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Biomedicine, Intelligent Systems, Educational Technology
RESEARCH GROUP

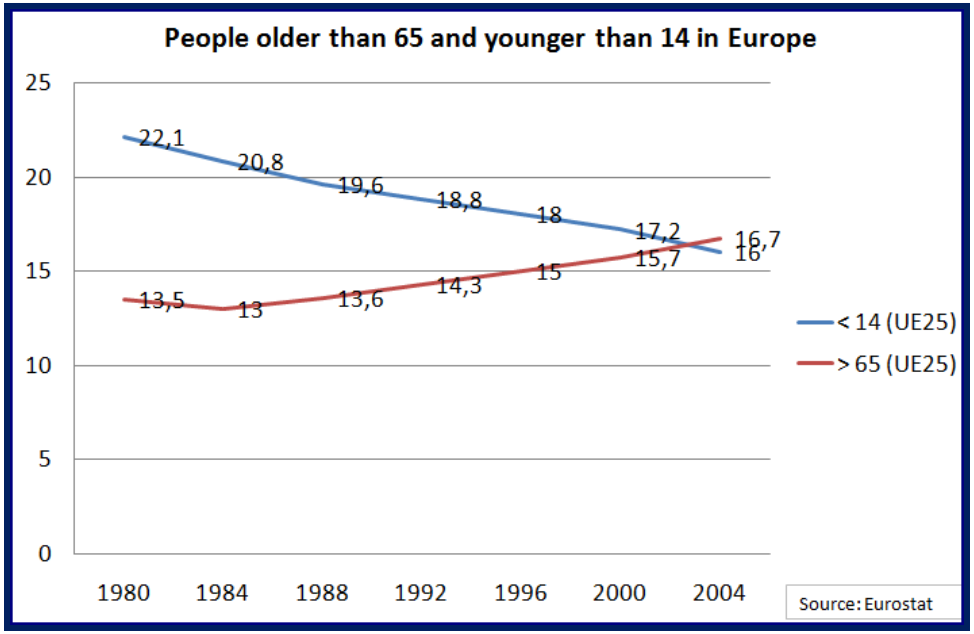
Agents and Computer Vision for Processing Stereoscopic Images

Sara Rodríguez, Fernando de la Prieta, Dante I. Tapia and Juan M. Corchado

Index

- Introduction
  - Motivation
  - Context
  - Technology
- Image analysis: Phases and Techniques
  - Entry
  - Filtering
  - Processing
  - Representation
- Stereo-MAS
- Results y Conclusions
- Future

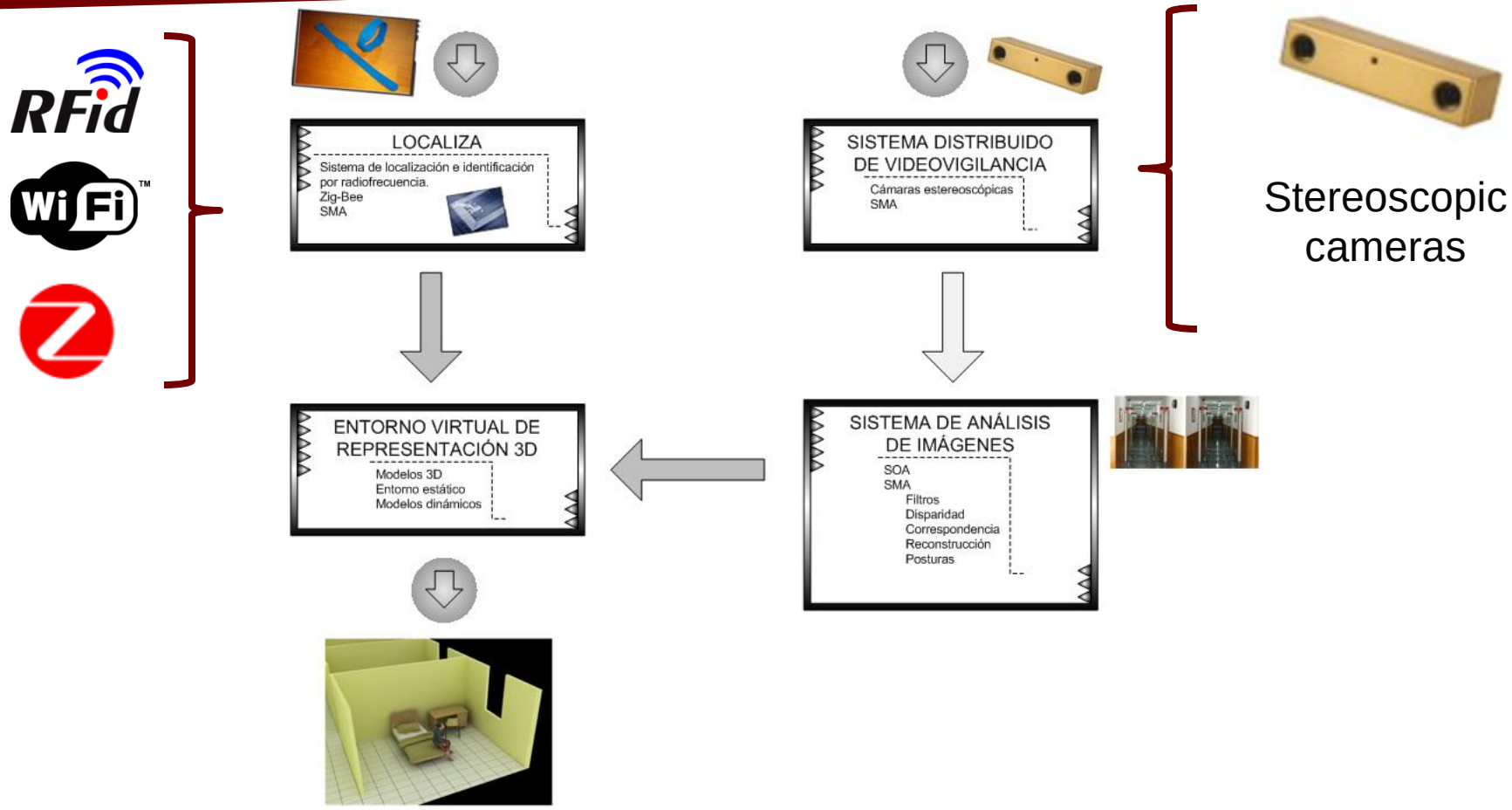
Motivation



One of the greatest challenges for Europe and the scientific community is to find more effective means of providing care for the growing number of people that make up the disabled and elderly sector.

• Multi-agent systems (MAS) and intelligent device have been examined recently as potential medical care supervisory systems for elderly and dependent persons.

Context


RFid
Wi Fi
LOCALIZA
Sistema de localización e identificación por radiofrecuencia.
Zig-Bee
SMA
SISTEMA DISTRIBUIDO DE VIDEOVIGILANCIA
Cámaras estereoscópicas
SMA
ENTORNO VIRTUAL DE REPRESENTACIÓN 3D
Modelos 3D
Entorno estático
Modelos dinámicos
SISTEMA DE ANÁLISIS DE IMÁGENES
SOA
SMA
Filtros
Disparidad
Correspondencia
Reconstrucción
Posturas
Stereoscopic cameras

Technology

Stereoscopy

+

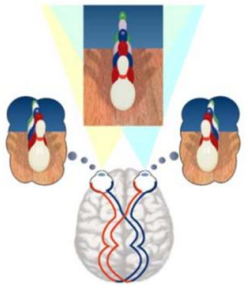
Multi-agent systems (MAS)

Technology

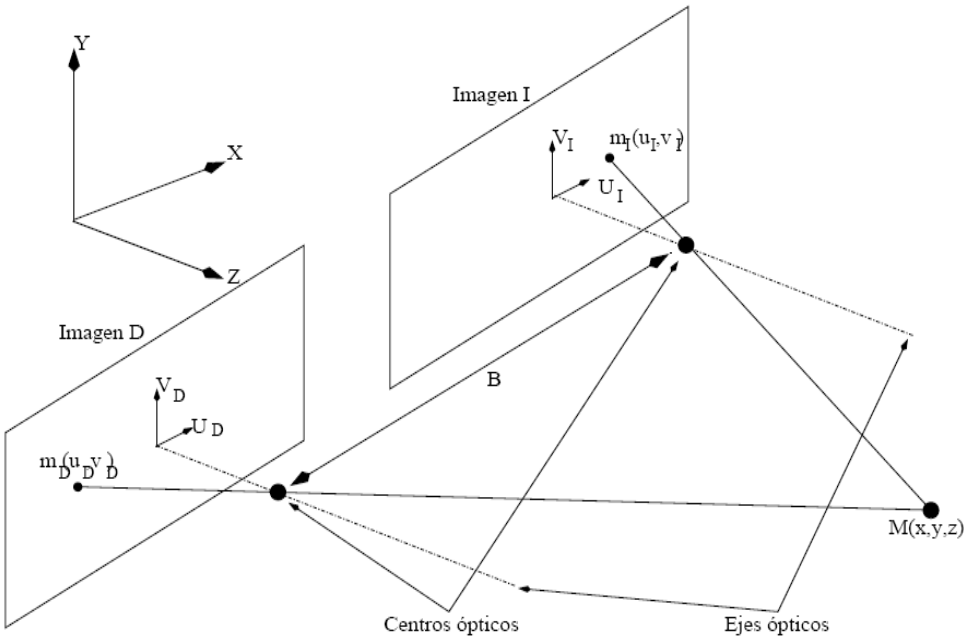
- **Stereoscopy**

•The study of artificial vision, specifically stereoscopic vision, has been the object of considerable attention within the scientific community over the last few years.

• Image processing applications are varied and include aspects such as remote measurements, biomedical images analysis, character recognition, virtual reality applications, and enhanced reality in collaborative systems, among others.



Technology



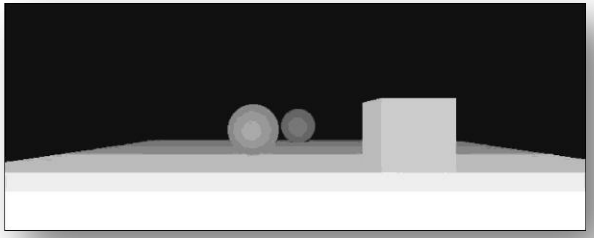
- Two problems in stereoscopy vision:
- The **correspondence problem** attempts to find which two pixels mL(uL,vL) from the left image and mR(uR,vR) from the right image correspond to the same pixel M in three-dimensional space (X,Y,Z).
- Once these pixels have been found, **the reconstruction problem** attempts to find the coordinates for pixel

Technology

• The ultimate goal of reconstruction is to find the coordinates for pixel M (x,y,z) based on the coordinates from the projections for the same point over the images (uL,vL) and (uR,Vr)

$$x = \frac{u_I \cdot B}{d}; y = \frac{v_I \cdot B}{d}; z = \frac{f \cdot B}{d}; d = u_D - u_I$$

•The value d is called the **disparity:** difference between the coordinates u_I and u_D respect the center of your images.
The set of all differences between two images of a stereo pair is called the **disparity map**.



Technology

- Agents
- The use of **agents** is essential in the development of the platform we are proposing.
- The human visual system deals with a high level of specialization when it comes to classifying and processing the visual information that it receives, such as reconstructing an image by texture, shadow, depth, etc. Computationally, it is difficult to compete with such specialization.
- In response to this problem, we propose implementing an algorithm over a distributed **agent-based architecture** that will allow visual information contained in an image to be processed in real time.

Index

- Introduction
  - Motivation
  - Context
  - Technology
- Image Analysis: Phases and Techniques
  - Entry
  - Filtering
  - Processing
  - Representation
- Stereo-MAS
- Results and Conclusions
- Future

Image Analysis: Phases and Techniques

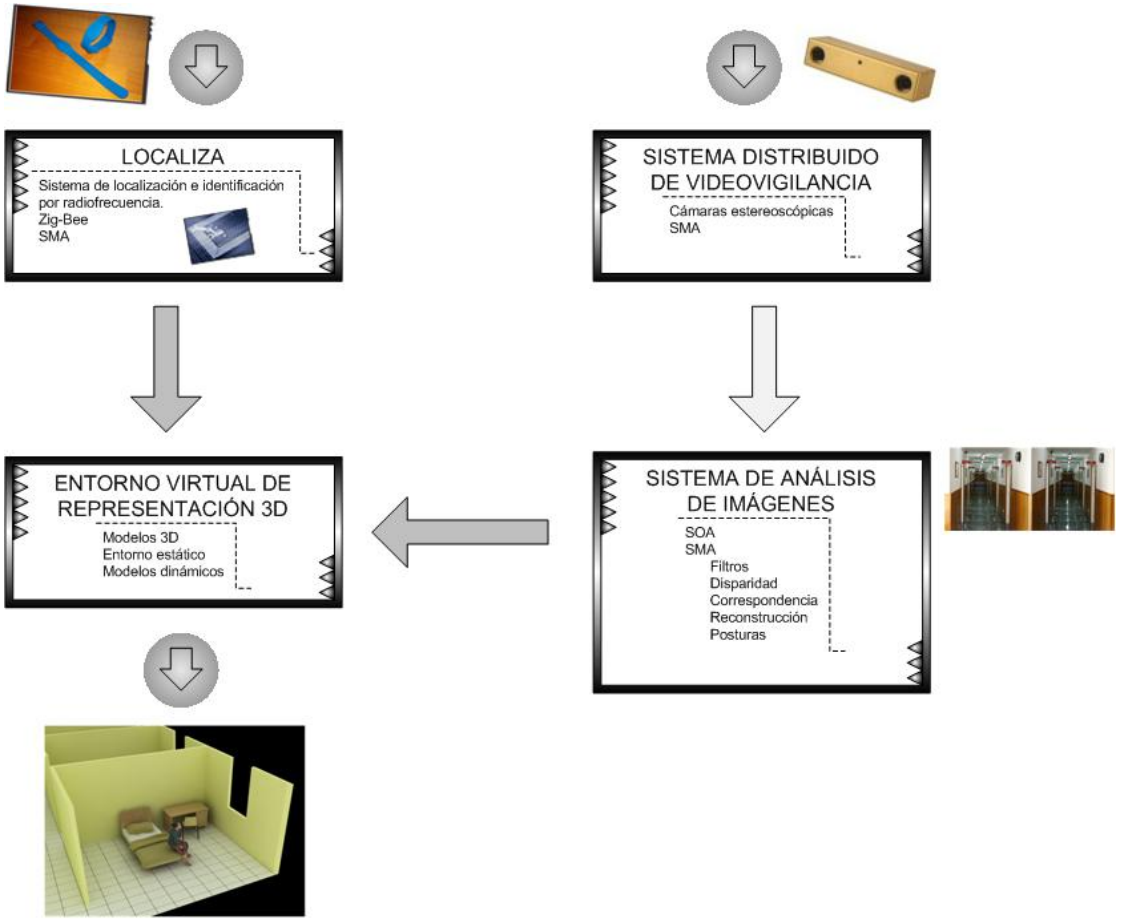


Image analysis: Phases and Techniques

Point Grey Bumblebee2, model BB2-COL-ICX424

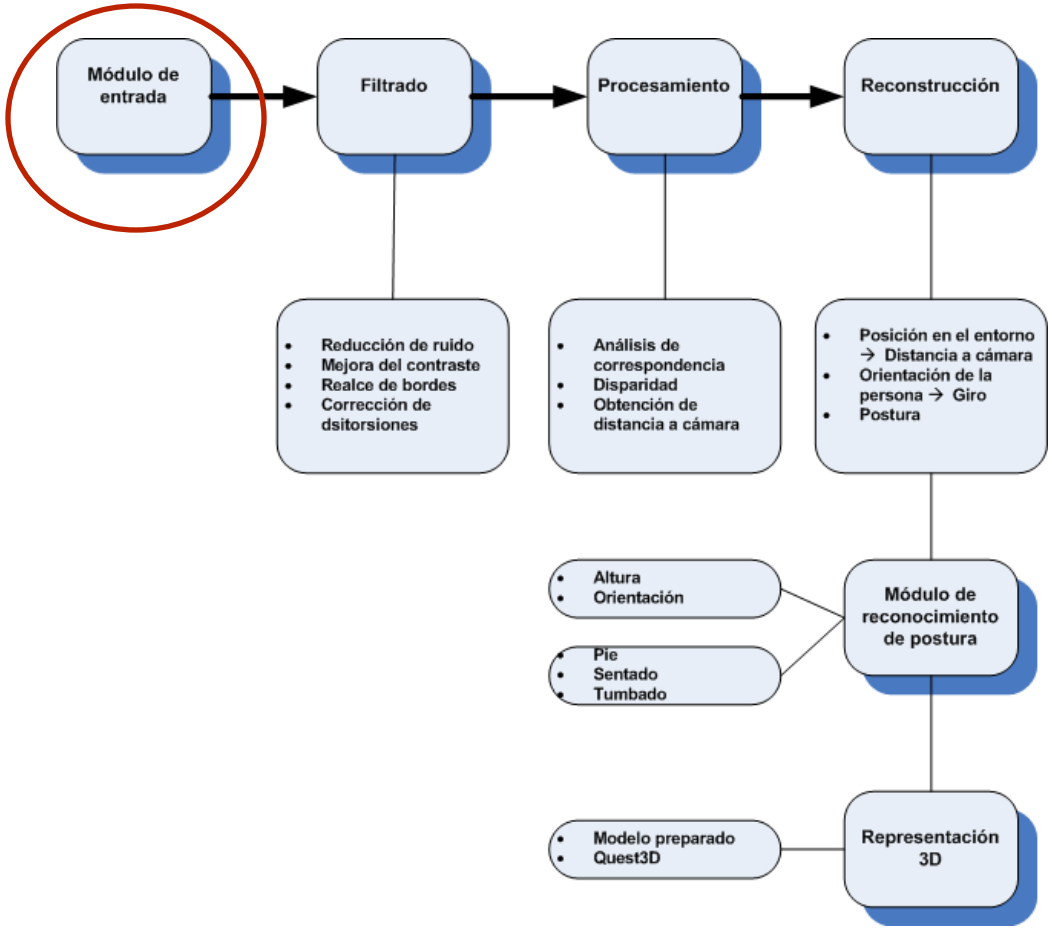


Image analysis: Phases and Techniques

- *Data entry module*
- It captures the images. It defines the number of cameras that will be used, their placement, etc.

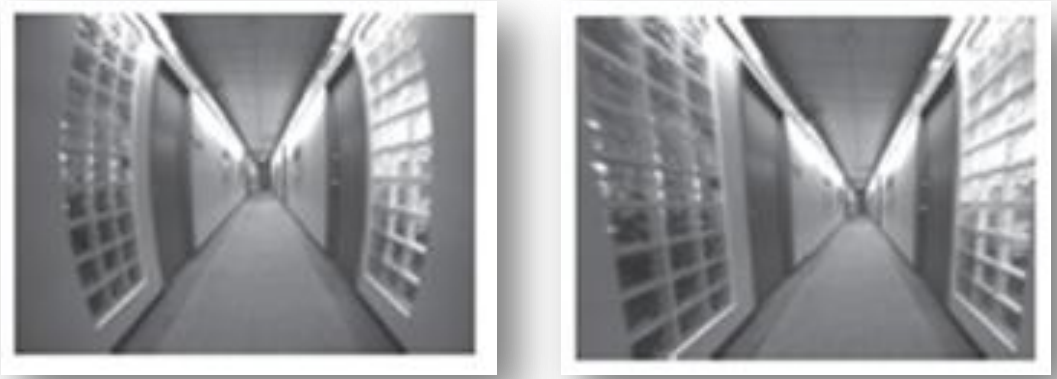


Image Analysis: Phases and Techniques

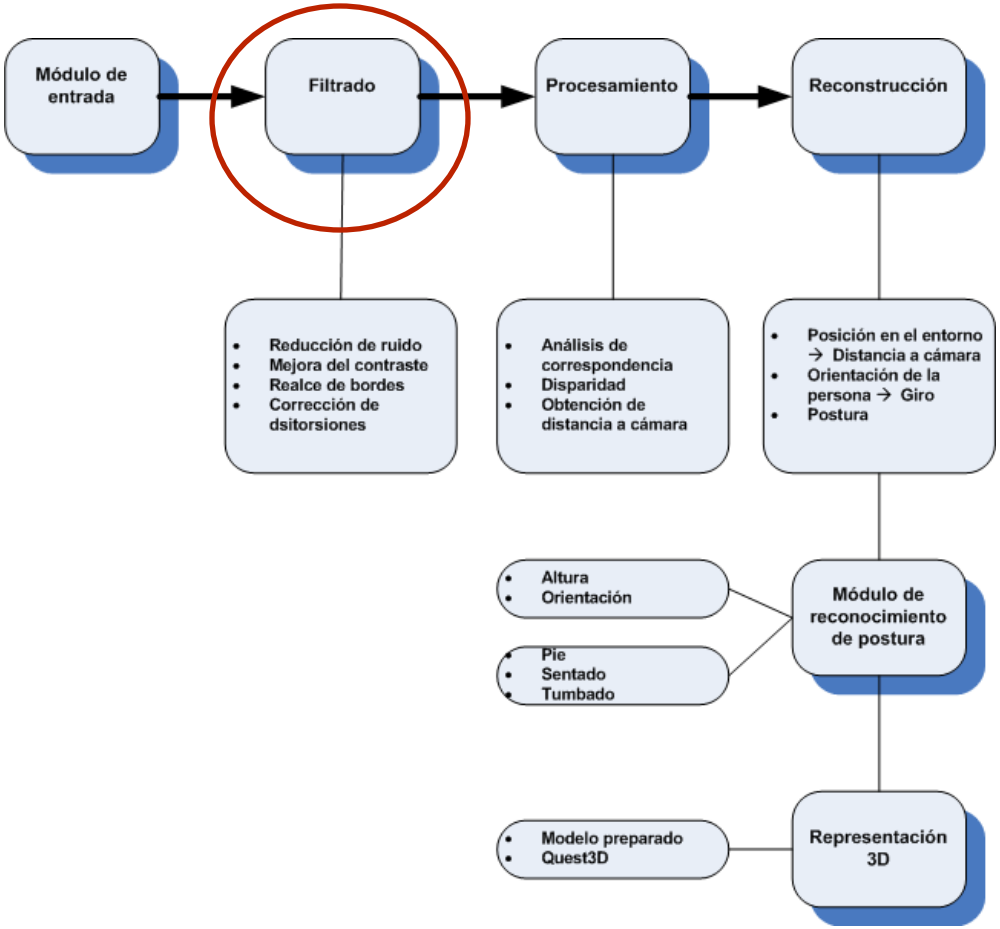
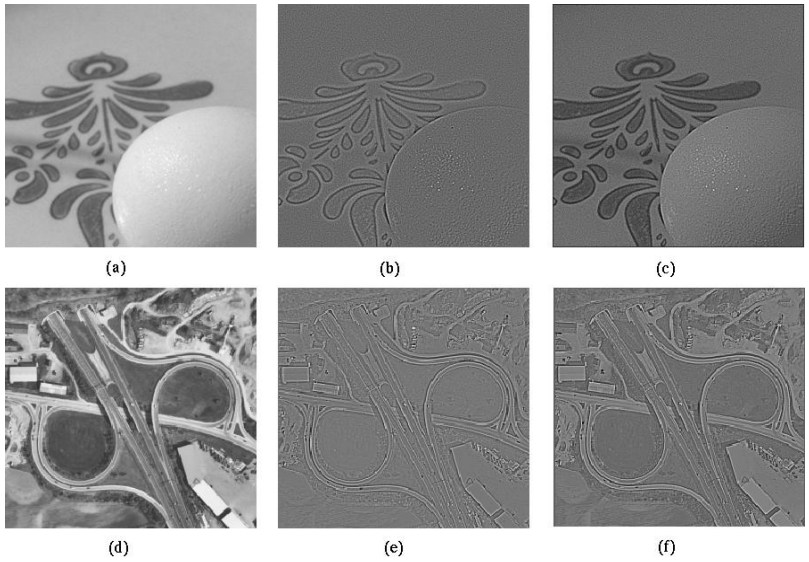


Image Analysis: Phases and Techniques

- *The Filtering Module*
- It reduces noise, improves contrast, sharpens edges or corrects blurriness. Some of these actions can be carried out at hardware level, i.e. with the features included within the camera.



$$g(x,y) = T[f(x,y)] \quad (4.1)$$

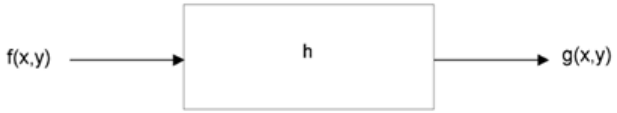


Image Analysis: Phases and Techniques

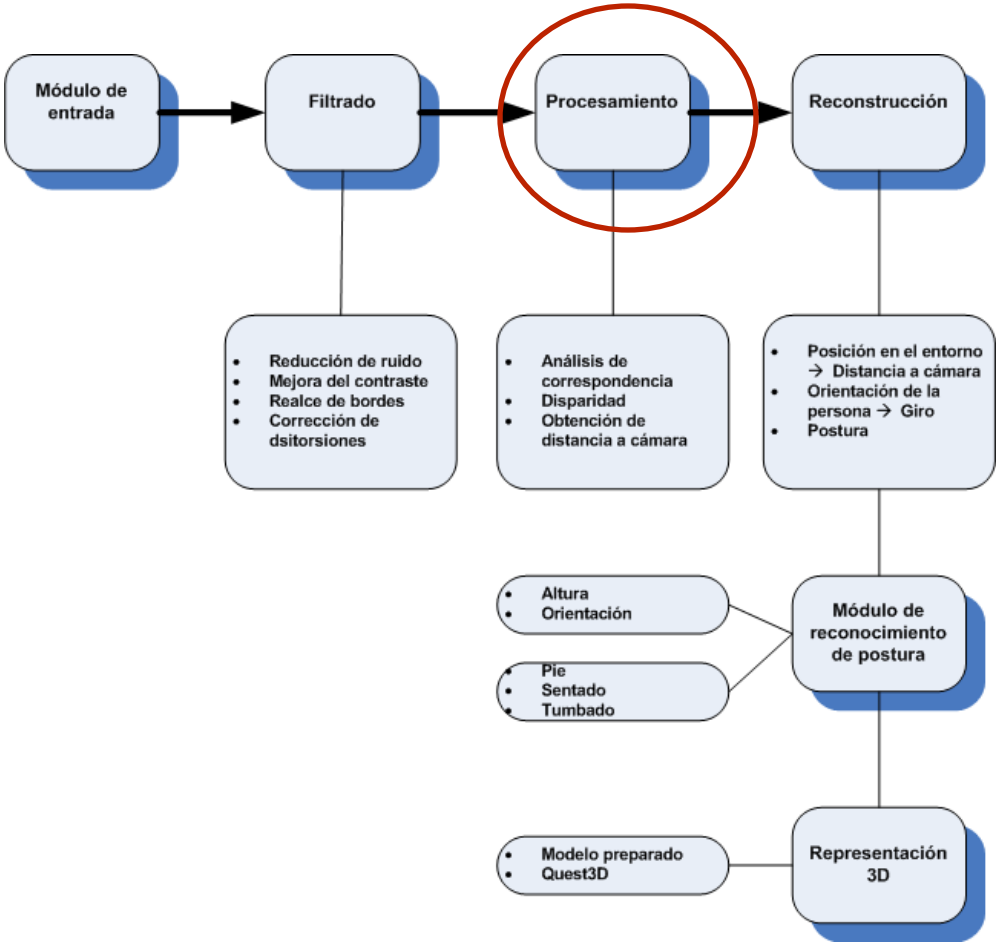


Image Analysis: Phases and Techniques

• *Processing Module*

• It can be considered the heart of the system since it is where the algorithms are applied to **analyze disparities** and the **correspondence of stereoscopic pairs**, and where the distance measurements for the camera are obtained.
• The measurements will prove useful in the next phase for reconstructing the image. For this phase, position recognition and 3D representation modules will model the image with the data that is received.
• We will focus on the processing module.

Image Analysis: Phases and Techniques

- *Processing Module*

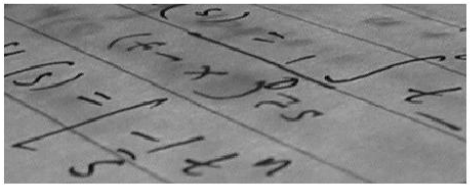
Three steps involved in image reconstruction.

1. Select a specific pixel from the object in one of the images (**preprocessing**).
2. Find the same pixel in the corresponding image (**correspondence analysis**).
3. Measure the relative difference between the two pixels (**disparity analysis and distance obtaining**).

Image Analysis: Phases and Techniques

- *Processing module*
- **Preprocessing**
  - The aim of *preprocessing* is to identify the representative characteristics of each image.
  - A *characteristic* is a relevant piece of information for completing the computational task.

Algoritmo	Borde	Esquina	Blob
Canny [16]	X		
Sobel [96]	X		
Roberts [88]	X		
Prewitt [81]	X		
Marr-Hildreth [65]	X		
Harris & Stephens/Plessey [38]	X	X	
SUSAN [95]	X	X	
Shi & Tomasi [94]		X	
FAST [102]		X	
Laplaciano del Gausiano [12][58][61]		X	X
Diferencia del Gausiano [12][58][61]		X	X
Determinante del Hessiano [12][58][61]		X	X
MSER [12][58][61]			X
Grey-level blobs [12][58][61]			X



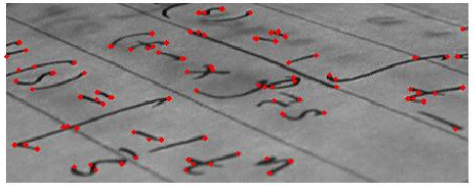
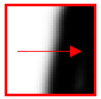
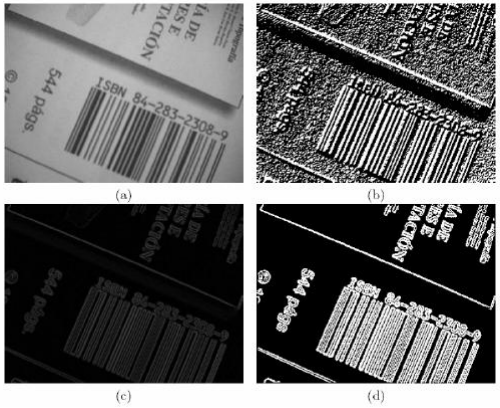


Image Analysis: Phases and Techniques

- *Processing module*
- **Preprocessing**
  - With artificial vision, edge detection is the most commonly used techique.
  - The Canny algorithm is considered one of the best methods for edge detection.



Canny



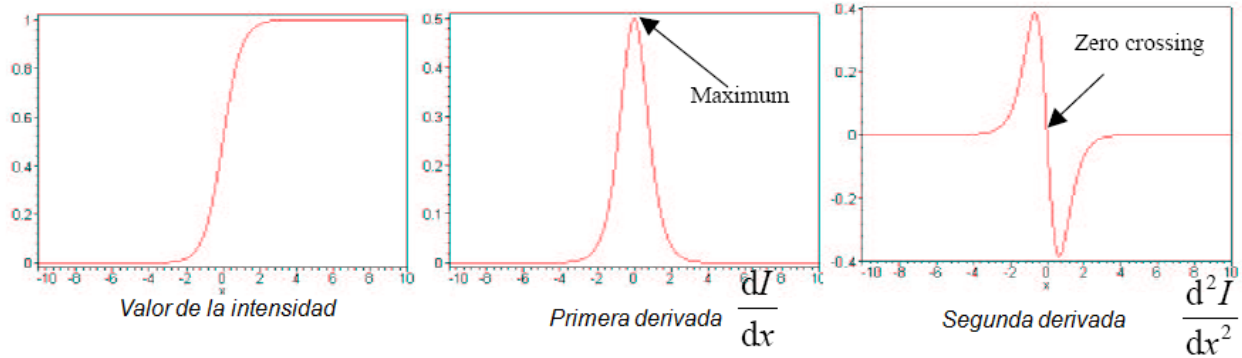


Image Analysis: Phases and Techniques

- *Processing module*
  - Preprocessing
  - **Obtaining Correspondence**
    - Find pairs of points in both images that correspond to the same point of the scene or image in 3D
    - Different ways:
      - *Area-Based Techniques*
      - Feature-based *techniques*

→ **SDA**
PMF

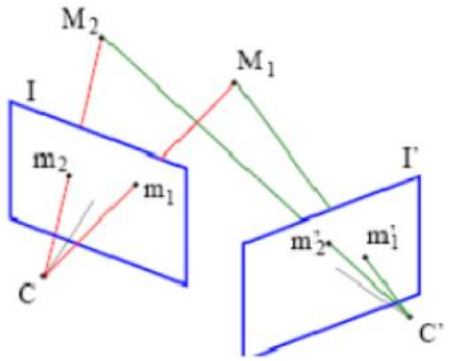


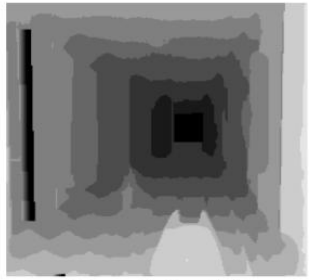
Image Analysis: Phases and Techniques

- *Area based techniques* consider the captured images to be transferred as two-dimensional signal. For each one of the pixels in the image, they try to make a transfer, minimizing certain criteria (correlation).
- One of the most simple techniques is the **Sum of Absolute Differences (SAD)**

$$C(x,y,s) = \sum_{u=-w,v=-w}^{u=w,v=w} |I_l(x+u,y+v) - I_r(x+u+s,y+v)|$$

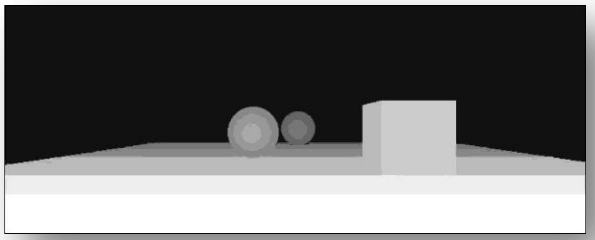
$$d_l(x,y) = arg\,min_s\, C(x,y,s)\ .$$

(a) imagen izquierda



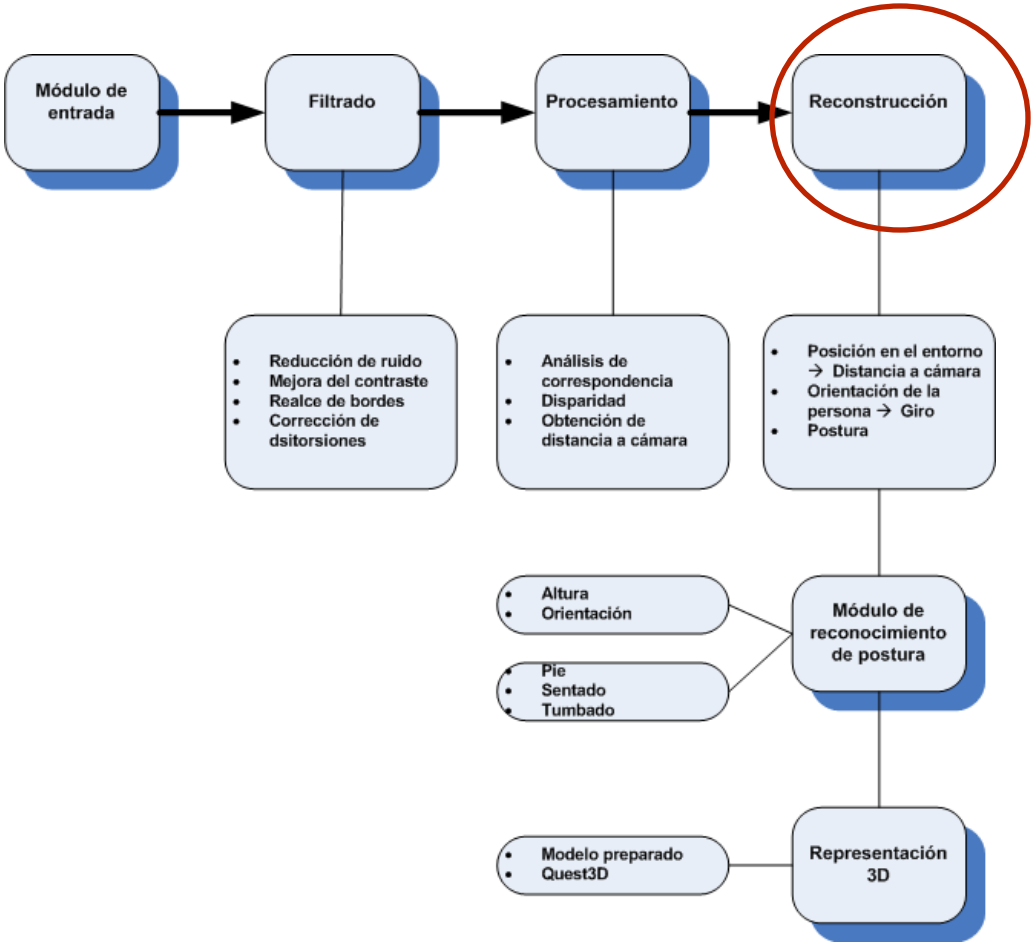
(b) mapa de disparidades

Image Analysis: Phases and Techniques



- *Processing module*
  - Preprocessing
  - Obtaining Correspondence
  - **Disparity analysis** allows us to obtain the depth for each of the pixels in the image, obtaining one single image as the disparity map.
  - Given that there is a direct correlation between the depth of the objects in an image and the disparity with a stereo pair, we can use the information from the disparity map as relative values for the depth of the objects.

Image Analysis: Phases and Techniques



Index

- Introduction
  - Motivation
  - Context
  - Technology
- Image Analysis: Phases and Techniques
  - Entry
  - Filtering
  - Processing
  - Representation
- Stereo-MAS
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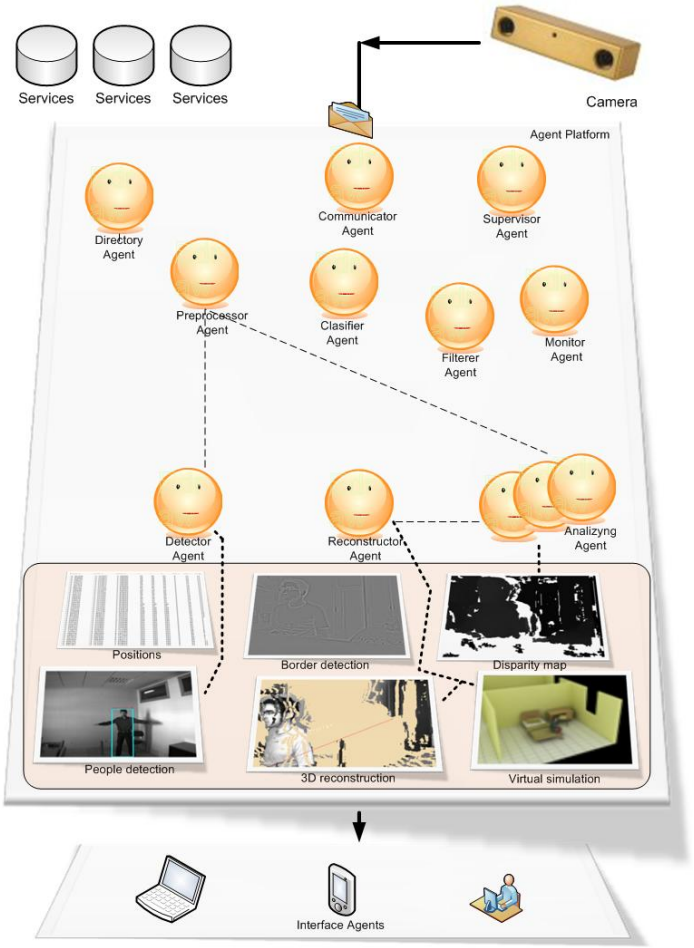
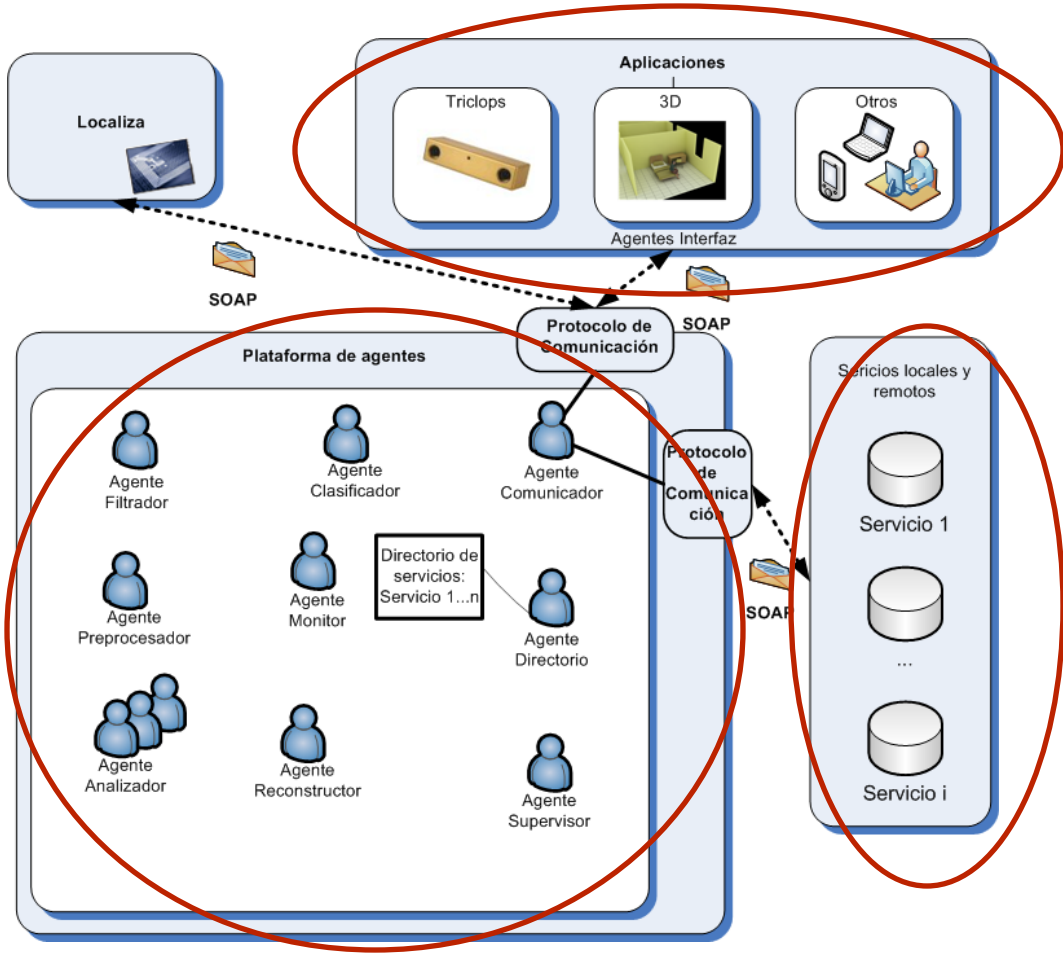
Stereo-MAS

The process of Stereoscopic Vision is implemented over a **distributed agent-based architecture**, which allows it to run tasks in parallel using each service as an independent processing unit.



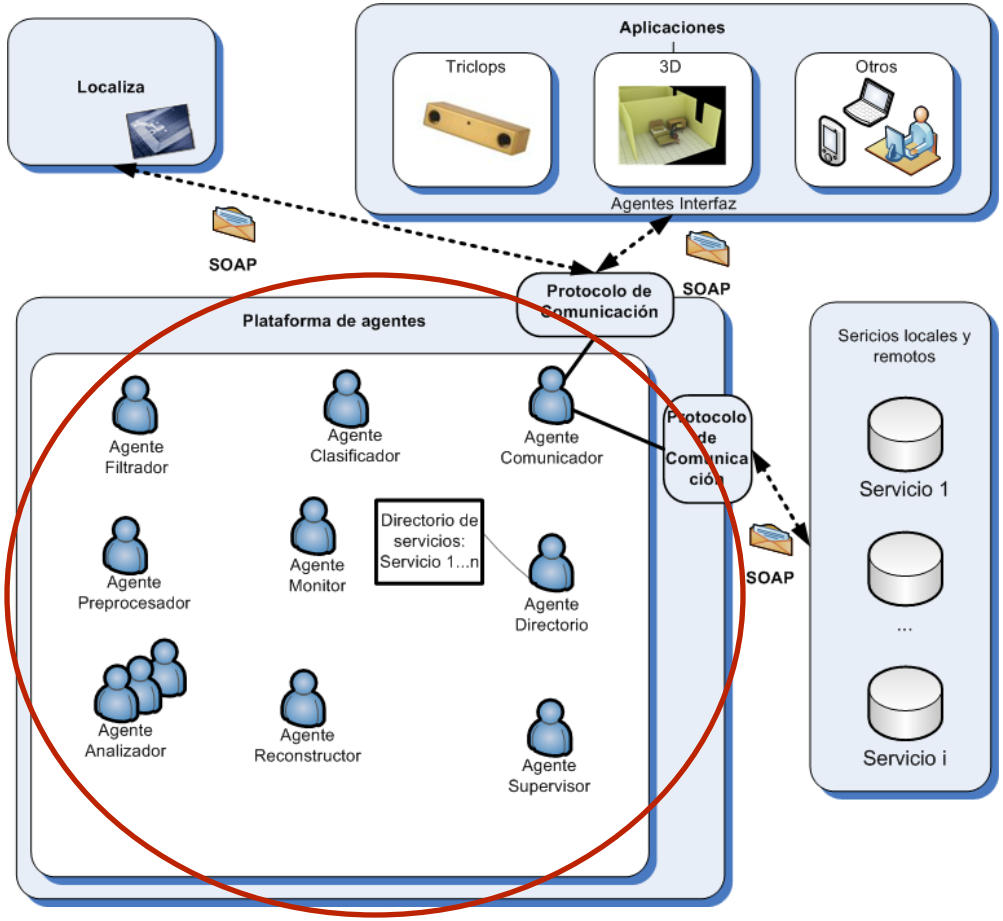
Stereo-MAS

- The **applications** that each of the programs can use for accessing the system functionalities.
- The **services** represent the bulk of the system functionalities at the information processing, submission and retrieval levels.



Stereo-MAS

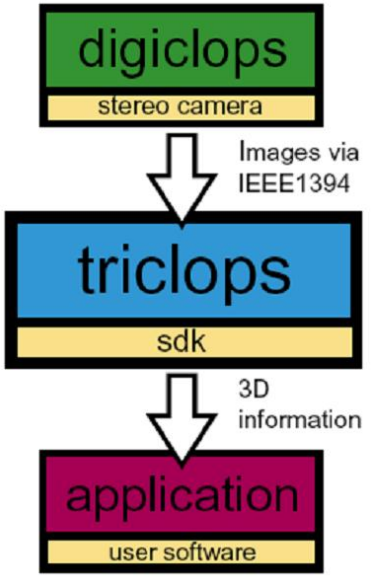
Roles of agents:
Classifier
Filterer
Preprocessor
Monitor
Interface
Analyzer
Reconstructor
Communicator
Supervisor
Directory



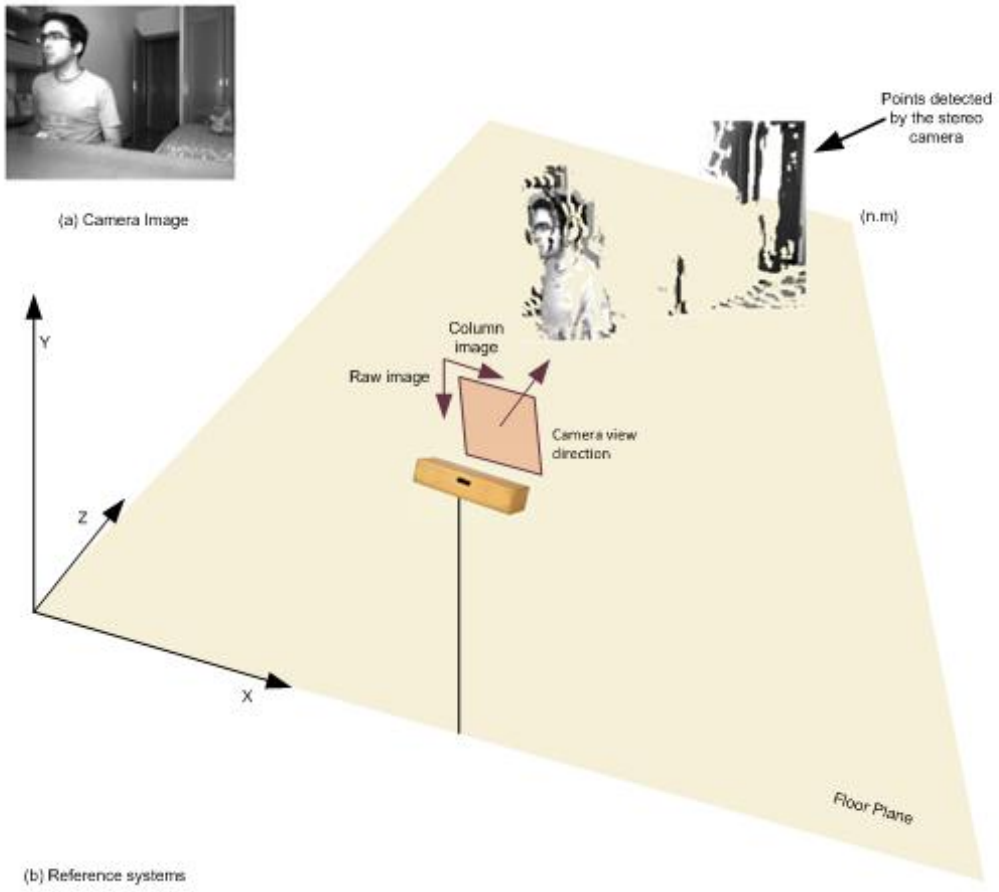
Stereo-MAS

- We have developed a prototype, implementing an analytical component.

Point Grey Bumblebee2, model BB2-COL-ICX424



Stereo-MAS



Three-dimensional reconstruction of the scene.

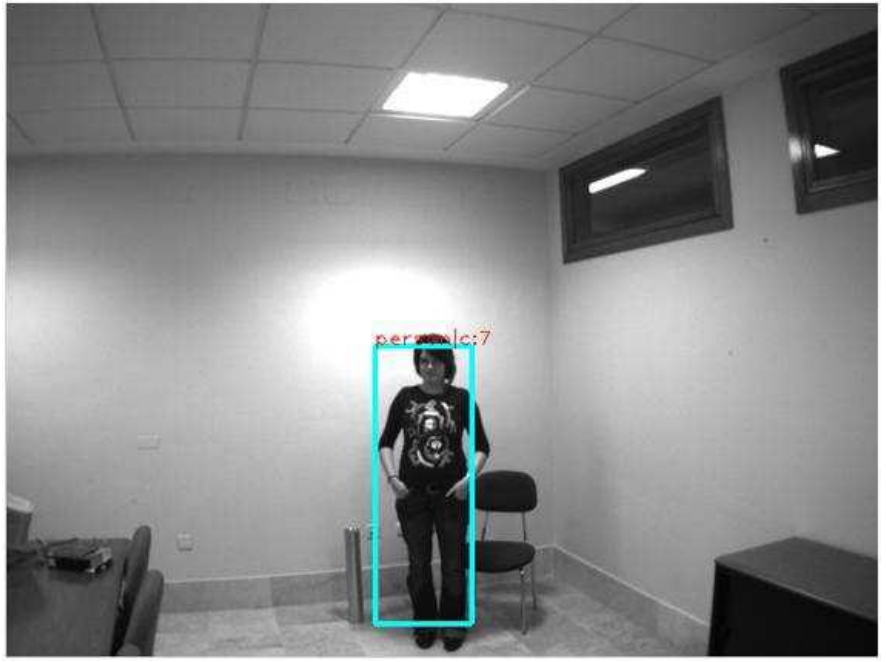
Stereo-MAS

- Image analysis provides a **point cloud** in which each point represents a pixel in the image that indicates the position of the **coordinates XYZ**.
- The starting point of the coordinates used to represent the image is taken from the right-side reference point of the camera.
- The x-axis is horizontal, i.e., the axis that joins the camera's two reference points.
- The y-axis is the vertical axis that follows the camera's orientation.
- The z-axis measures the distance to the camera and is the axis that is perpendicular to the reference point.

Stereo-MAS

- **People detection** and **stereo processing** are treated as separate processes in this study.
- Every time a new image is captured, the system must first apply stereo processing to obtain the distances of the objects in the image. After that, the system can decide to apply people detection to the same image. To achieve this goal, the **HOG** (Histogram of Oriented Gradients) algorithm is used.
- The fundamental idea is that the appearance of objects and the shape of an image can be described by the distribution of gradient intensity or direction.
- The application of these descriptors can be achieved by dividing the image into small connected regions, called cells. A histogram of oriented gradients is compiled for every cell and for the pixels contained within each one.

Stereo-MAS



Stereo-MAS

Results and Conclusions

•The proposed agent-based architecture allows us to automate our analysis and optimize its performance.

•Stereoscopic Vision Algorithms are implemented in the architecture, allowing tasks to be carried out in parallel, using each service as an independent processing unit.

•Finally, we integrate the HOG feature into the multiagent platform in order to detect people

Results and Conclusions

We present a stereo processing system that integrates several capabilities into an effective and efficient multiagent platform: stereo image processing, distance calculation, real time graphical representation of depth, the identification of elements found within the area and human detection.

Thanks!

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Index

- Introduction
  - Motivation
  - Context
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  - Entry
  - Filtering
  - Processing
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Future

- And now….

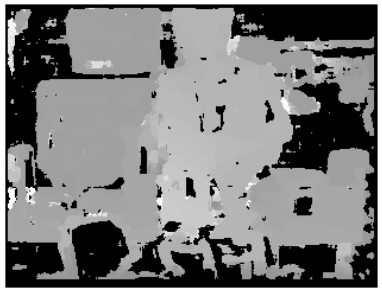
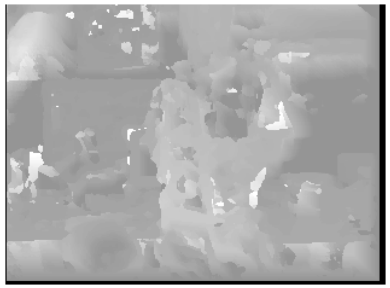
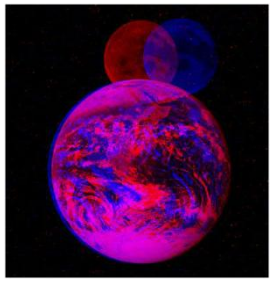
  - Continue to develop the analysis functions, comparing the results, choosing the best techniques and using Point Gray hardware.

  - Continue with the development of the optimization of the correspondence system.

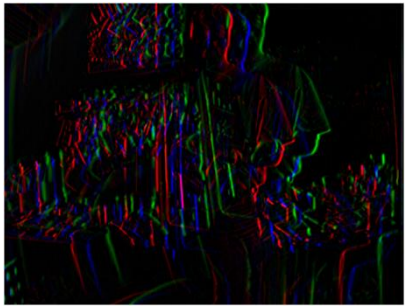
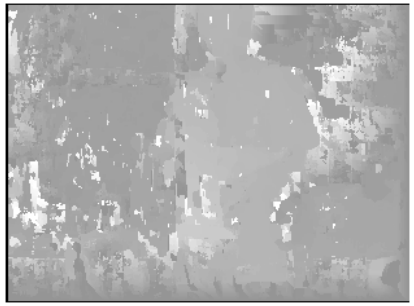
  - Integrate the functions within the distributed architecture proposal.

  - Integrate the modules of the global system (analysis module, filtering module,etc.).

  - Include the system in a bigger architecture that could deal with large and crowded environments



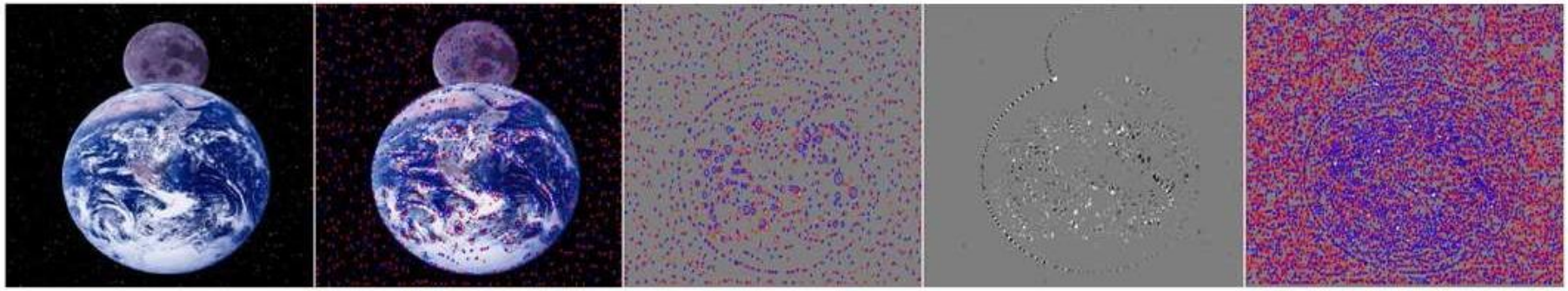
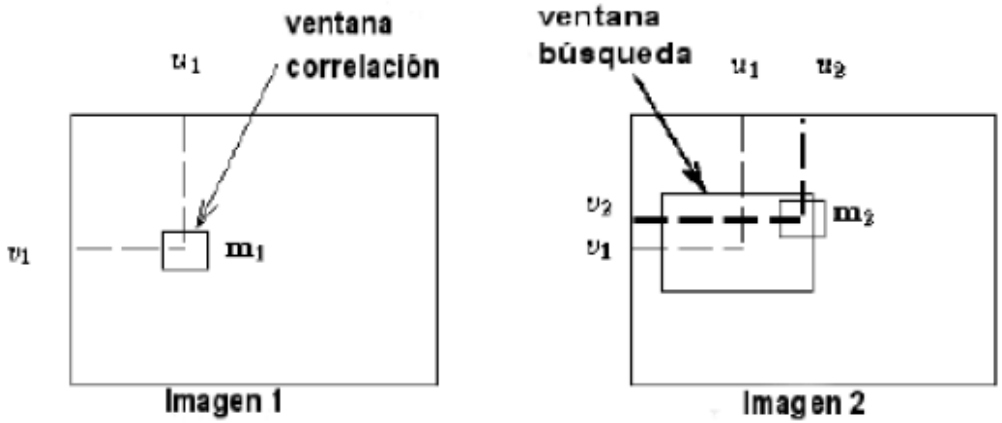
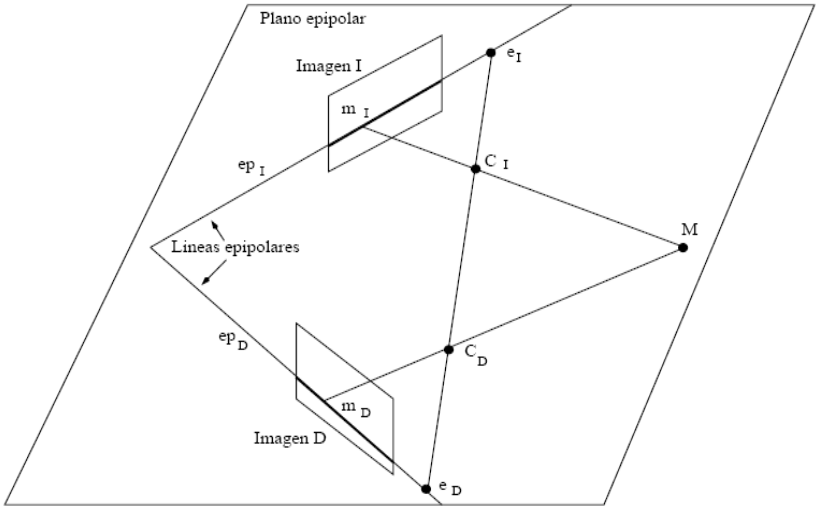


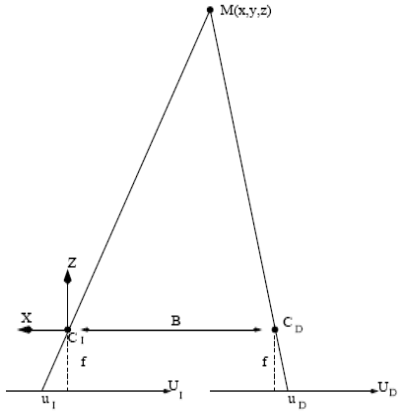
imagen original estéreo derecha, extracción de características por número de líneas n sobre la imagen original, extracción de características por número de líneas n, detección de contorno y extracción de características por número de líneas m > n

- En la siguiente figura se muestra cómo se definen las ventanas de correlación y búsqueda, y las distintas posiciones de correlación que se calculan.



Primeros pasos: estudio de la tecnología





- **plano epipolar** *(C_I MC_D)*
  - *centros ópticos C_I y C_D de los objetivos de las cámaras con cualquier punto M*
- **líneas epipolares** *(ep_I y ep_D)*
  - *Corte del plano con I y D*
- **epipolos** *e_I y e_D*
  - *proyección del centro óptico de cada cámara sobre la otra cámara*
- **configuración de cámaras paralelas**
  - *líneas epipolares serán todas paralelas entre sí*

Primeros pasos: estudio de la tecnología

- La forma en que interactúan los agentes entre sí para alcanzar un objetivo, viene dada por la **arquitectura de agente** (deliberativas, reactivas, híbridas).

- Arquitectura deliberativa BDI (*Belief, Desire, Intention*)
  - *la estructura interna de los agentes y sus capacidades de elección se basan en aptitudes mentales, como son creencias, deseos, e intenciones .*

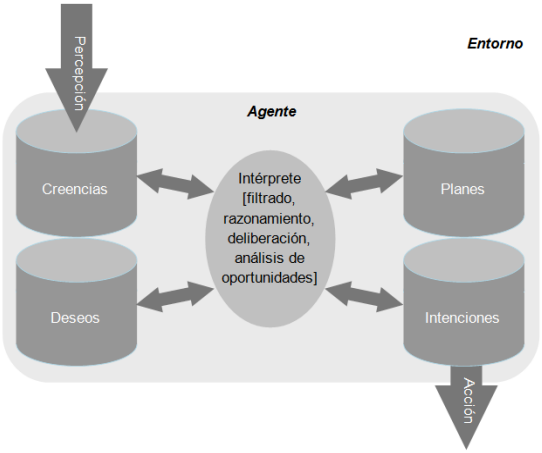
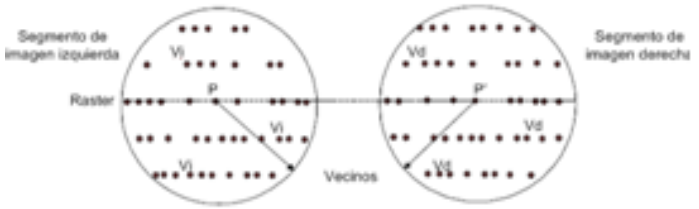


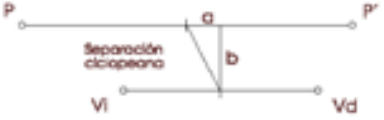
Image analysis: Phases and Techniques

•The *techniques based on features* obtain high quality primitives (edge, segments, curves, regions, etc.) that store a set of properties that remain unchanged with the projection.

The PMF theory**Pollard-Mayhew-Frishby (PMF)** assumes two fundamental restrictions:

1. The features contained in line "n" from the left image should likewise appear (allowing for certain disparity) in line "n" from the right image, thus the correspondence process would be carried out only between those features that are located on the same line in both images.
2. The second restriction is given by the gradient disparity (GD) concept.





Disparidad (DP) = P - P', Disparidad (DV) = Vi - Vd
Diferencia de Disparidad (DD)= DP - DV
a = (Dp/2) - (Pv/2), b = Separación entre *rasters*
Separación ciclopeana (SC) = $(a^2+b^2)^{1/2}$ DG = DD/SC <= 1