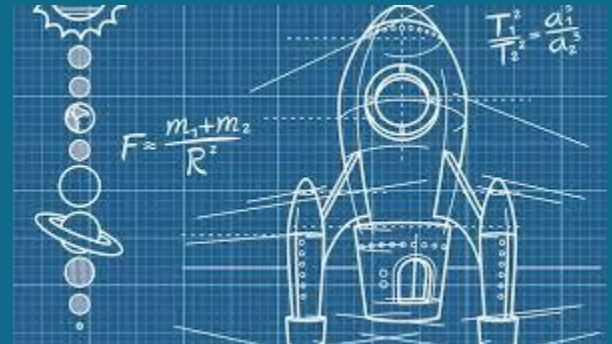
LBG Development Process

- Game Development Challenges
 - Multidisciplinary activity
 - Multimodal interface testing and evaluation
- Pervasive System Development Challenges
 - Mobile device heterogeneity
 - Sensor code complexity
 - Resource constrained devices

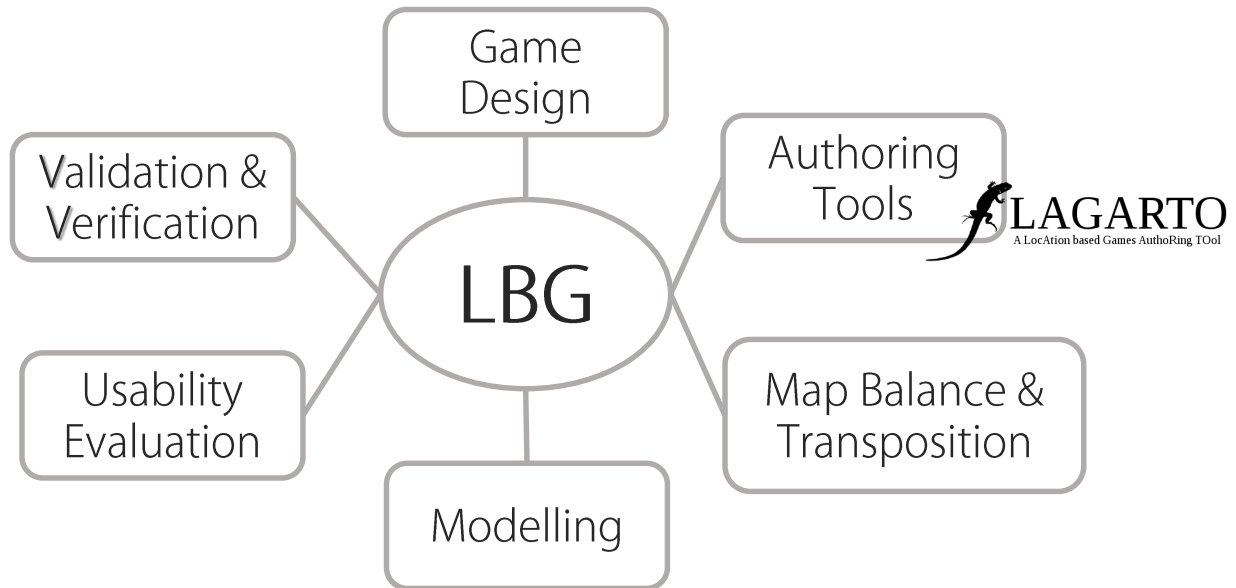
LBG Development Process – in a nutshell



Our Research



Location-Based Games - Research



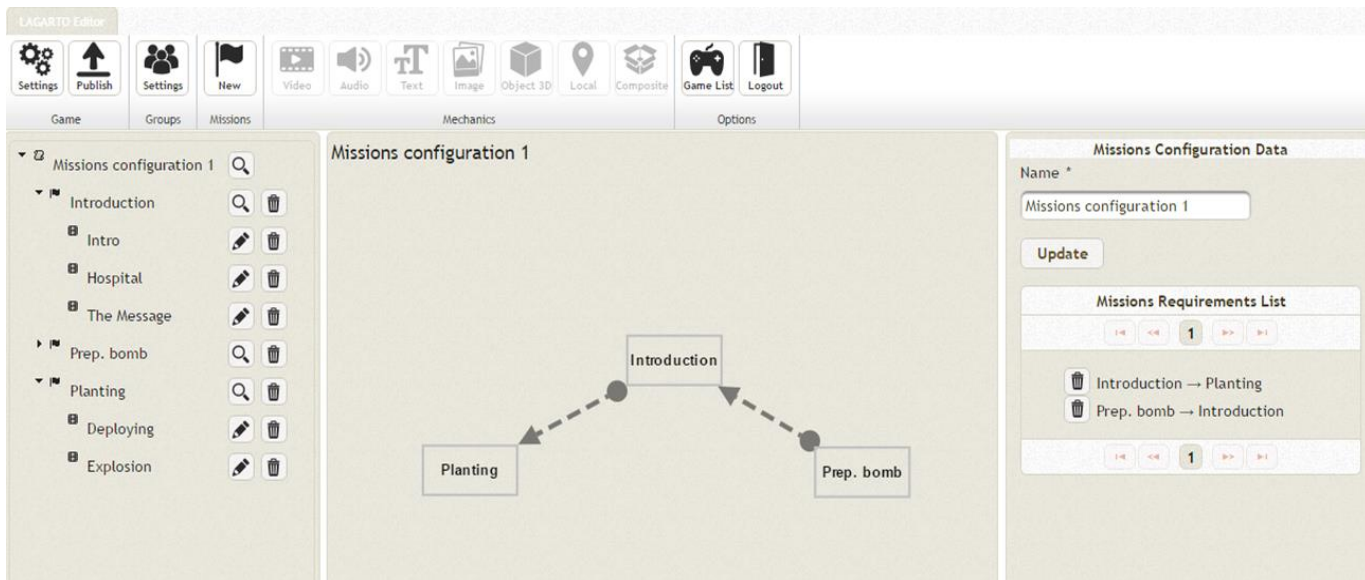
Game Design – Auragame



MAIA, L. F.; RODRIGUES, W.; VIANA, W.; TRINTA, F. Auragame: A Case Study of a Zero Programming AR Game. In: XV Simpósio Brasileiro de Jogos e Entretenimento Digital, 2016, São Paulo, Brazil. Proceedings of SBGames 2016.

LBG Authoring Tool: LAGARTO

A LocAtion based Games AuthoRing TOol



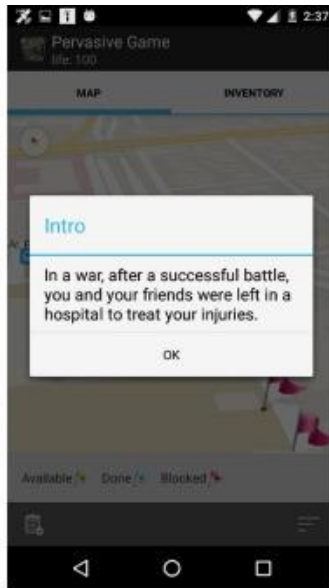
The screenshot displays the LAGARTO Editor interface. The top toolbar includes icons for Settings, Publish, Groups, Missions, Video, Audio, Text, Image, Object 3D, Local, Composite, Game List, and Logout. The main workspace is titled 'Missions configuration 1' and shows a flowchart with three nodes: 'Introduction' at the top, 'Planting' at the bottom left, and 'Prep. bomb' at the bottom right. Dashed arrows indicate a sequence from 'Introduction' to 'Planting' and from 'Introduction' to 'Prep. bomb'. On the right, the 'Missions Configuration Data' panel shows the name 'Missions configuration 1' and an 'Update' button. Below this, the 'Missions Requirements List' shows two requirements: 'Introduction → Planting' and 'Prep. bomb → Introduction', each with a trash icon and a sequence number '1'.

NOLETO, C. O. ; LIMA, M. ; SILVA, LUIS FERNANDO MAIA ; VIANA, W. C. ; TRINTA, F. A. M. . An Authoring Tool for Location-based Mobile Games with Augmented Reality features. In: XIV Simpósio Brasileiro de Jogos e Entretenimento Digital, 2015, Teresina. Proceedings of SBGames 2015.

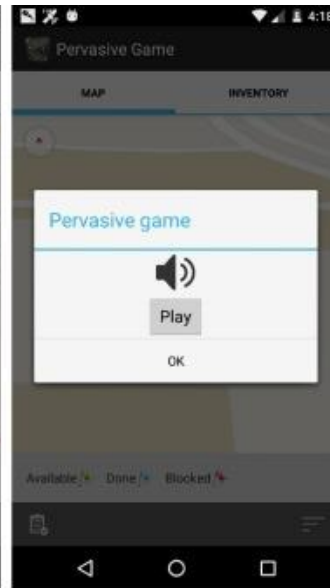
LBG Authoring Tool: Lagarto Scout



(a) Missions



(b) Text

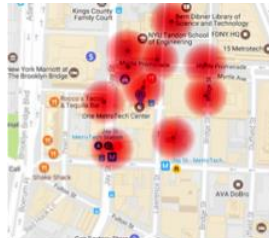


(c) Audio file



(d) AR content

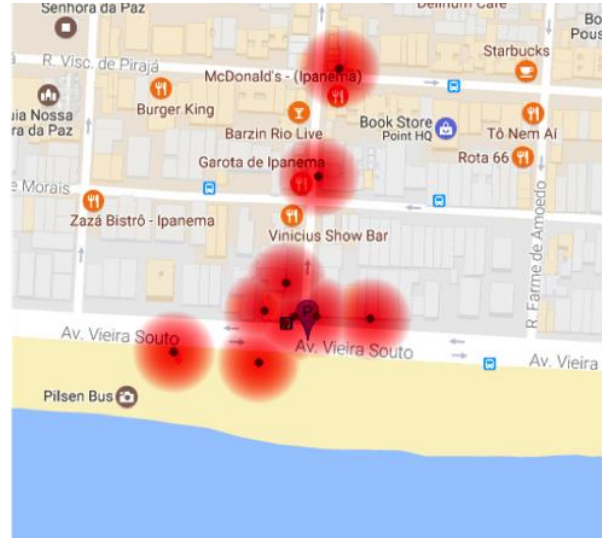
Map Balance: Monte Carlo Tree Search Approach



Original New York



Original Rio de Janeiro



Balancing RJ Pokestop Map

MAIA, LUIS F. ; VIANA, W. ; TRINTA, F. . Using Monte Carlo Tree Search and Google Maps to improve Game Balancing in Location-based Games. In: IEEE Conference on Computational Intelligence and Games - CIG 2017, New York. Proceedings of the IEEE Conference on Computational Intelligence and Games (CIG), 2017. p. 1-8.

What have we learned?



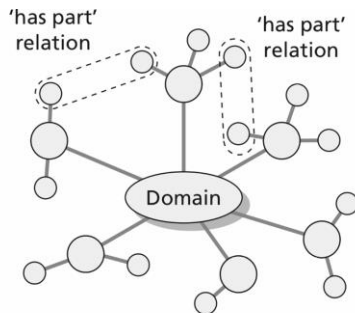
Problems and Challenges

- No well-defined model for representing LBGs
 - Team communication issues
- Authoring Tools
 - Specific internal or visual representation
 - Interoperability issues
 - No availability of LBG V&V
- Game Development
 - Difficult to global deploy an LBG
 - Game Map Balancing is not a trivial task

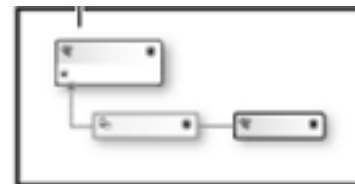
Game Modelling Approaches



Game UML Modelling



Game Ontologies

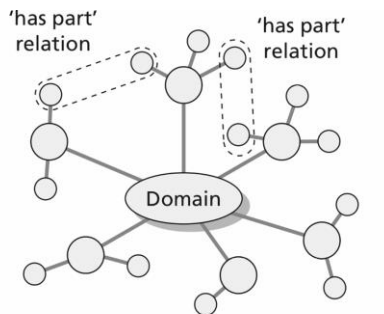


DSL

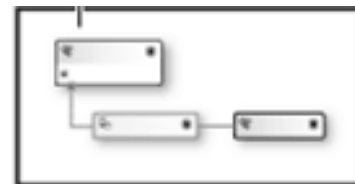
Game Modelling Approaches



Game UML Modelling



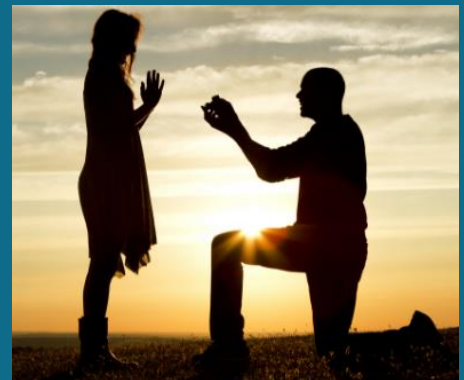
Game Ontologies



DSL

None of them supports LBG Design Patterns
They were designed to specific context

Our proposal



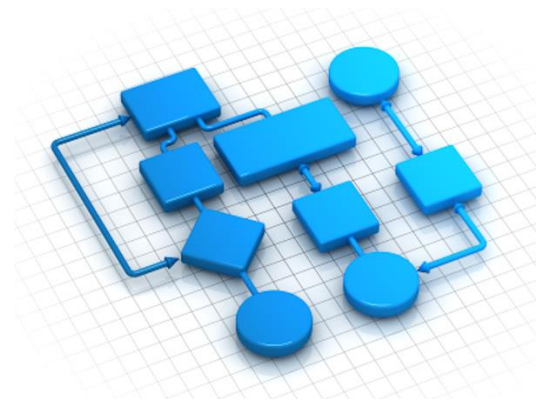
Model-based Approach

- LBG Design and Development
- High-Level Descriptive Model
 - Game description separated from the game visual presentation
 - Quest/Mission - based games
- Aiming at support the Four LBG Design Patterns
 - Follow-the-Path
 - Search-and-Find

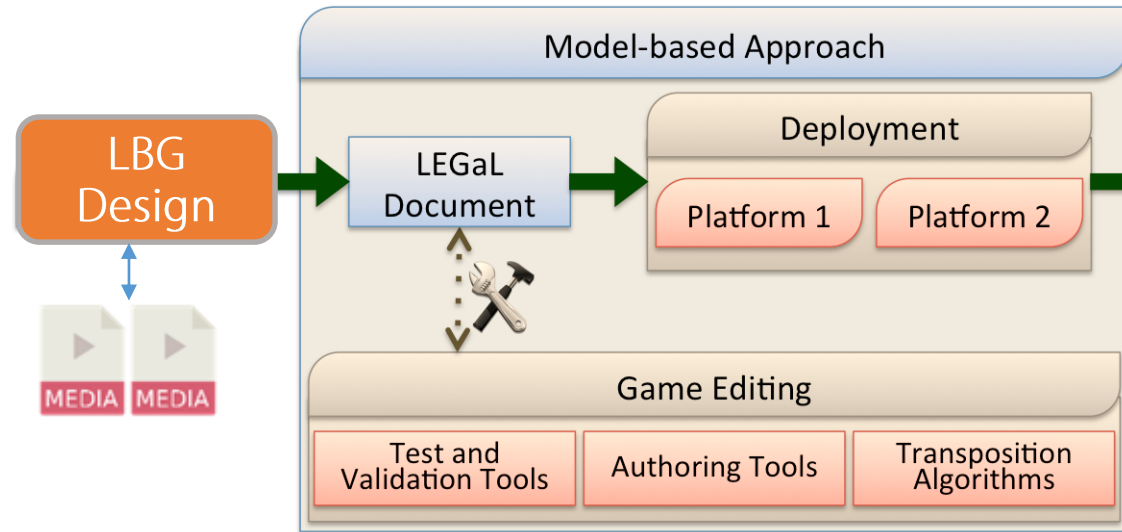


Model-based Approach

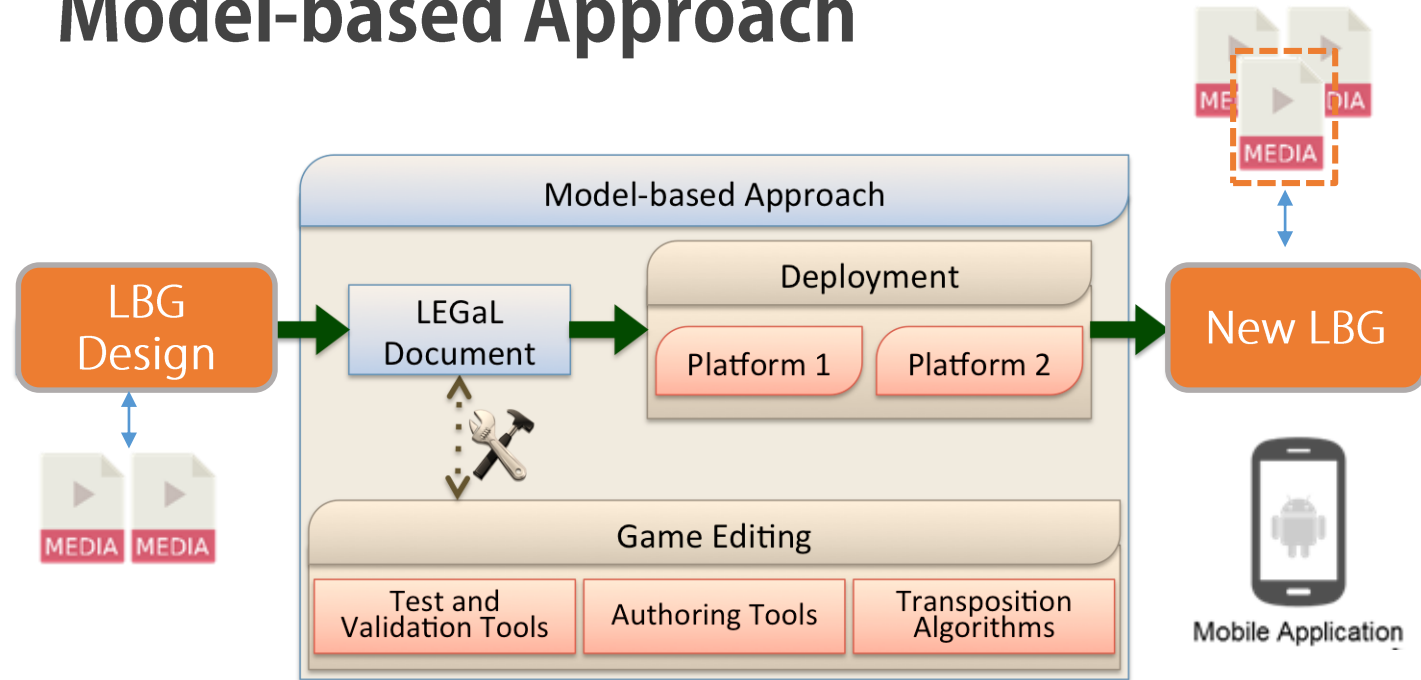
- Agnostic Textual Representation
 - Interoperability
 - Easy derivation of/from LBG Workflow



Model-based Approach



Model-based Approach



LeGaL: Location-based Game Language

- A language to represent LBGs and their elements
 - Quest-based games
 - Based on NCL (Nested Context Language)
- LeGaL allows to define
 - Game missions and workflow
 - Media used in missions
 - Player actions, media synchronization, and spatial relationships
- LeGaL does not allow to define
 - Media presentation
 - Game visual interface

Why did we adopt NCL?

- NCL is more natural to model both missions concept and temporal synchronism as first-class entities
 - Temporal synchronism
 - Temporal relationships among media contents
- Community and Tools
 - Document Edition
 - V&V



NCL Extension

Missions are NCL context nodes

Mission properties

Teams, Game Actions, and Score

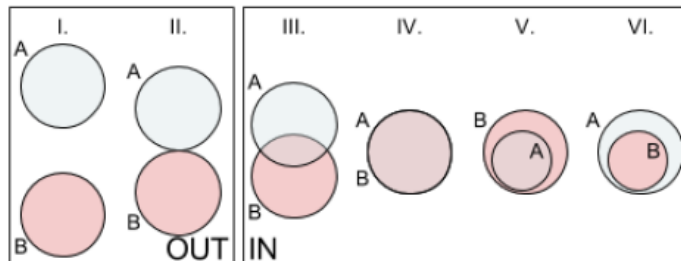
Sequence of missions are links

GML for Spatial Data



NCL Extension

Space Connections and Events -> New NCL connectors

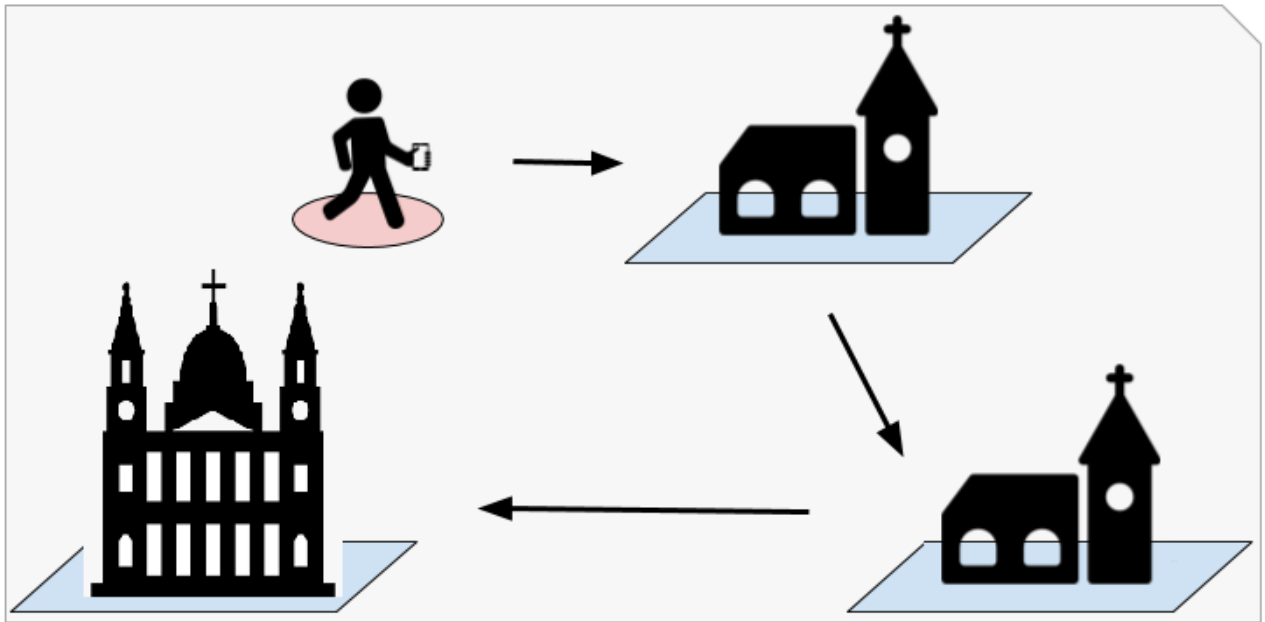


AR Media

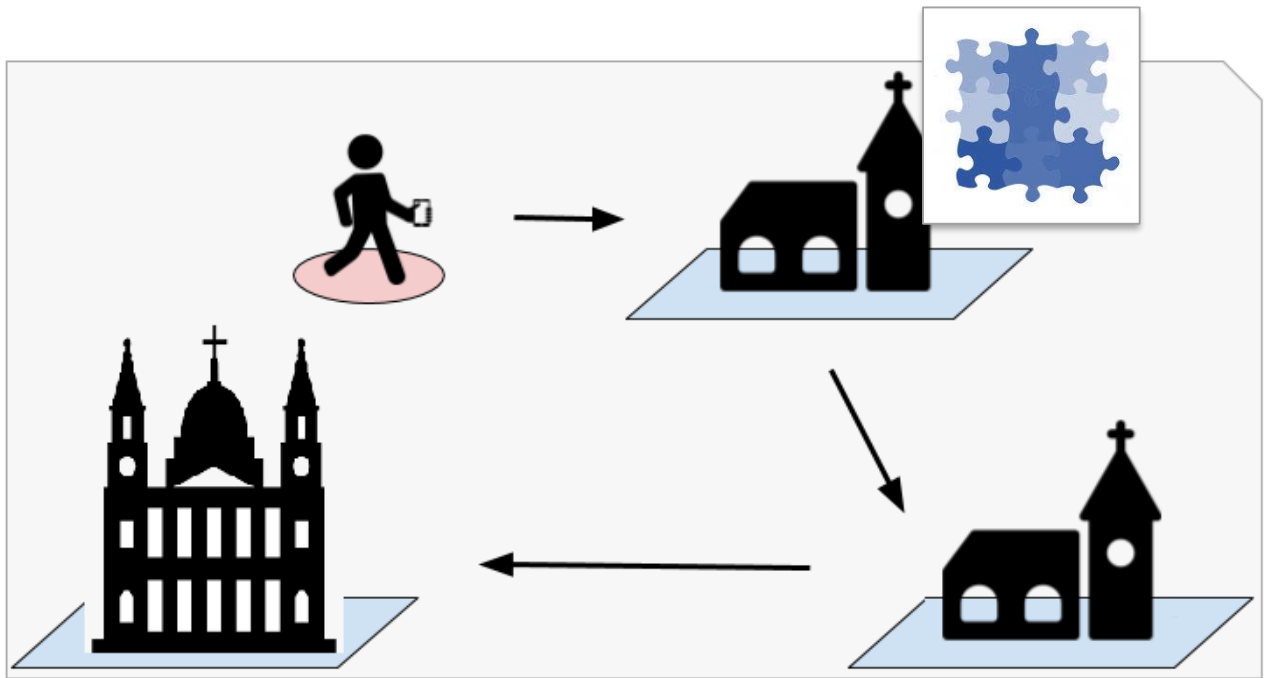
Table 2: LEGaL Media types.

type/subtype	File format	type/subtype	File format
text/plain	txt	image/png	png
image/jpeg	jpg, jpeg	audio/mp3	mp3
video/mpeg	mpeg, mpg	video/3gpp	3gp
text/plain	obj, mtl	application/gml+xml	gml

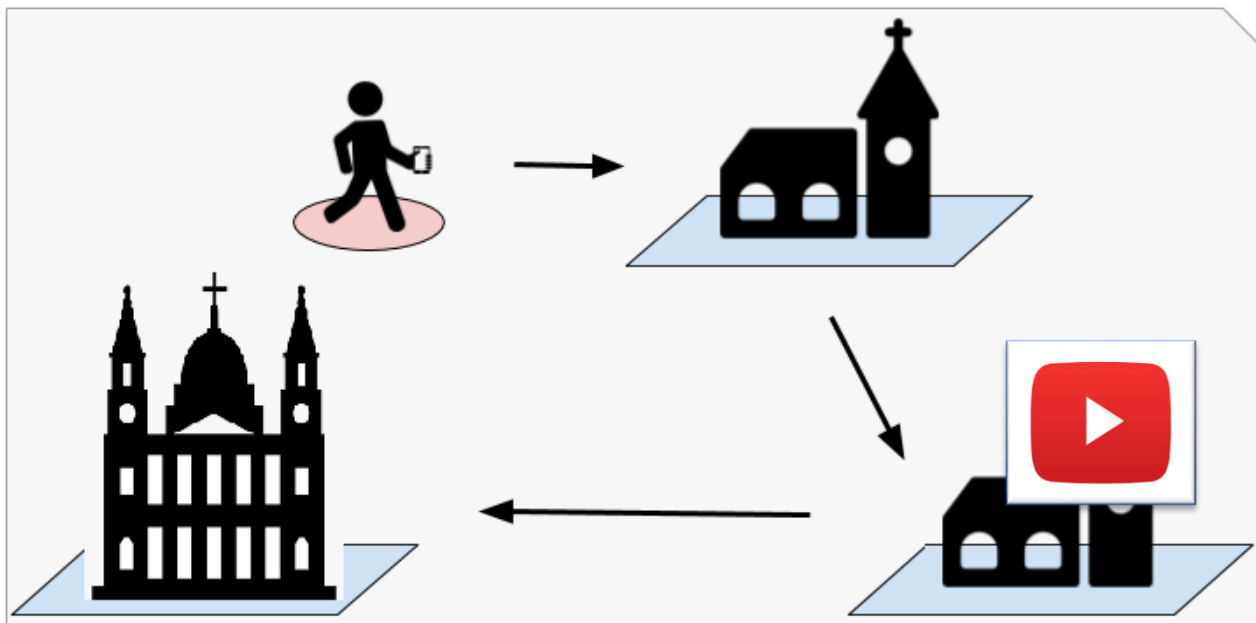
LBG Example



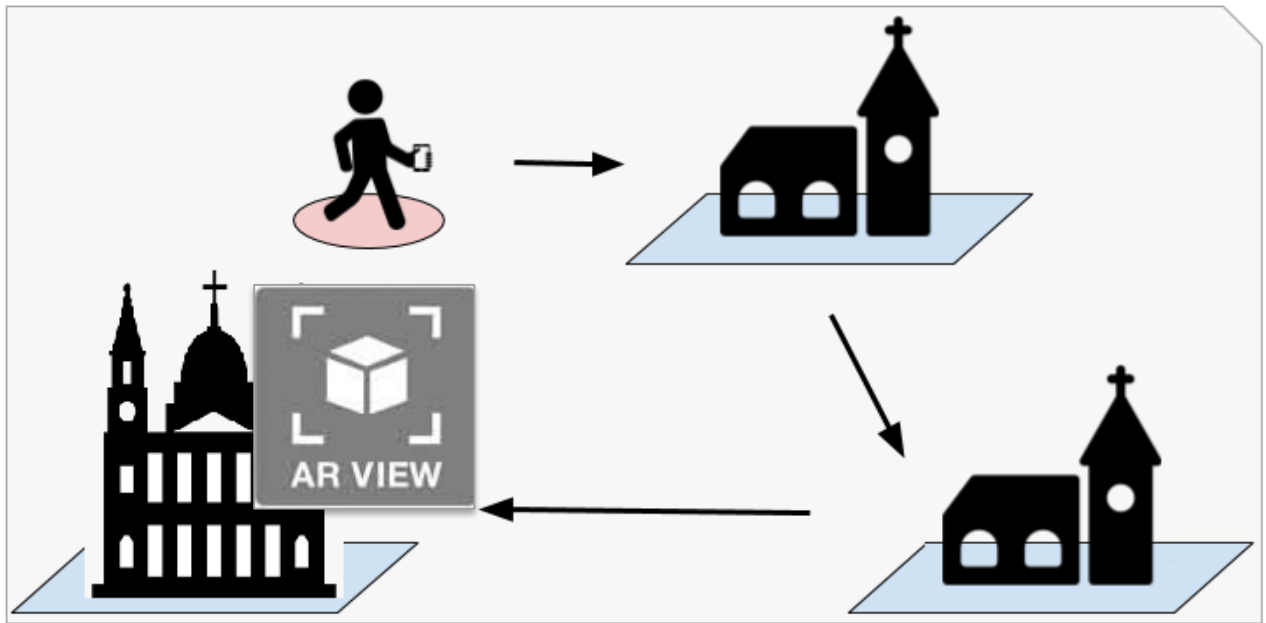
LBG Example



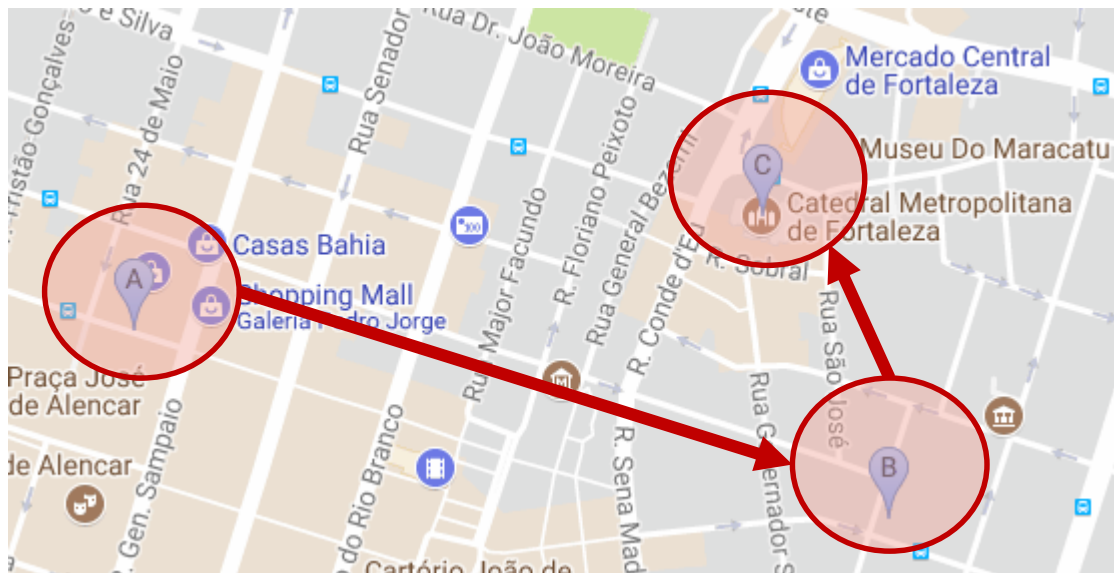
LBG Example



LBG Example



LBG Example in Fortaleza



NCL and GML Files at

<https://github.com/CristianeMayara/LEGaL/tree/master/ChurchExample>

XML Representation – First Mission

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<ncl id="churches"
xmlns="http://www.ncl.org.br/NCL3.0/EDTVProfile">
  <head>
    <connectorBase id="connBaseId">
      <importBase alias="conn" documentURI="ConnectorBase.ncl"/>
      <importBase alias="space"
documentURI="SpaceConnectorBase.ncl"/>
    </connectorBase>
  </head>
  <body>
    <!-- game start ports -->
    <port id="pEntrance1" component="msChurch1"
interface="pChurch1"/>
```

XML Representation – First Mission

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    </connectorBase>
  </head>
  <!-- game start ports -->
  <port id="pEntrance1" component="msChurch1"
interface="pChurch1"/>
```

XML Representation – First Mission

```
<!-- mission in the patrocinio church -->
```

```
  <context id="msChurch1">
```

```
    <port id="pChurch1" component="locChurch1"/>
```

```
<property name="mandatory" value="true"/>
```

```
  <property name="occurrence" value="unbounded"/>
```

```
  <property name="visibility" value="true"/>
```

```
  <media id="locChurch1" type="application/gml+xml"
src="media/Church1.gml"/>
```

```
    <media id="mdImage" type="image/jpeg"
```

```
src="media/peqGrandeChurchIndicator.jpg"/>
```

```
  <link xconnector="space#onEnteringStart">
```

```
    <bind role="onEntering" component="locChurch1"/>
```

```
    <bind role="start" component="mdImage"/>
```

```
  </link>
```

```
</context>
```

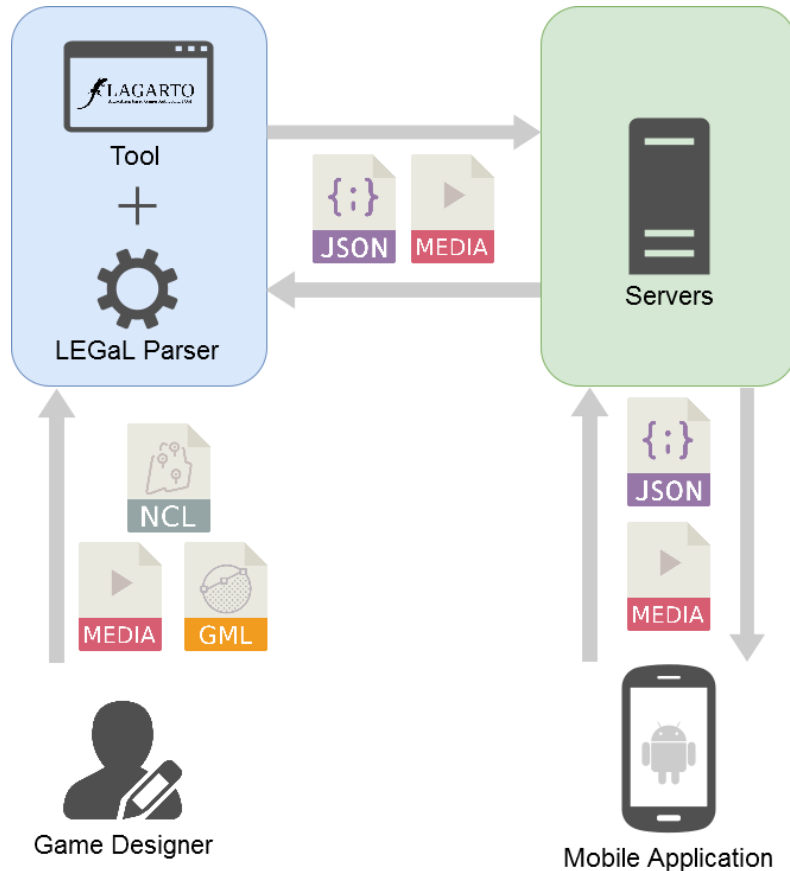
XML Representation – First Mission

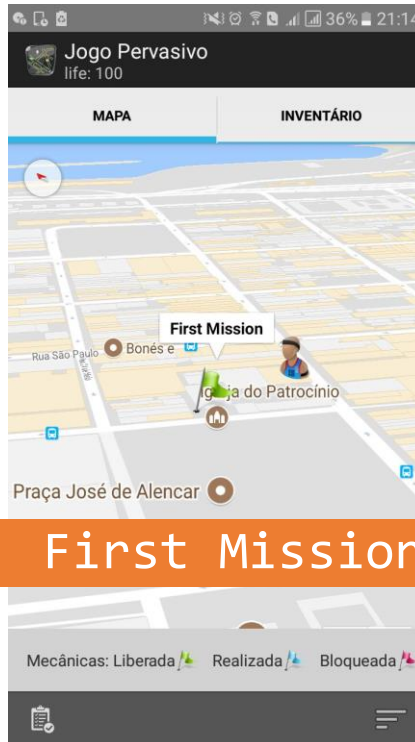
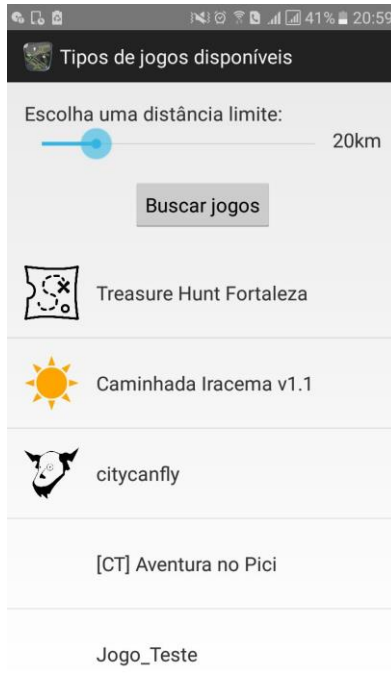
```
<!-- mission in the patrocinio church -->
  <context id="msChurch1">
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    <property name="mandatory" value="true"/>
    <property name="occurrence" value="unbounded"/>
    <property name="visibility" value="true"/>

    <media id="locChurch1" type="application/gml+xml"
src="media/Church1.gml"/>
    <media id="mdImage" type="image/jpeg"

<link xconnector="space#onEnteringStart">
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</context>
```

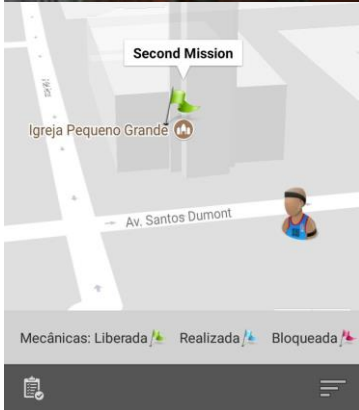
Parser



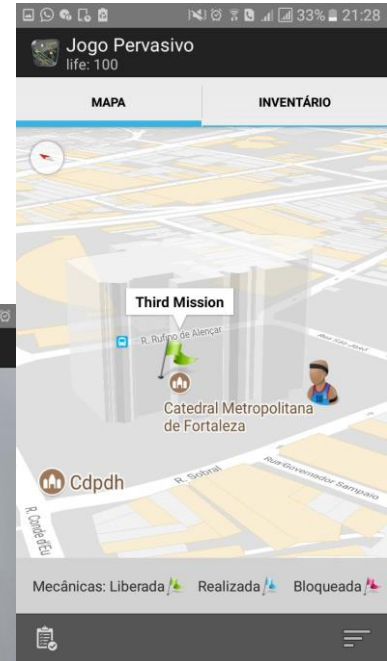
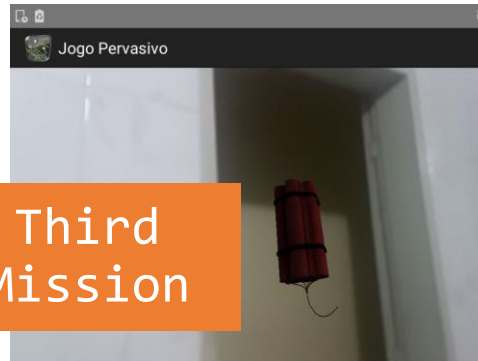


First Mission

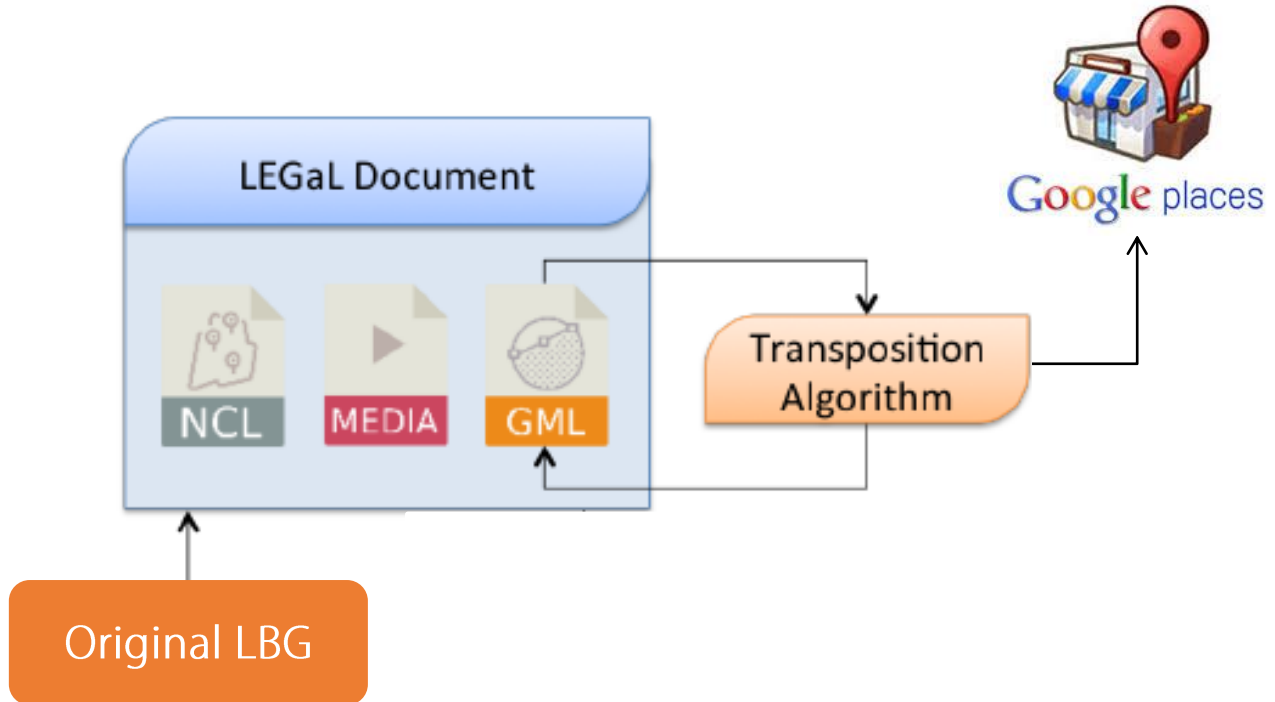
Second Mission



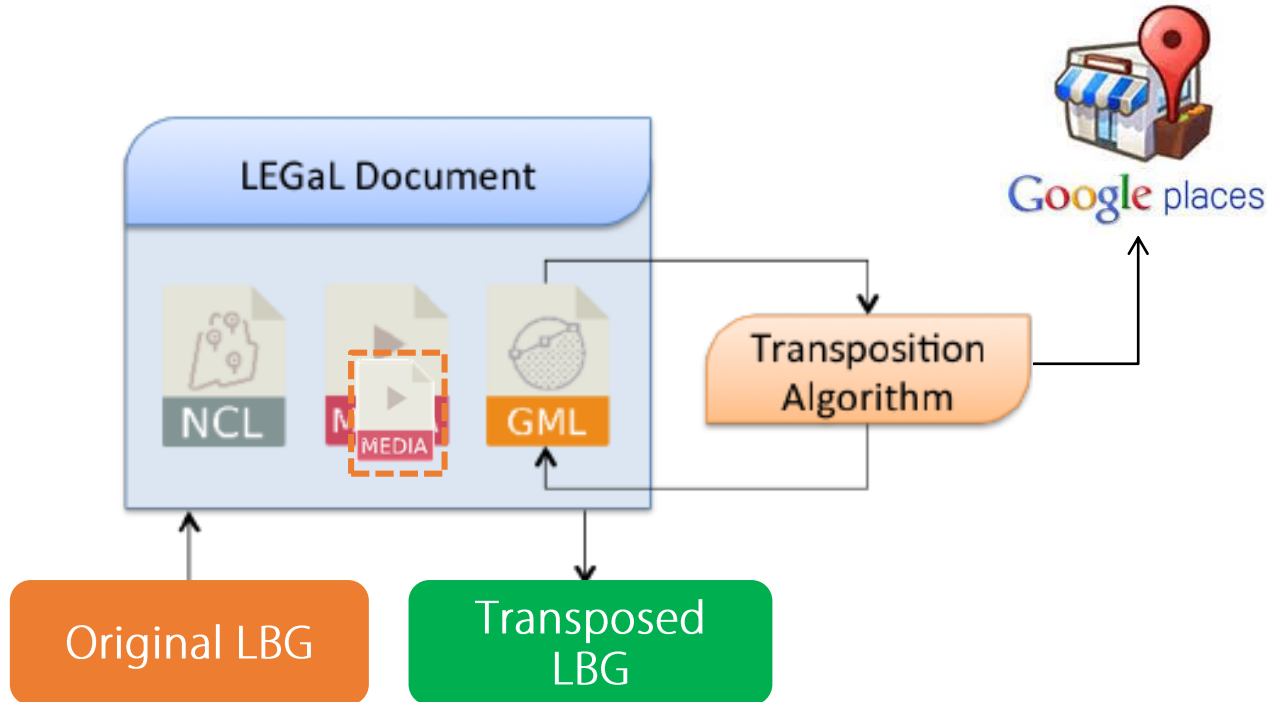
Third Mission



Transposition Algorithm



Transposition Algorithm



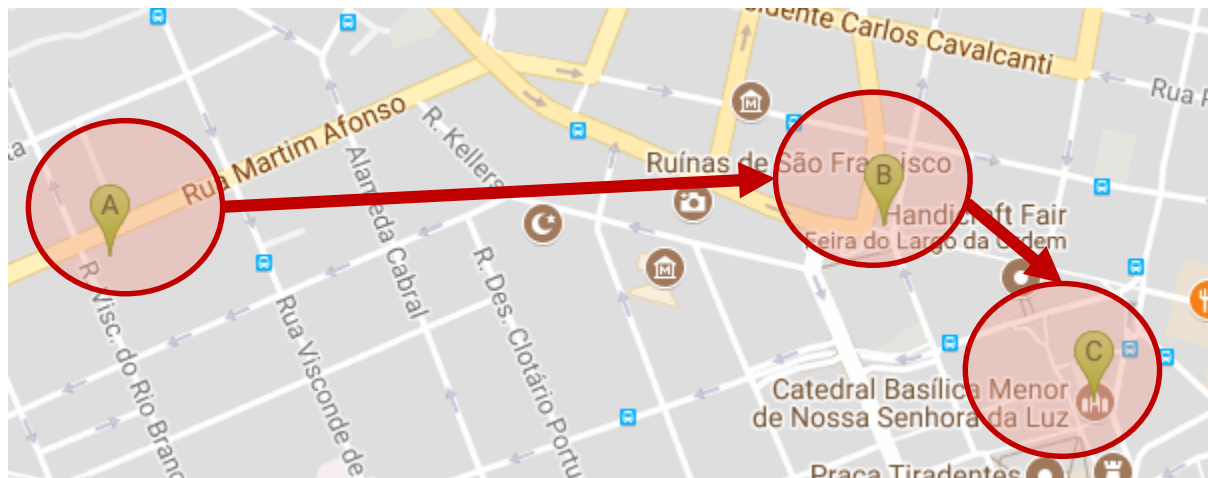
Transposition of the LBG example

- Target location
 - Curitiba
- Restrictions
 - The LBG must end at a Cathedral
 - Puzzle and video content are location-dependent
- Balance Strategy
 - Game walk distance time should be similar

Transposition of the LBG example

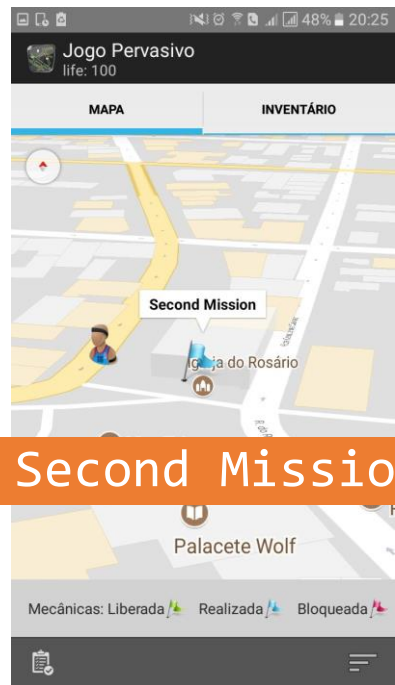
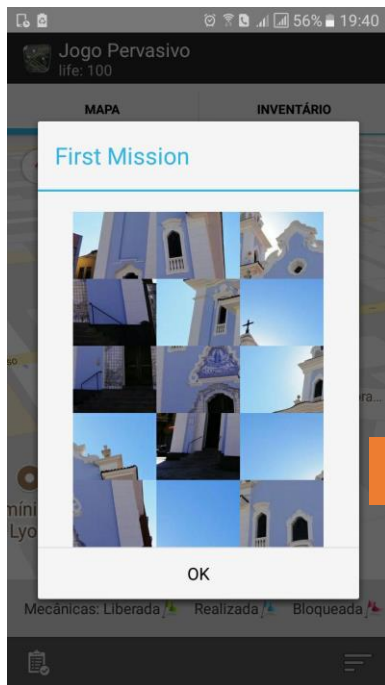
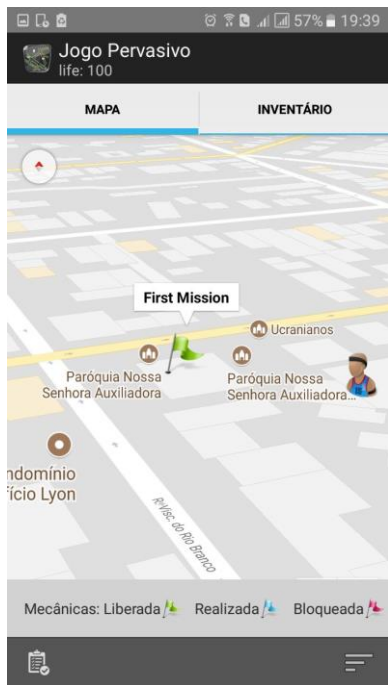
- Algorithm method and input
 - MCTS
 - Nine churches at the Downtown nearby the Cathedral
 - Google API Distance Matrix
- Only a new GML need to be generated
 - Media files are changed in the repository
 - Parser processes the New Game with the same NCL file

Transposed version of the game map for Curitiba



It presents only 13.06% of difference in comparison to the distances to be traveled in the original game

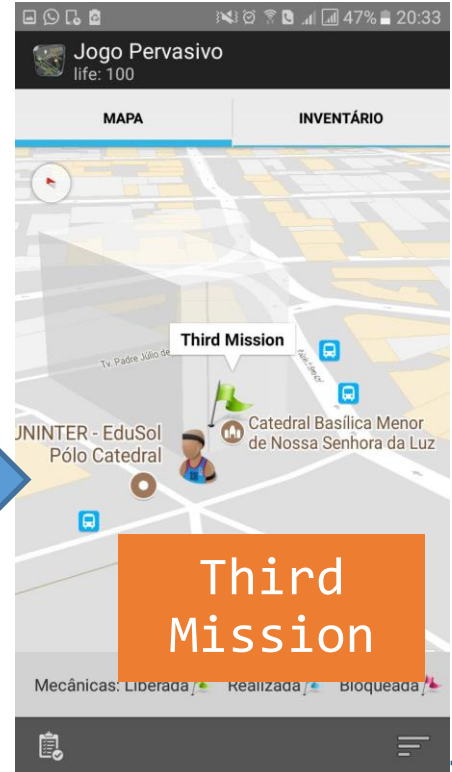
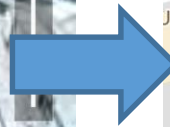
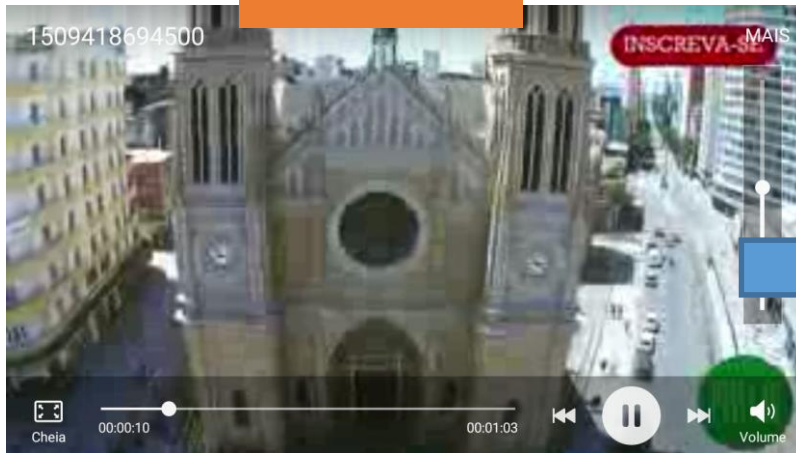
Transposed version of the game map for Curitiba



Second Mission

Transposed version of the game map for Curitiba

Second Mission



Evaluation

Three Types of Evaluation



NCL
Developers



Game
Recodification
in LeGaL



Game
Transposition

Evaluation with NCL Developers

- Language Usability Evaluation
 - Five NCL Developers from UFMA
 - Using NCL Tools for Game Edition
- Results
 - Success in the generation of the games proposed in the evaluation
 - Participants reported positive acceptance
 - LeGaL is simple
 - LeGaL is easy to access
 - Difficult to model team-based information

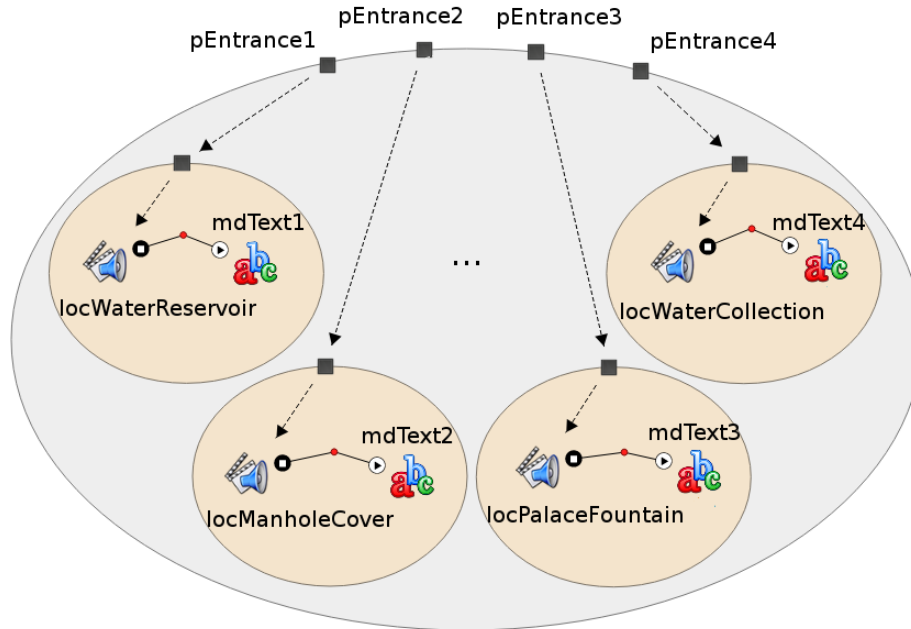
Game Rewriting: AudioRio

- Audio-based gamified journey
- 18 Missions
 - Text and Sound
 - Search-and-Find



Model at <https://tinyurl.com/khgeusz>

AudioRio LeGal Model at NCL Composer



LeGaL Model: AudioRio

- With AudioRio textual description
 - LeGaL parser was used to regenerate the game.
- The parser took 1599 milliseconds to generate the Hibernate instances and to transfer the media associated with the game

The game ran in exactly the same way as its previous version

Final Remarks

Conclusion

- Advantages of LeGaL
 - Interoperability
 - High Level Description
 - Structure separated from Visual Representation
 - Spatial Representation
- LeGaL parser embedded to LAGARTO
- Evaluation indicates soundness



Future Work

- Short term
 - Experiments involving more developers and more complex games
 - Representing games in other LBG Patterns, besides Follow-the-path and Search-and-Find
 - Implement other Transposition Algorithms
- Long term
 - Model Checking for semantic and synthetic verification
 - LeGaL Visual Representation



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Mestrado e Doutorado em Ciência da Computação



GREat

Grupo de Redes de Computadores
Engenharia de Software
e Sistemas

Thank you!

Prof. Dr. Windson Viana

windson@virtual.ufc.br

References

Hong, G. (2015). Concepts and Modelling Techniques for Pervasive and Social Games. PhD thesis, Norwegian University of Science and Technology.

Kasapakis V., and Damianos G. Pervasive gaming: Status, trends and design principles. In Journal of Network and Computer Applications, 55, pp. 213-236, 2015.

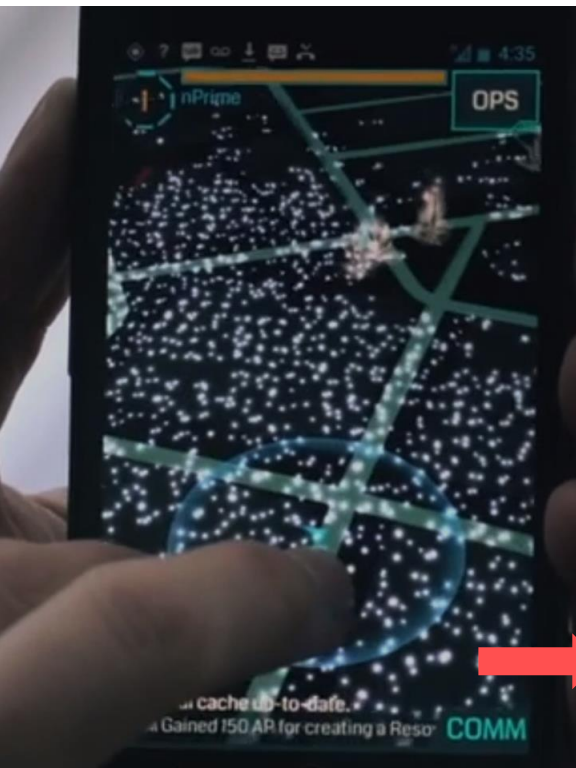
Nieuwdorp, E. (2007). The pervasive discourse: an analysis. Computers in Entertainment (CIE), 5(2):13.

Nolêto C., Viana W., and Trinta F. Uma ferramenta de autoria para o desenvolvimento de jogos móveis baseados em localização com realidade aumentada. 2015. Dissertação de Mestrado. Universidade Federal do Ceará.

Lehmann L. Location-Based Mobile Games. Munich, Germany: GRIN Verlag, 2012.

Soares, LFGS. Programando em NCL 3.0: desenvolvimento de aplicações para middleware Ginga: TV digital e Web. [SI]: Elsevier, 2009.

LBG Design Patterns



LBG	P1	P2	P3	P4	MP	Teams	AR
Geocaching [26]	x						
Parallel Kingdom [28]		x			x	x	
Tourality [39]		x	x		x		
Shadow Cities [4]			x		x	x	
The Walk [35]				x			
SpecTrek [11]		x					
Ingress [16]	x			x	x	x	
Tidy City Scout [37]		x					
Barbarossa [15]	x		x				x
Gossip at Palace [31]			x				
Woody [34]		x					
TARX [19]		x					
BattleSuit Runner [27]				x			
Zombies, Run! [38]				x			
Pokémon GO [17]	x		x	x	x	x	x

XML Representation – Third Mission

```
<!-- mission in the metropolitan cathedral -->
<context id="msMetropolitanCathedral">
  <port id="pMetropolitanCathedral" component="locMetropolitanCathedral"/>
  <property name="mandatory" value="true"/>
  <property name="occurrence" value="unbounded"/>
```

```
<property name="visibility" value="false"/>
```

```
  <media id="locMetropolitanCathedral" type="application/gml+xml"
src="media/metropolitanCathedral.gml"/>
```

```
    <media id="mdMetropolitanCathedral" type="text/plain"
src="media/treasure.obj">
```

```
<media id="mdMetropolitanCathedral"
type="text/plain" src="media/bomb.obj">
```

```
  <link xconnector="space#onEnteringStart">
```

```
    <bind role="onEntering" component="locMetropolitanCathedral"/>
```

```
    <bind role="start" component="mdMetropolitanCathedral"/>
```

```
  </link>
```

```
</context>
```