# Spatial Computing experience

NOVA VR Lab and YDreams

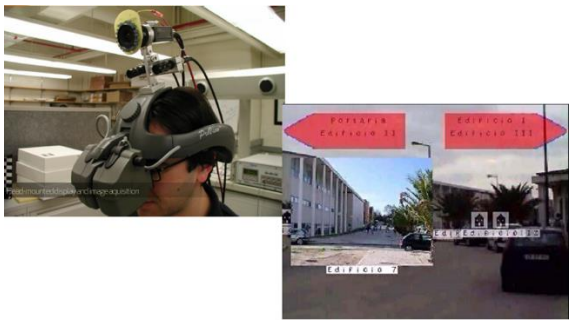
1992-2020

1. Initial efforts in VR: flying over large terrains, spatial simulation and optimization, gesture-based interaction (partners: Warren Robinett at NASA and UNC, Randy Pausch at UVA and Disney Imagineering, Ken Pimentel at Sense8 and Kevin Teixeira at Intel, Silicon Graphics; our team at New University of Lisbon's VR Lab, 1992)

Digital Portugal was used by 1.5million people at Expo 98.
First flyover in VR at this scale in the World.
Financed by Ministries of Planning and Science

Books: Spatial Multimedia and Virtual Reality, Taylor&Francis 1999, Environmental Systems, Oxford University Press, 2002

2. Initial efforts in AR: superimpose labels on reality (Steve Feiner at Columbia, 1997: our team at the New University of Lisbon's VR Lab, 1999)



Research project financed by Portugal's NSF

3. Virtual sightseeing: first AR device (pioneer effort by our team at YDreams, 2004; covered by Economist and Wired)


https://www.youtube.com/watch?v=GCB1OeYw

Virtual sightseeing units were sold to municipalities in Portugal and Brazil

4. Projection/image recognition-based systems (our team at YDreams since 2003; contemporary efforts at MIT Media Lab and few other places): interactive carpets and billboards

https://www.youtube.com/watch?v=YCuPU6fVGCo


https://www.youtube.com/watch?v=5-bNZRAypgQ

Clients included NOKIA, Nissan, Barclays, Ford in Portugal, Spain, Brazil and China

5. Marker based AR (our team at YDreams, 2004; contemporary efforts around the World)

https://www.youtube.com/watch?v=jmrLAaF2DgA
https://www.youtube.com/wat

More than 100 projects developed for museums, stores and events in Portugal, Brazil, Spain, France

6. Markerless AR (pioneer efforts by our current team at YDreams in 2008; rest of the World including Apple, Google and the AR crowd caught up only in 2017)

https://www.youtube.com/watch?v=qXcIZ1R68SQ
https://www.youtube.com/watch?v=XlYxEbznsfU

Applied in projects for brand awareness and audience gaming (Portugal, Brazil, France and US). See for instance https://www.youtube.com/watch?v=CmphF7SMkK4 (Cannes Festival). Clients included Disney, Microsoft, Samsung, Volvo and Dove in Portugal, US and Brazil

7. Markerless Augmented Reality+ Depth Perception (pioneer effort by YDreams, 2010)

Project for Nike at Staples Center (2010).Partnerships with Canesta and later Microsoft (that acquired Canesta)

https://www.youtube.com/watch?v=eM_cv3blX_w

8. Natural interfaces based on AR

https://vimeo.com/6734803

FlyAR,
a gesture-based interface
for Twitter

https://www.youtube.com/watch?v=91F6zErnCrs

YScope, a gesture-based interface
for surgeons, financed by
Hospital Santa Maria

9. Augmented Reality+ Artificial Intelligence+ Indoor Location for Autonomous Robots (pioneer effort by our team at YDreams, 2010)

Clients: Santander Bank (Spain) and Bradesco (Brazil)

https://www.youtube.com/watch?v=bzDIJ6TTc6w

An exploratory research project including a virtual bot and ambient intelligence can be seen at https://www.youtube.com/watch?v=AmlKYMDO8x8

10. These developments were anchored in the YVision platform

YVision has an architecture based on a Core that enables the coordination of modules. These modules can include 3rd party software developments. The platform enabled the creation of hundreds of projects that fall on what we can call the interaction with the Real World, or more broadly the Internet of Everything. It relies on a deep knowledge of mathematics.

# YVision mathematics

- 3D Rendering: Linear Algebra - Differential Geometry - Geometry (Projective Transformations)
- Physics Simulation: Linear Algebra - Differential Calculus - Integral Calculus - Numerical Analysis (for approximating continuous mathematics)
- Computer Vision: Linear Algebra - Geometry (Homographies, Projective Transformations) - Cellular Automata - Convolutions - Fourier Analysis
- Synthesis and Transform Audio: Fourier Analysis, Synthesis and Transform
- Machine Learning: Statistical Analysis - Artificial Neural Networks - Principal Component Analysis - Regression - Function Approximation
- Evolutionary Computation Core Framework: Lambda Calculus (root of functional programming) - Turing Machines - Theory of Computation

11. Augmented reality work at YDreams was complemented by pioneer developments in location- based technologies:

- Pioneer mobile map channel and location-based services for Vodafone (2000);
- Pioneer location-based games: Undercover (Vodafone, 2003); Lex Ferrum (Bluetooth location-based game, NOKIA, 2004); Spooks (BBC, 2004);
- Pioneer interaction system connecting mobile phones and large screens (Vodafone, 2003 and Adidas, 2006);
- Pioneer indoor location system (EU sponsored project, 2005; patent sold in 2017 to Uber);
- Pioneer contextual content filtering (Portugal Telecom; patent sold in 2012 to US based fund);
- Pioneer collision and occlusion detection plus shadow casting for virtual characters inserted in real scenes (patent infringed by Microsoft HoloLens; sold to Ovidian in 2016);
- Pioneer short range 3D location mapping using 2D cameras

12. YDreams was initially a private “Media Lab” with thirty members coming from the New University of Lisbon’s VR Lab. Most of them studied or worked in the US. It received 8.5 million Euros investment in 2006. It was close to break even in the first semester of 2009. The company had revenues between 5 and 10 million Euros from 2008 until 2012.

It spun-off and AR company that signed a term sheet to merge with Ogmento, now Apple’s AR team, in 2011. The deal was not completed as the leading VC thought it was too early for AR.

YDreams ties with other major companies’ AR developments include two leading ex-YDreams developers, that are now members of Google’s AR team. Another former YDreams Director, specialized in machine learning, now leads a Google division. A former member of our VR Lab at the University is a leading data scientist at Amazon, after being Chief Data Scientist for Climate Change at President Obama’s White House.

YDreams AR company attracted the interest of Sequoia, Kleiner Perkins and Bessemer in 2011, after impressive showings at major events (YDreams won the first Auggies in 2010, the major AR award in the industry). Investment and sale were discussed with Intel, a major partner in 2012-13. Technology Crossover Ventures also approached YDreams for investment in 2015, when the company was already being re-structured.

Ex-YDreamers work in more than 10 AR companies in Portugal, having started five of them. YDreams trained at least 50 AR developers.

YDreams key knowledge base was split in two companies in 2016: YDreams Global (formerly YDreams Brazil, and now a public Canadian Virtual Reality company); and Aromni.

13. Aromni started in November 2016 and was founded by key YDreams team members. Our first analysis concluded that AR became additive: a digital layer was being created to be superimposed to Real World places, objects and activities That digital layer could include Wow effects or be oriented to be useful.



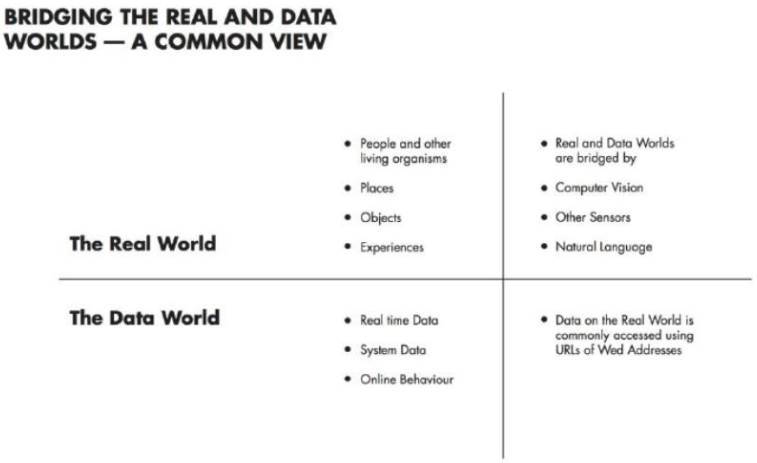
https://www.youtube.com/watch?v=FfiXhOmw2Rs

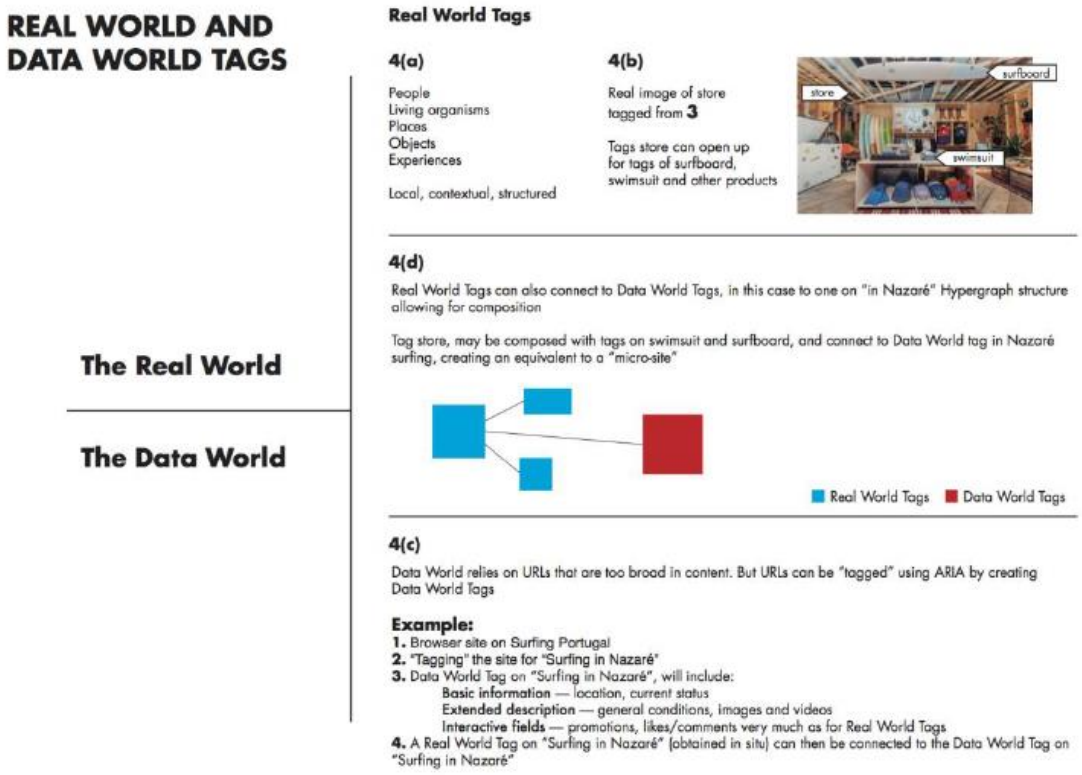
https://www.youtube.com/watch?v=me3J2l7tc70&feature=youtu.be

Aromni started attracting for clients and partners that wanted useful AR applications: urban guides which were a succession of useful digital layers spatially located (Serpa municipality); digital layers that were operating manuals for devices (Delta coffee machine; Boston Scientific in the US); and digital layers that were objects that could be inserted in real scenes (Sumol-Compal).

14. In July 2017, we realized that in addition to simply additive AR one could use AR to index the Real World by considering that the augmented digital layers could be considered tags. These tags could be divided into: smart tags to index objects and facilitate spatial exploration (Explore tags); and smart tags enabling experiences (Experience tags).

15. Explore tags bridge the Real and Data Worlds including places, objects and activities. They can “paint” the World with data (coming from the Data World). But tags associated with computer programs (such as machine learning) can extract data from the Real World and store in the Data World.

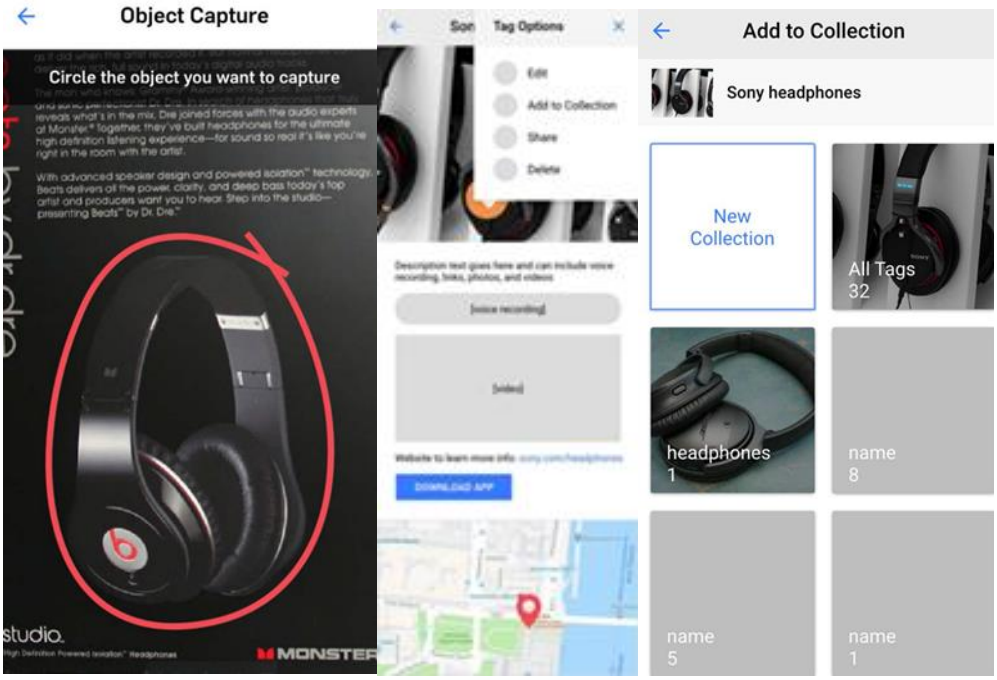


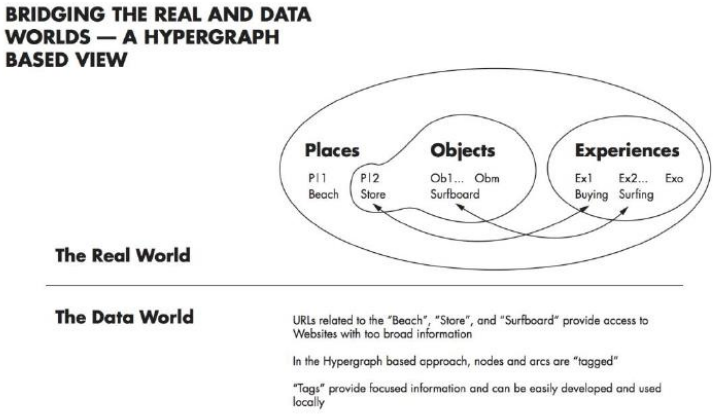
16. Aromni's tags can index objects by image recognition, location, reading codes and sensors. It can also derive labelling from the Web using parsing for places, objects and activities


17. Aromni developed the Meemoo app to facilitate user tagging by voice or writing when there are no tags available. It can be used to tag places

Or objects




18. Tagging the Real World places, objects and experiences means the Digital Twinning of the Real World. By viewing the Real World as a network (both physical and conceptually), we were drawn to represent it as a hypergraph where nodes are tags. Tags can have hierarchical and horizontal relationships between them. The hypergraph may be also seen as a multi-commodity network.



19. Aromni Explore tags, the digital twins of the Real World, are being developed to be more than simply labels. They include computer programs, and by nature of their incorporation in hypergraph representations they can be used to help in the relative positioning of objects

1. "Structured Tags" as the digital layer bridging the Real and Data Worlds using augmented reality

Structured tags include:

- Basic labeling of a real image;
- Extended labeling including metadata, text, static and dynamic images (including 360 images), and audio that may be annotated and sketched;
- Two way communication and sharing channels;
- Computer programs that may facilitate information generation, image and audio recognition, fitting information to real images, and the conversion of "tags" into key elements of the Internet of Everything.

2. Information generation for augmented reality tags using machine learning

Information generation is achieved via machine learning: either by learning from the Real World; and by extracting information from the Data World to fill the tags.

3. Image and audio recognition

Image and audio recognition also applies machine learning and uses, additionally, decision trees to automatically solve, or at least aid in the solution of the problem. The decision trees include pre-defined filters for pre-defined classes of problems that include recognition of places, objects (both non-living and living), and experiences. The image recognition is also facilitated by virtually sketching a target on top of the real image, using a gesture based interface.

Meemoo uses inconspicuous physical tag systems, namely NFC smart labels, for specific objects that require precise identification

4. Fitting the information to the real images

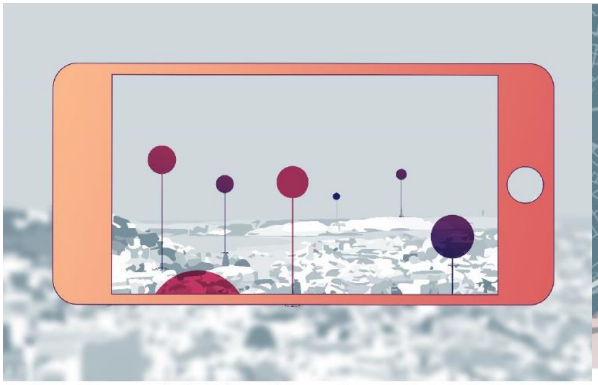
Fitting information to real images is achieved by fusion of information provided by different sensors: digital cameras, gyroscope, compass, accelerometer, GPS, WiFi, Bluetooth and cellular systems. It is also aided by the virtual sketching on the real images used in the image recognition stage.

5. Tag visualization

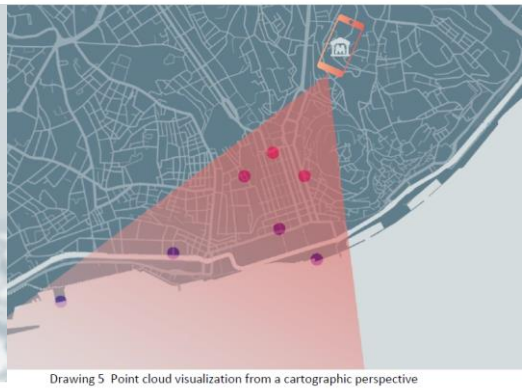
Tag visualization is achieved by applying relevance filtering and using rotating tags that are visible from any angle.

20. Aromni developed an Augmented Positioning System that uses image processing, sensor fusion, heuristics, triangulations and, in the short range, SLAM techniques to infer the location of any point in the Field of View (FoV) of a user. The resulting point clouds can be used in the tagging process for the Explore Mode. They can also be used as a canvas for imaging and sculpting to create Experiences as in 21.

    One can see the point clouds in 3D but also in 2D representations



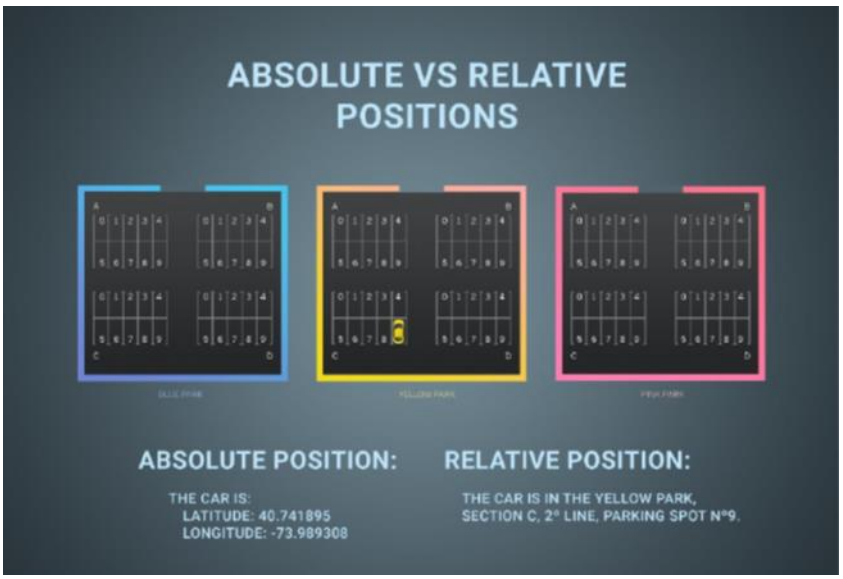
Drawing 6 Point cloud visualization from a reality perspective



Drawing 5 Point cloud visualization from a cartographic perspective

Many systems are trying to work towards machine readable image processing systems fueled by machine learning to infer absolute positioning for every point in the FOVs. There are three important Aromni features that enable a simplification and a significant enhancement of what is called the creation of the AR cloud:

- By considering the hierarchical relationships between tags, relative positioning is often enough without the need of detailed calculations for absolute positioning



- Aromni AR framework is not limited to successive FoVs, considered one at a time. In each moment we have a FoV, but the platform is always aware of places, objects and activities occurring anywhere and specially in the users' neighborhood. It uses an approach like the level-of-detail (LOD) management used in virtual reality;
- This view of the World, the hypergraph structure and the nature of the tags facilitate spatial search but also more complex browsing, search and analysis operations.

21. Aromni can deal with depth by using 2D-3D transformations, in the absence of depth sensors both at the smartphone and AR glasses levels. By knowing the coordinates of every point in the FoV point cloud, it can then facilitate 3D interactions, drawing and sculpting as depicted below. These 3D images can be inserted and received and sent to other users by knowing their position (a simple semi-holographic messaging system). This approach enables the association of experiences to tags and create what we call Experience Tags.

Drawing 10. APS based "semi-holographic" sculpting (1 and 2 on top) , querying and messaging -sending and receiving tri-dimensional animated images system (3 and 4 below)

22. Aromni is developing pilots based on these technologies for retail, a priority vertical market, with Jeronimo Martins.

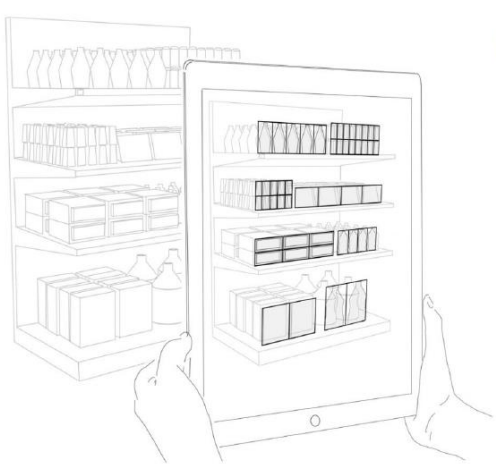
## Retail

- Aromni has **now** a fully functional planogram compliance tool that will be deployed at Jeronimo Martins flagship store at NOVA SBE.
- By having solved this problem, Aromni can solve its dual: an in-store navigational tool for consumers.
- Jeronimo Martins wants Aromni to work on developing unique in-store experiences in 2019 based on the company's digital signage and console developments.
- Jeronimo Martins (approximately 4.000 stores and a 11 billion dollar valuation) will sign briefly a contract with Aromni covering the pilot projects and future roll-out.
- These developments can be licensed to other international tech, consulting and other retail companies that have worked in the past with Aromni's team.

Planogram compliance has been the initial focus of this effort as it represents between 5 to 15% of a store's revenues

**Figure 6** – Use SLAM techniques to get a stable superimposition between the real (products in the shelf) and virtual (planogram) elements.


**Figure 4** – Using augmented reality to superimpose the virtual planogram on the real shelf.



By solving the planogram compliance problem and having tag information associated to every product, Aromni will be able to solve four other problems:

- The location of every product at any given moment in every store. An information that can be useful for store managers and consumers;
- Efficient searches for those products based on location and other criteria (including price)-also useful for store managers and consumers;
- Searches for combinations of products satisfying constraints (i.e., recipes) and comparison between competing products also on constraints, also useful for store managers and consumers;
- By adding either useful information or effects contributing for product awareness (via the tagging system) and managing them in a digital signage platform, Aromni can increase the attractiveness of products and the value of their positioning in the shelves.

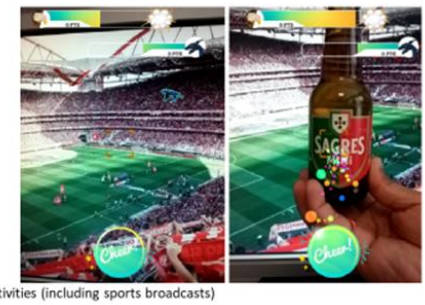
In addition, Aromni can use its console (see below) to promote brands within the store.

23. Aromni has been also working with NOKIA and Benfica to bring AR to sports and entertainment.

    A digital signage platform has been proposed based for NOKIA in its engagement with NFL, based on Denver Broncos' 50% increase in its stadium revenues using such a platform. Aromni's innovation results from its AR approach that does not require the expensive physical infrastructure of traditional digital signage efforts as those used in Denver Broncos' stadium.

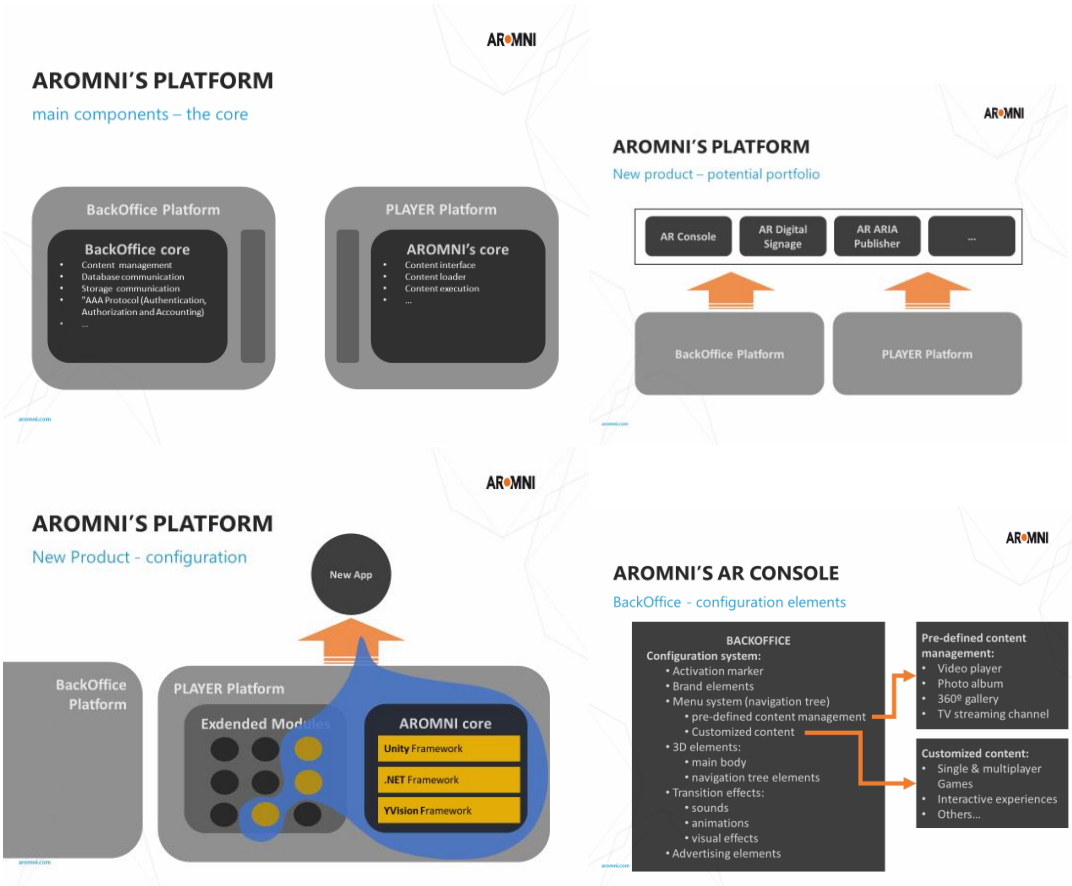
    It is also working in a console concept for Benfica, that can be used for any community as a window to existing and new media.

## Sports and Entertainment




- Aromni has now developed a new concept and demo for sports and entertainment based on the console concept for Benfica that includes:
  - Paper mats that trigger an AR based console and buttons
  - Buttons opening to:
    - Videos and 360 images showing stadium and arena places and activities (including sports broadcasts)
    - Mascots as drones that can be flown virtually
    - Individual games
    - Multi-player games
- Aromni is working with Benfica to bring it to market in Portugal and later globally. Benfica is part of a network including all top soccer clubs in the World and is developing a network of its own in China, India, US and Emirates.
- Aromni is further working with NOKIA and NFL, and will explore existing relationships with NBA and IDEAS (a company associated with Disney)
- Sponsorship and licensing will be the main business models.

24. Aromni plataform enables the solution of spatial problems such as planogram compliance, location and navigation using Explore tags. It also enables the creation of experiences complementing digital signage networks via Experience tags. Finally, Aromni created a framework called Console triggered by an object recognition, where old media and new media (using AR, VR and MR) experiences are possible.



25. The platform is based on a Backoffice and a Player. It relies on Unity, .Net and Yvision (see 10.) frameworks. Aromni platform enables the development of Meemoo (the tagging app), digital signage and the console as products. It is also used for other developments including the planogram compliance project, developments for vertical markets, and special projects such as the AR repair, maintenance, exploration and experiencing systems for the i.triu special project

# Mobility

- Aromni owns 33% of the i.triu company, was formally set up on Nov. 22nd. i.triu will develop a micro-vehicle with three key add-ons: a robotic dock for smartphones, a periscope and a last mile scooter.
- Aromni is developing a virtual i.triu, add-ons and software to enable the vehicle operation, maintenance, repair, and in-car entertainment. It will also develop autonomous driving in the future. The software developments are based on Aromni's platform, relying on its tag structure and console concept.
- i.triu will be brought to market following different business models including full ownership, sharing and rental models, and software and add-on licensing. A first virtual prototype will be available **in January 2019**.