Taha Ridene

Dr. Taha RIDENE

Behavioral Interaction Server in VR : "Multi-Sensors Module for a Cave"

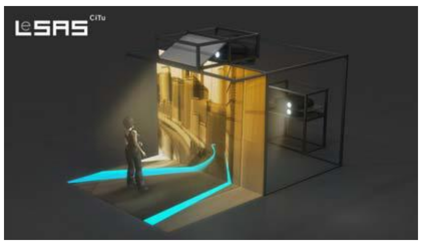
July 2016

Outline

1. Global Context
2. Interaction Server : VR-SIX
3. Multi-Kinect Module For VR-SIX
   1. Material Configuration – Kinect
   2. Geometric dispatching
   3. Fusion Rules
4. Conclusion
5. References

I. Global Context : Domain

Virtual Reality and Augmented Reality Domain



« The SAS : an immersive room with a screen wall and a screen floor »

« Example of using of the SAS: Permis Pieton »

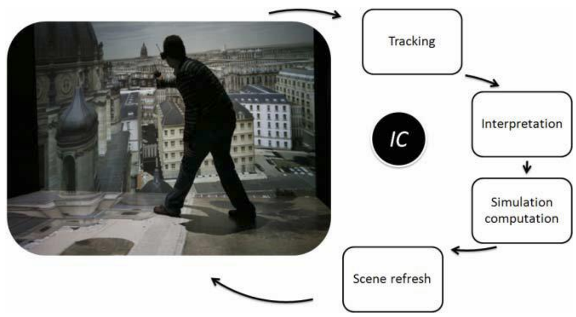
I. Global Context :

main goal :

Proposing a **low cost**, **feasible** and **accurately** system **Tracking** for **user position** and **orientation** inside the **SAS**

1. **How to build this system ?**
2. **Which sensors for this system ?**
3. **Why we need Interaction Server ?**

I. Global Context : Interaction Server ?



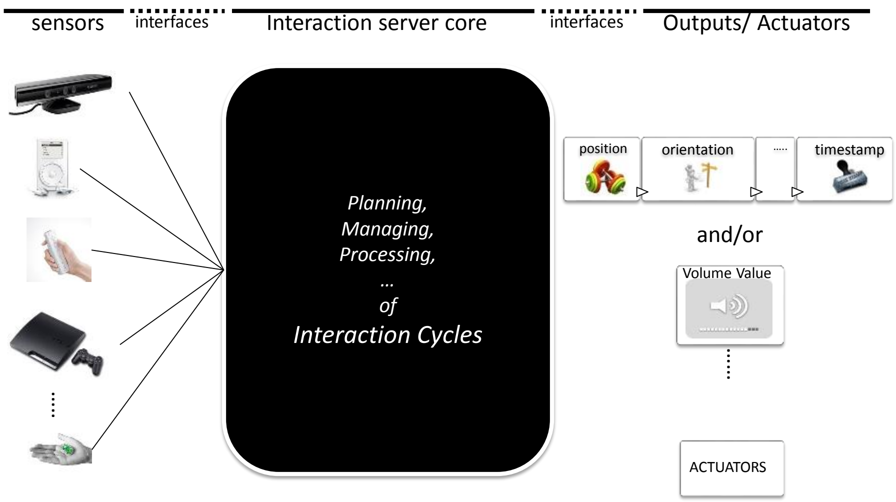
Interaction Cycle (*source – [ridene, Leroy, Chendeb; VR-SIX]*)

To process and to synchronize interaction Cycle(s) :
We need a dedicated platform : « software –drivers- codes » :
Interaction Server

Outline

1. Global Context
2. <u>Interaction Server : VR-SIX</u>
3. Multi-Kinect Module For VR-SIX
   1. Material Configuration – Kinect
   2. Geometric dispatching
   3. Fusion Rules
4. Conclusion
5. References

II. Interaction Server: VR-SIX



Global architecture of VR-SIX. (left) example of some sensors used for interaction in virtual reality application. (middle) the core of the interaction server VR-SIX. (right) example of the output after IC processing. (source - ***[ridene, Leroy, Chendeb; VR-SIX]***)

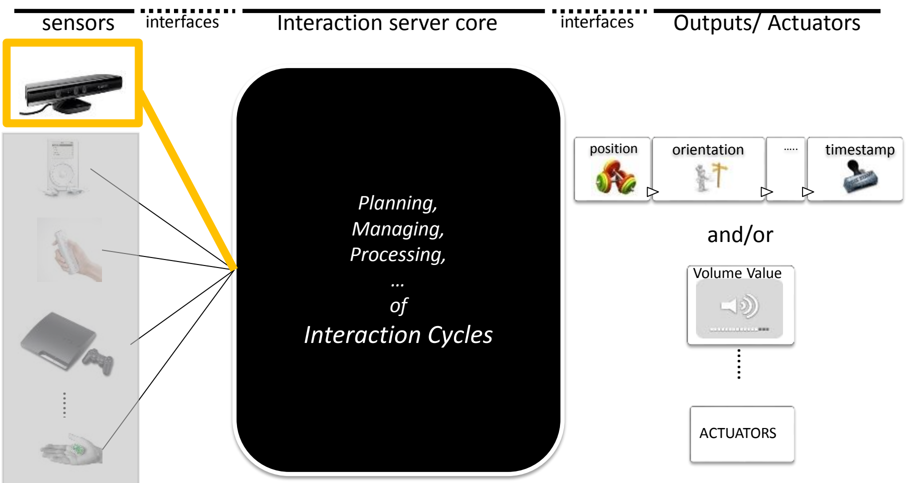
II. Interaction Server: VR-SIX

Thesis main goal :

Proposing a **low cost**, **feasible** and **accurately** system for track **user position** and **orientation tracking** inside the **SAS**

1. **How to build this system ?**
2. **Which sensors for this system ?**
3. **Why we need Interaction Server ?**

II. Interaction Server: Multi-Kinects Module



Process an Interaction Cycle Using Multi-Kinects Module in VR-SIX platform

- **Cheaper compare to ARTrack**
- **Need for more than 1 Kinect to cover the SAS**
- **This system can be used in other platform than the SAS**

II. Interaction Server: Multi-Kinects Module

Thesis main goal :

Proposing a **low cost**, **feasible** and **accurately** system for **user position** and **orientation tracking** inside the **SAS**

1. **How to build this system ?**
2. **Which sensors for this system ?**
3. **Why we need Interaction Server ?**

Outline

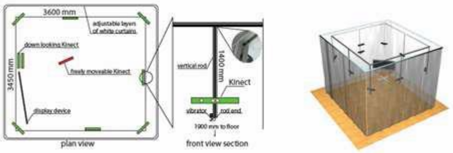
1. Global Context
2. Interaction Server : VR-SIX
3. Multi-Kinect Module
    1. Material Configuration – Kinect
    2. Geometric dispatching
    3. Fusion Rules
4. Conclusion
5. References

III. Multi-Kinect Module: Material Configuration

« In collaboration T.Ridene & J.S.Newton »

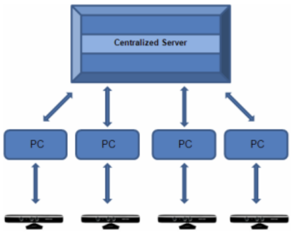
Existent Configuration of Platforms

(Config 1)



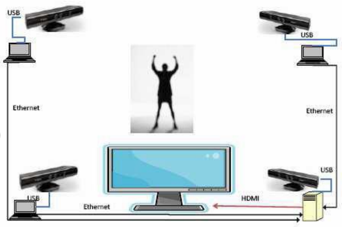
(Kainz and al, 2012)

(Config 2)



(Satta and al, 2013)

(Config 3)



(Brian and al, 2012)

III. Multi-Kinect Module: Material Configuration

« In collaboration T.Ridene & J.S.Newton »

Existent Configuration of Platforms : comparison

	Multi-Kinect / Single PC (config 1)	Multi-Kinect / Multi PC / Server (config 2)	Multi-Kinect / Multi PC / PC + Server (config 3)
Cost	The cost of a single high-specs computer and the Kinects	Depends on the number of Kinects and the computer specs	Depends on the number of Kinects and the computer specs
Convenience	Convenient, as there is no network to manage	Setting-up the network and the Kinects can be a bit inconvenient	Setting-up the network and the Kinects can be a bit inconvenient
Hardware requirements	A single powerful computer and USB 2.0 Hub Controllers	A server, network cables, as well as laptops or microcomputers for each Kinect	A server, network cables, as well as laptops or microcomputers for each Kinect minus one
Advantages	-Everything is already centralized on a single computer. -No need to create a network	-This solution is scalable and adapts itself to the number of Kinects used -Aside from the server, most machines are not costly	- This solution is scalable and adapts itself to the number of Kinects used - Aside from the server, most machines are not costly
Drawbacks	-The computer has to do a lot of processing -A single computer may not be enough for a very high number of Kinects, even with additional USB Controllers	-The network has to be reliable and fast to avoid de-syncs	- The network has to be reliable and fast to avoid de-syncs -The Kinect connected to the PC-server might have a speed advantage over the other Kinects when sending data.

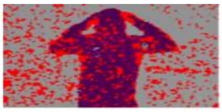
13

III. Multi-Kinect Module: Material Configuration

« In collaboration T.Ridene & J.S.Newton »

Kinect's main problem and solutions

Interferences between kinects



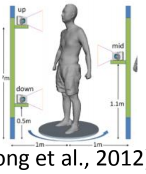
(Butler et al., 2012)

Vibrations

(Maimone & Fuchs, 2012)

Time multiplexing

(Scholz et al., 2011)



(Tong et al., 2012)

14

III. Multi-Kinect Module: Geometric Dispatching

Kinect's Xbox Depth Sensor FOV & SAS caracteristics

-Horizontal FOV : 57 degrees
-Vertical FOV : 43 degrees
-Tilt angle : from -27 degrees to 27 degrees
-Range : from 1.2 to 3.5 meters

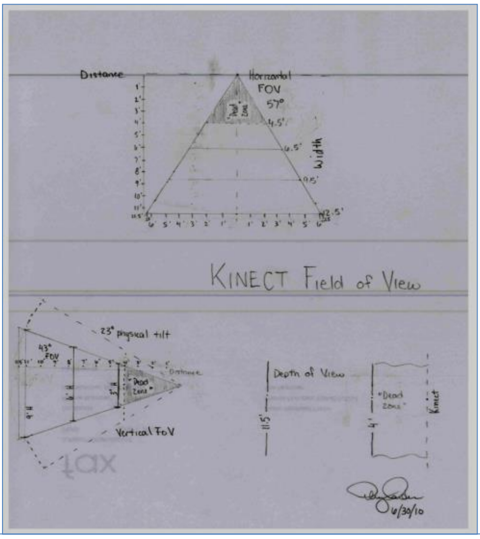


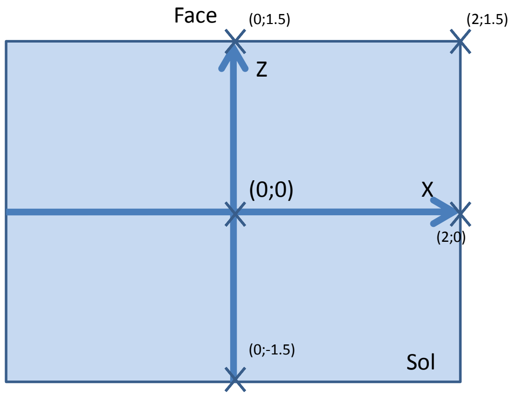
Diagram showing the Kinect Xbox FOV by Mr. Riley Porter

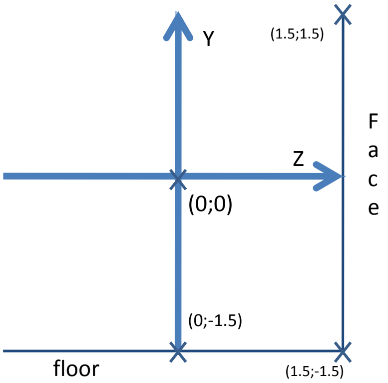
« In collaboration T.Ridene & J.S.Newton »

III. Multi-Kinect Module: Geometric Dispatching

Kinect's Xbox Depth Sensor FOV & SAS caracteristics

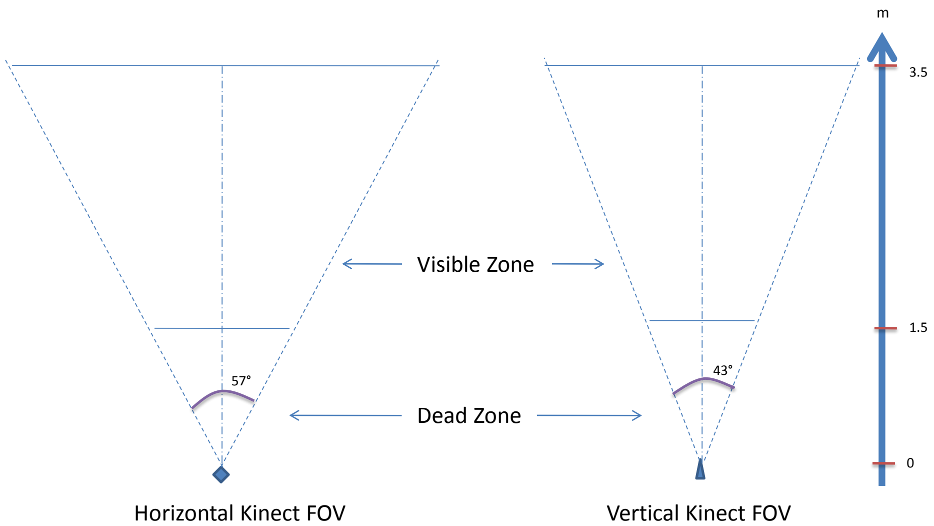
-Horizontal FOV : 57 degrees
-Vertical FOV : 43 degrees
-Tilt angle : from -27 degrees to 27 degrees
-Range : from 1.2 to 3.5 meters
-The floor screen is 3*4m and the wall is 4*3m





III. Multi- Kinect Module: Geometric Dispatching

Graphic representation of the Kinect FOV



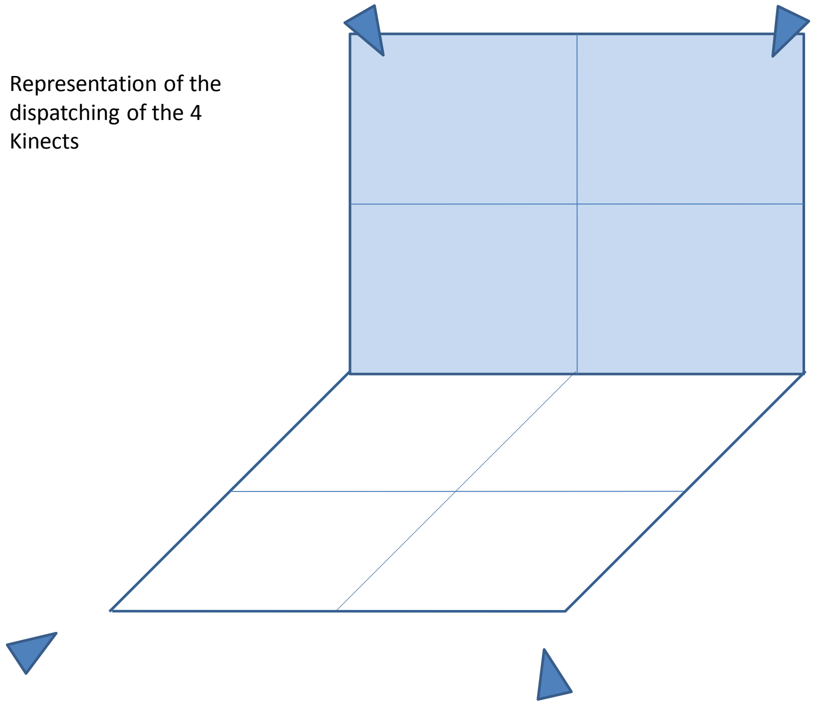
17

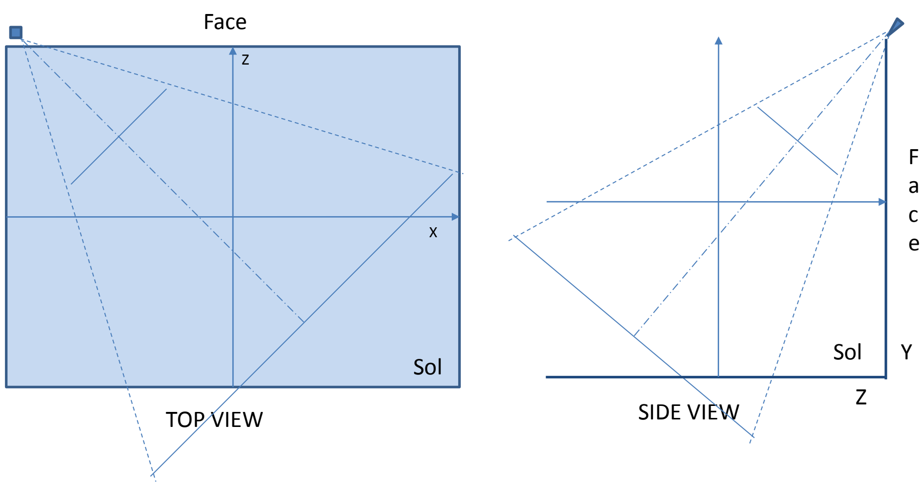
III. Multi- Kinect Module: Geometric Dispatching

Kinect Dispatching and FOV Inside the SAS

18

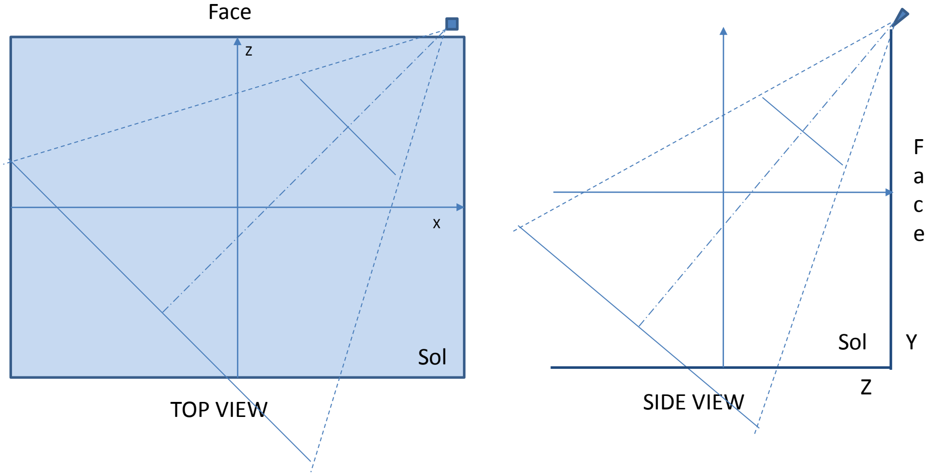
Representation of the dispatching of the 4 Kinects





TOP-LEFT KINECT

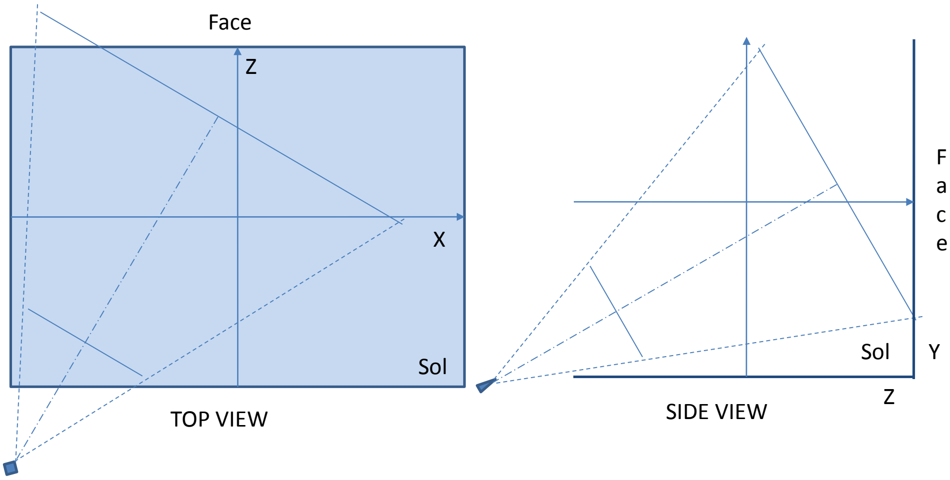
NB : The orientation of the Kinect sensor should be taken into account with high accuracy



TOP-RIGHT KINECT

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

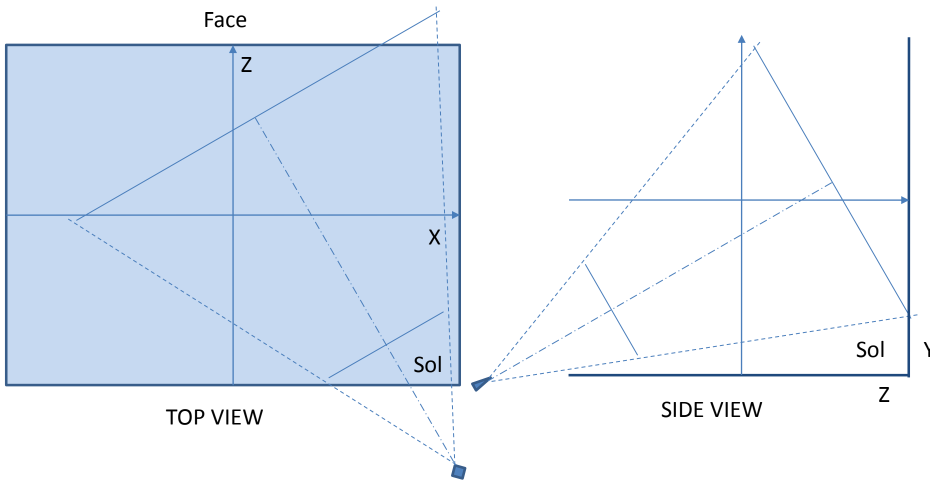
21



BOTTOM-LEFT KINECT

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

22



BOTTOM-RIGHT KINECT

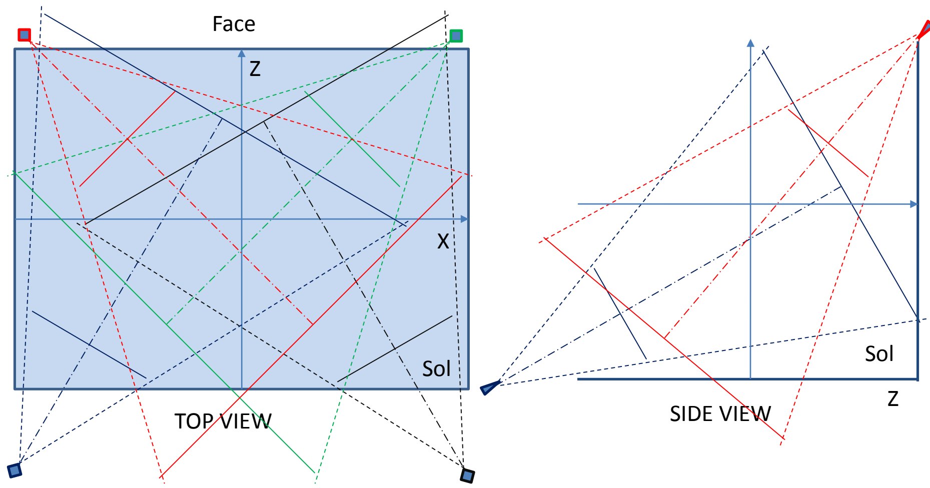
NB : The orientation of the Kinect sensor should be taken into account with high accuracy

23

III. Multi- Kinect Module: Geometric Dispatching

Overlapping between Kinects' FOV – Inside the SAS

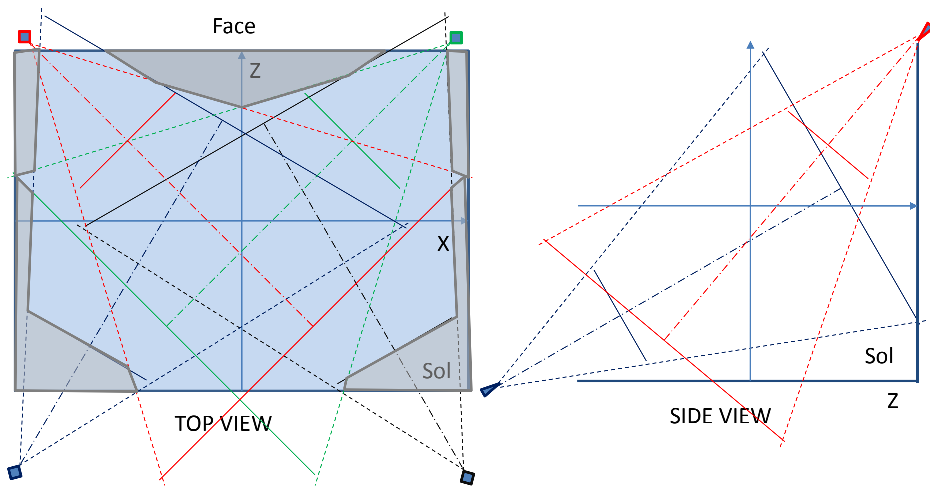
24



ALL KINECTS

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

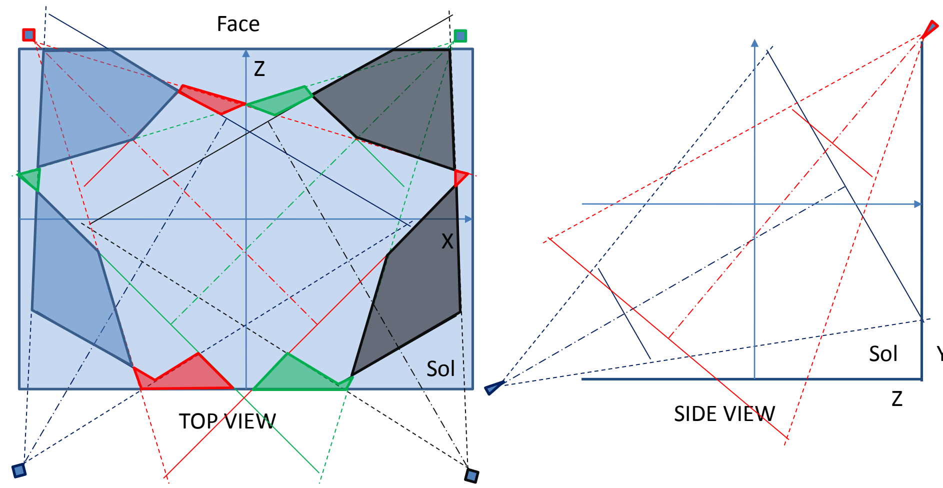
25



Areas not covered by any Kinect

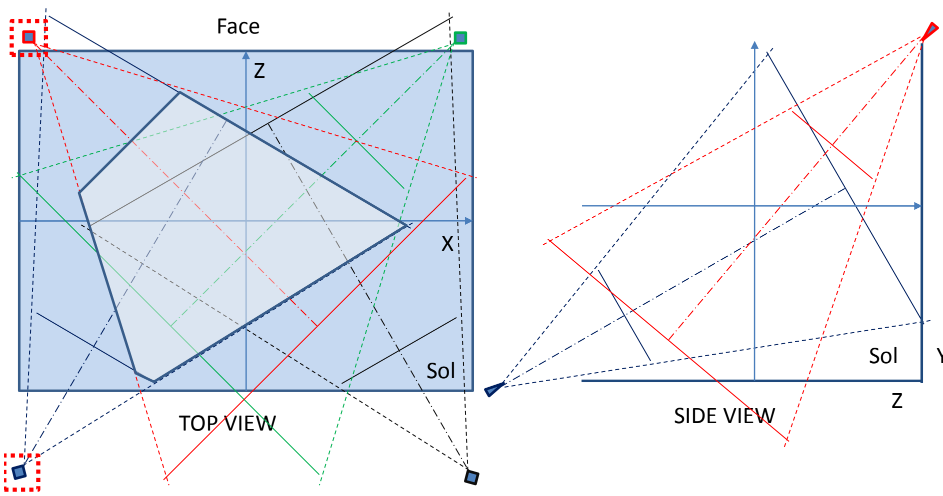
NB : The orientation of the Kinect sensor should be taken into account with high accuracy

26



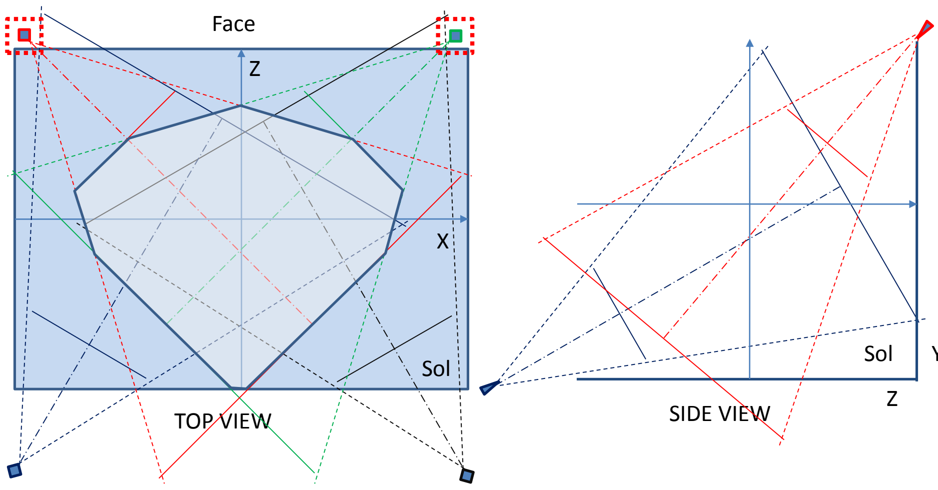
Areas covered by a single Kinect only

NB : The orientation of the Kinect sensor should be taken into account with high accuracy



Area covered by Red and Blue Kinect

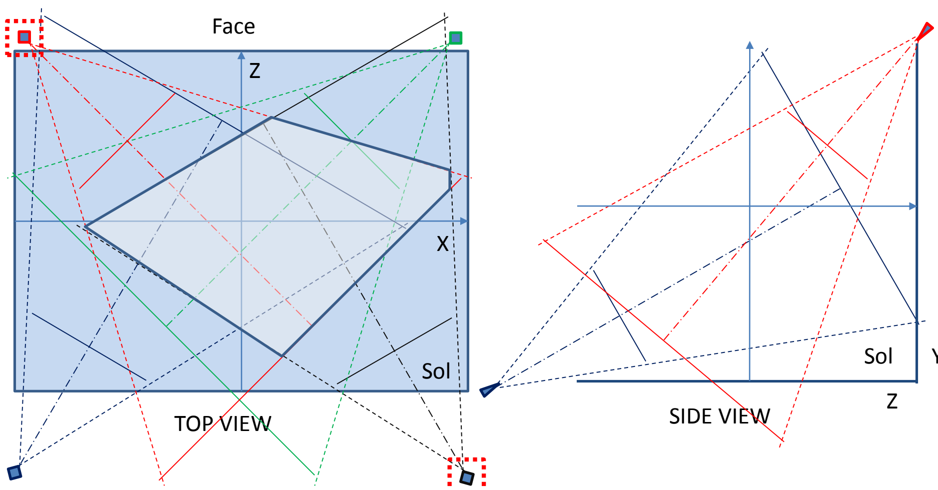
NB : The orientation of the Kinect sensor should be taken into account with high accuracy



Area covered by Red and Green Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

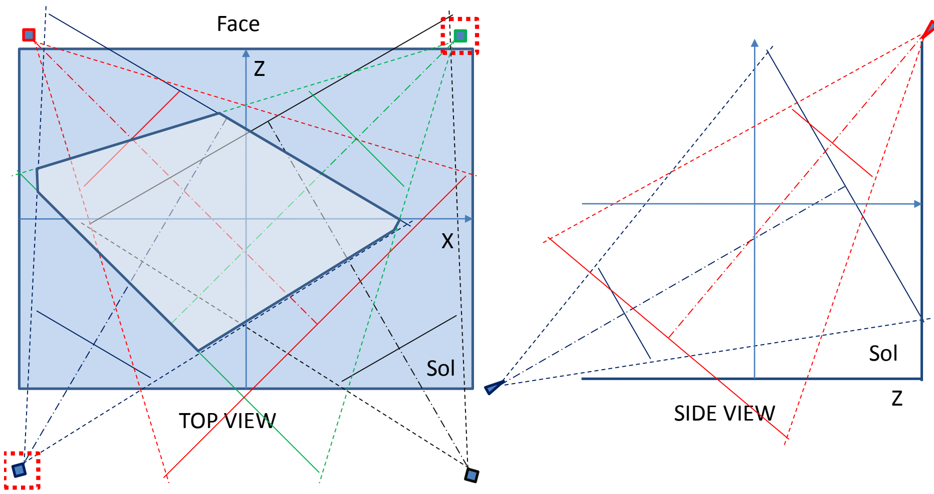
29



Area covered by Red and Black Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

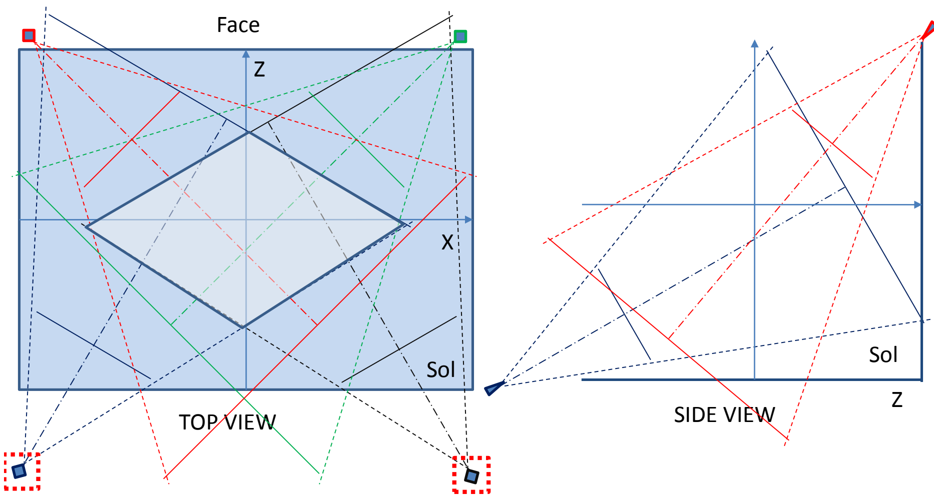
30



Area covered by Green and Blue Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

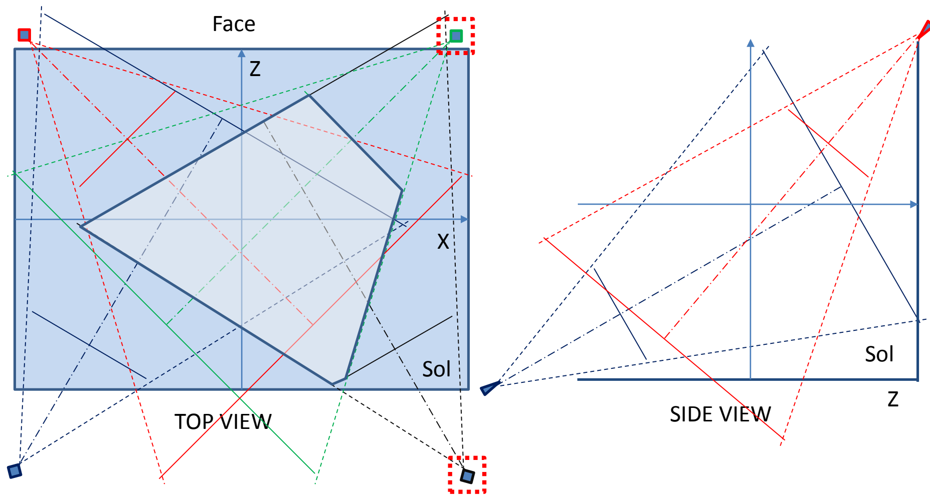
31



Area covered by Black and Blue Kinect

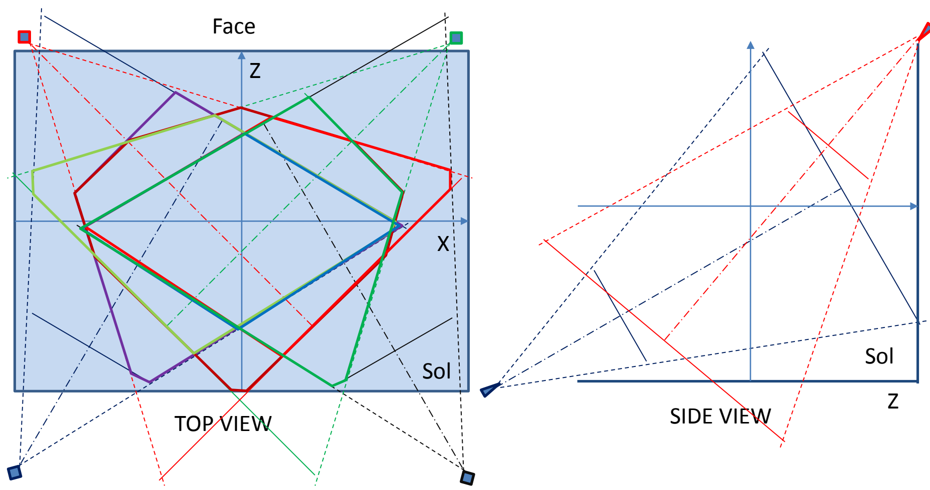
NB : The orientation of the Kinect sensor should be taken into account with high accuracy

32



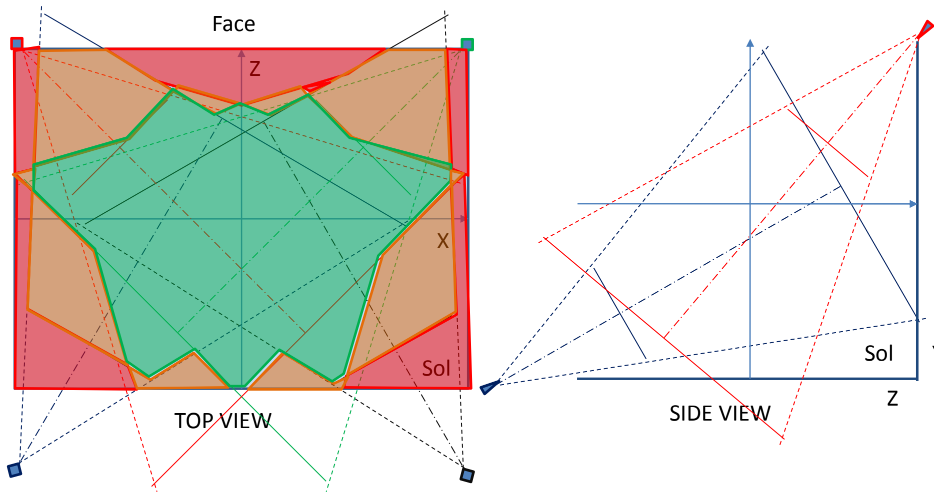
Area covered by Green and Black Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy



All covered areas

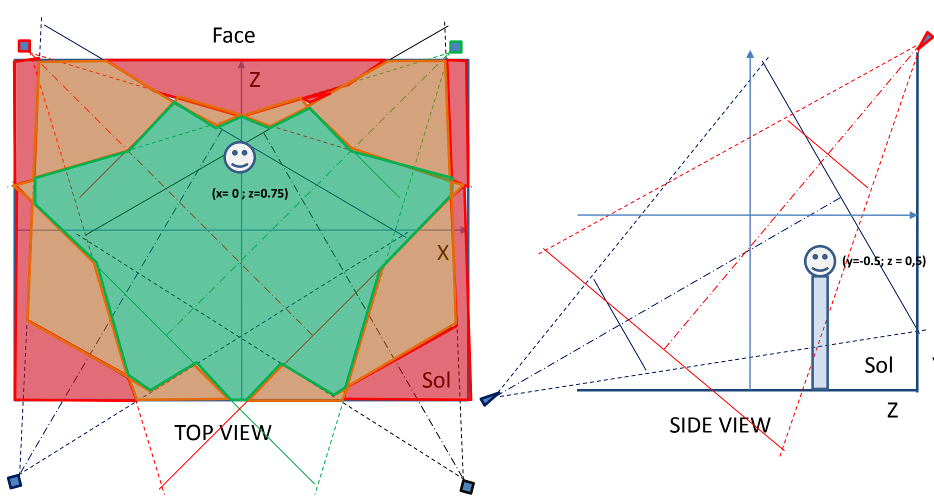
NB : The orientation of the Kinect sensor should be taken into account with high accuracy



Area classification based on Kinect fusion coverage area :
-Red: Area not covered
-Orange : Middle coverage(1 Kinect)
-Green: Excellent coverage (2+ Kinects)

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

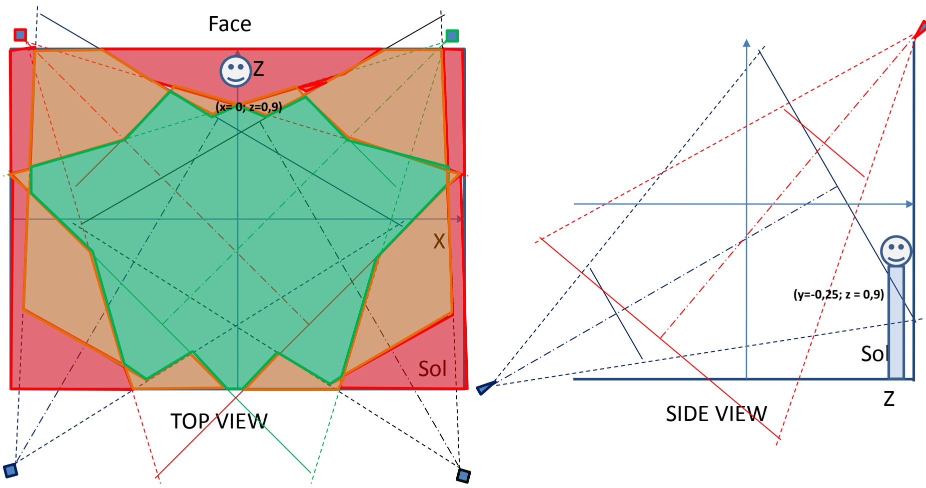
35



TRACKING SUCCESSFUL

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

36



TRACKING
FAILED

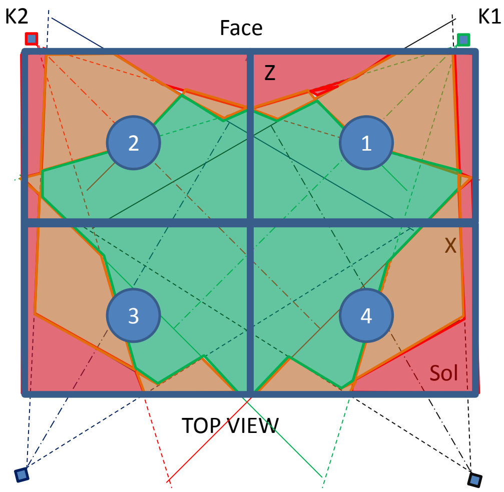
NB : The orientation of the Kinect sensor should be taken into account with high accuracy

37

III. Multi- Kinect Module: Geometric Dispatching

Multi-Kinect – Fusion – Rules based on Overlapping Inside the SAS

38



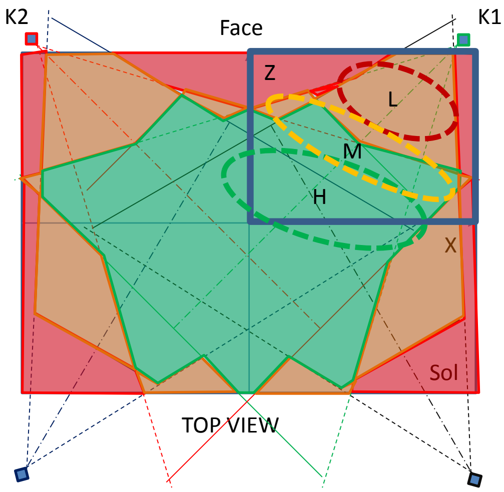
• Definition of 4 rectangle-shaped areas within the « SAS » for the fusion rules

1 : Upper Right   2 : Upper Left

3 : Lower Left   4 : Lower Right

• The 4 Kinects are also given a number ID, from K1 to K4

NB : The orientation of the Kinect sensor should be taken into account with high accuracy



Fusion rules – Area 1

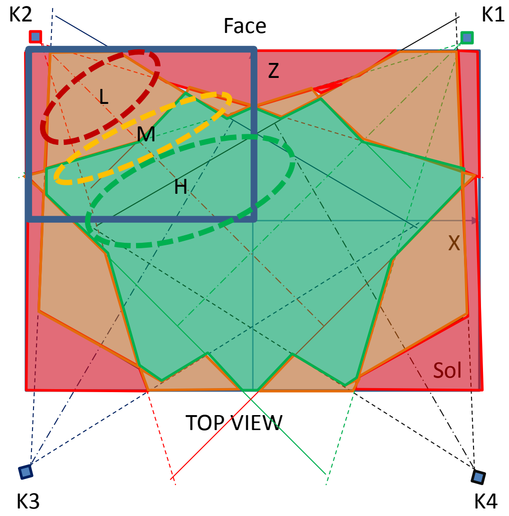
•High-coverage zone :
H : Fusion (K1;K2)

•Medium-coverage zone :
M : Fusion (K1;K4)

•Low-coverage zone :
L : Get (K4) + Complementary data (K3)

•Dead Zone :
No Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy



<u>Fusion rules – Area 2</u>

•High-coverage zone :
H : Fusion (K1;K2)

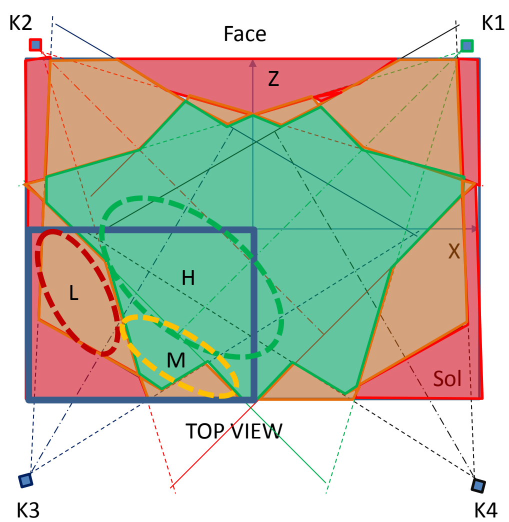
•Medium-coverage zone :
M : Fusion (K2;K3)

•Low-coverage zone :
L : Get (K3) + Complementary data (K4)

•Dead Zone :
No Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

41



<u>Fusion rules – Area 3</u>

•High-coverage zone :
H : Fusion (K1;K3)

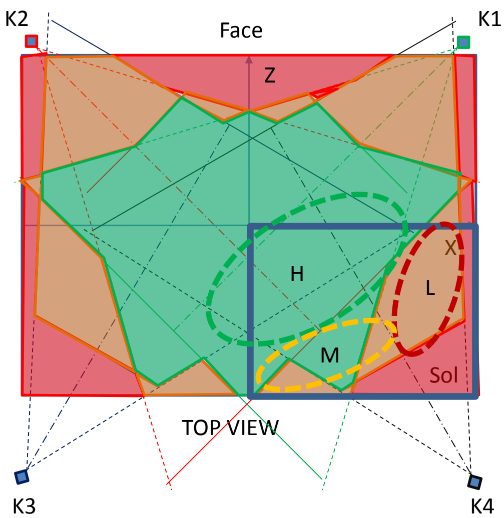
•Medium-coverage zone :
M : Fusion (K2;K3)

•Low-coverage zone :
L : Get (K3) + Complementary data (K1)

•Dead Zone :
No Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

42



Fusion rules – Area 4

- High-coverage zone :
  H : Fusion (K2;K4)
- Medium-coverage zone :
  M : Fusion (K1;K4)
- Low-coverage zone :
  L : Get (K4) + Complementary data (K2)
- Dead Zone :
  No Kinect

NB : The orientation of the Kinect sensor should be taken into account with high accuracy

43

```
#INCLUDE Coordinates of High, Low and Medium zones (1_High, 1_Medium, 1_Low,
2_High, 2_Medium, 2_Low, 3_High, 3_Medium, 3_Low, 4_High, 4_Medium, 4_Low)
BEGIN
Activate the Kinects
Calibration of the Kinects
Declaration of deadZone variable
DO {
FOREACH Activated Kinect DO {Obtain skeleton joints coordindates (x,z) }
Calculation of the user's world coordinates (x,z) in a posUser[][] array
SWITCH posUser
CASE ((posUser[x] >= 0) AND (posUser[z] >=0)) :
IF posUser[x][z] IN 1_High THEN Activate Kinects 1 and 2
ELSE IF posUser[x][z] IN 1_Medium THEN Activate Kinects 1 and 4
        ELSE IF posUser[x][z] IN 1_Low THEN Activate Kinects 3 and 4
deadZone = 1
BREAK
CASE ((posUser[x] >=0) AND (posUser[z] <0)) :
IF posUser[x][z] IN 2_High THEN Activate Kinects 1 and 2
ELSE IF posUser[x][z] IN 2_Medium THEN Activate Kinects 2 and 4
        ELSE IF posUser[x][z] IN 2_Low THEN Activate Kinects 3 and 4
                ELSE Disable all Kinects
deadZone = 1
BREAK

CASE ((posUser[x]<0) ET (posUser[z] <0)) :
IF posUser[x][z] IN 3_High THEN Activate Kinects 1 and 3
ELSE IF posUser[x][z] IN 3_Medium THEN Activate Kinects 2 and 3
        ELSE IF posUser[x][z] IN 3_Low THEN Activate Kinects 1 and 3
                ELSE Disable all Kinects
deadZone = 0
BREAK

CASE ((posUser[x]<0) AND (posUser[z] >=0)) :
IF posUser[x][z] IN 4_High THEN Activate Kinects 2 and 4
ELSE IF posUser[x][z] IN 4_Medium THEN Activate Kinects 1 and 4
        ELSE IF posUser[x][z] IN 4_Low THEN Activate Kinects 2 and 4
                ELSE Disable all Kinects
deadZone = 0
BREAK
} WHILE ((Skeleton detected) OR (deadZone == 1))
END
```

44

Outline

1. Global Context
2. Interaction Server : VR-SIX
3. Multi- Kinect Module
    1. Material Configuration – Kinect
    2. Geometric dispatching
    3. Fusion Rules
4. Conclusion
5. References

V. Conclusion

Thesis main goal :

Proposing a **low cost**, **feasible** and **accurately** system for **user position** and **orientation tracking** inside the **SAS**

1. **How to build this system ?**
2. **Which sensors for this system ?**
3. **Why we need Interaction Server ?**

V. Conclusion

1. How to build this system ?

- Install a real System
- A calibration step inside the SAS
- Develop the fusion Rules algorithm for real time tracking

47

Outline

1. Global Context
2. Interaction Server : VR-SIX
3. Multi- Kinect Module
    1. Material Configuration – Kinect
    2. Geometric dispatching
    3. Fusion Rules
4. Conclusion
5. References

48

V. References

INTERNAL

- S. Chendeb, T. Ridene, L. Leroy, **A GENERIC AUGMENTED REALITY TELESCOPE FOR HERITAGE VALORIZATIO**N. 3D GeoInfo, Nov. 2013.
- L. Leroy, S. Chendeb, **Innovative Virtual Reality Application For The road safety education for Child In Urban Areas**, ***[IN PROGRESS]***, 2014.
- T. Ridene, S. Chendeb, L. Leroy; **Virtual Reality Server of Interaction eXtensible VR-SIX** , ***[IN PROGRESS]*** 2014.
- J.S. Newton, T. Ridene, **"Module d'acquisition Multi-Kinect pour le Serveur d'Interaction VR-SIX »**, Note de Synthèse, ECTEI, July. 2013
- CiTU Lab;" **Multi-Kinect Architecture for Virtual Reality room: "Le SAS**" ", Technical report, July 2013.
- CiTU Lab; "**Multi-Kinect Geometric Dispatching inside the "SAS"** ", Technical appendix, July 2013.
- CiTU Lab; "**Multi-Kinect Fusion Rules Based on Overlapping inside the "SAS"** ", Technical appendix, July 2013.

COMUNITY

- Butler, A., Izadi, S., Hilliges, O., Molyneaux, D., Hodges, S., & Kim, D. (2012). **Shake ' n ' Sense : Reducing Interference for Overlapping Structured Light Depth Cameras.**
- Maimone, A., Bidwell, J., Peng, K., & Fuchs, H. (2012). **Enhanced personal autostereoscopic telepresence system using commodity depth cameras**. *Computers & Graphics*, *36*(7), 791–807. doi:10.1016/j.cag.2012.04.011
- Maimone, A., & Fuchs, H. (2012**). Reducing interference between multiple structured light depth sensors using motion**. *2012 IEEE Virtual Reality (VR)*, (May), 51–54. doi:10.1109/VR.2012.6180879
- Tong, J., Zhou, J., Liu, L., Pan, Z., & Yan, H. (2012). **Scanning 3D full human bodies using Kinects**. *IEEE transactions on visualization and computer graphics*, *18*(4), 643–50. doi:10.1109/TVCG.2012.56
- Suma, E.A. and Lange, B. and Rizzo, A. and Krum, DM and Bolas, M., "**Faast: The flexible action and articulated skeleton toolkit**", Virtual Reality Conference (VR), IEEE, 2011**.**
- Bernhard Kainz, Stefan Hauswiesner, Gerhard Reitmayr, Markus Steinberger, Raphael Grasset, Lukas Gruber, Eduardo Veas, Denis Kalkofen, Hartmut Seichter, and Dieter Schmalstieg ; "**OmniKinect: Real-Time Dense Volumetric Data Acquisition and Applications**", VRST 12, 2012.
- Riccardo Satta, Federico Pala, Giorgio Fumera and Fabio Roli. "**Real-time appearance-based person re-identification over multiple Kinect cameras**"; VISAPP, 2013
- Brian M. Williamson and Dr. Joseph J. La Viola Jr, Tim Roberts and Pat Garrity;"**Multi-Kinect Tracking for Dismounted Soldier Training**"; I/ITSEC 2012
- Yannic Schröder**,** Alexander Scholz, Kai Berger, Kai Ruhl, Dr. rer. nat. Stefan Guthe, Prof. Dr.-Ing. Marcus Magnor; "**Multiple Kinect Studies**"; Technical Report; 2011
- David Leonardo Acevedo Cruz; "**Calibration of a Multi-Kinect system**"; Master of science thesis; 2012

Appendix 1 - Review of existing solutions

Solution name	Solution configuration (see previous table)	Hardware Specs.	Number of Kinects used	Cost	Application of the solution
OmniKinect: Real-Time Dense Volumetric Data Acquisition and Applications [2]	Config 1	-1 PC with an ASUS Sabertooth X58 mainboard, an Intel Core i7 980X processor, 16 GB RAM, and a NVIDA Quadro 6000 graphics card -3 built-in USB Host controllers and 4 additional USB controllers -OpenNI and Microsoft Kinect SDK	7 (with both streams per Kinect at a time) or 12 (with only the RGB or depth stream)	5.000 US $	Tool that uses the data provided by multiple Kinects to recreate a 3D representation of an object or a person for various purposes such as augmented reality or full-body scanning
Real-time appearance-based person re-identification over multiple Kinect cameras [3]	Config 2	-1 centralized server -1 cheap miniPC per Kinect	2 in the test, but the architecture allows for more		System that identifies persons in a Kinect's range and allows the other connected Kinects to also recognize the same person when it will be in their range
Multi-Kinect Tracking for Dismounted Soldier Training [4]	Config 3	-3 Dell Inspirion N7110 laptops -1 Dell Precision T3500 -Microsoft Kinect for Windows SDK	4		Multi-Kinect setup that tracks a soldier in training and his VR helmet for a virtual reality military training application
Fast Image Processing Using Multiple Kinect Cameras on a Portable Platform [5]	Config 1	-1 Laptop computer running Windows 7 on a 1.5GHz Core 2 Duo processor	2	500 NZ $	Creation of a real-time image processing application that uses the data from several Kinects
Intelligent Sensor-Scheduling for Multi-Kinect-Tracking [6]	Config 2	-2 PCs with 2 Kinect connected to each -1 server connected via LAN -Ubuntu OS and libfreenect drivers	4		Algorithm that determines what Kinects are the closest to the scanned objects or persons and deactivate the others'IR streams to reduce interferences in a Multi-Kinect configuration
Multiple Kinect Studies [7]	Config 2	-4 PCs, one per Kinect. One of them also controls the IR-lens shuttering disks.	4		General studies about the use of multiple Kinects together and the results of a multiplexing method involving revolving discs.
PESI: Extending Mobile Music Instruments with Social Interaction [8]	Config 2	-2 PCs, one per Kinect -1 server that receives OSC data -OpenNI library + Processing and Openframeworks	2		Using the Kinects to tracks users as part of a musical application that produces music according to the users' movements and the movements of modded smartphones

Appendix 2.1 Proposed Config 2 : Hardware details

Hardware

Device	Pros	Cons
Microsoft Kinect	• High quality of device drivers • Stable work with various hardware models • Has motor that can be controlled remotely by iPi Recorder application: this makes device positioning more convenient	• Bigger size (12" x 3" x 2.5" against 7" x 2" x 1.5") • Higher weight (3.0 lb agains 0.5 lb) • Require ACDC power supply • Higher interference with another Kinect sensor in "Dual depth sensor" configuration • Lower RGB image quality in comparison with MS Kinect
ASUS Xtion / PrimeSense Carmine	• More compact (7" x 2" x 1.5" against 12" x 3" x 2.5") • Lighter weight (0.5 lb agains 3.0 lb) • Does not require power supply except USB • Lower interference with another ASUS Xtion / PrimeSense Carmine sensor in "Dual depth sensor" configuration • Better RGB image quality	• Less popular device • Lower drivers quality • Does not work with some USB controllers (especially USB 3.0) • No motor, allow only manual positioning

What kind of sensor should we choose? Kinect or Asus Xtion? (Table taken from iPiSoft Wiki)
[J.S.Newton, T.Ridene, Internship report, 2013]

Appendix 2.2 Proposed Config 2 : Hardware details

Hardware

Materiel	Number	Required configuration	Price per unit
Kinect for XBOX / Kinect for Windows	4	• Windows 7, Windows 8, Windows Embedded Standard 7, or Windows Embedded POSReady 7. • 32 bit (x86) or 64 bit (x64) processor • Dual-core 2.66-GHz or faster processor • Dedicated USB 2.0 bus • 2 GB RAM • Ethernet	XBOX : 150€ Windows : 230€
Embedded PC	4 (config 2)	Mini PC fanless eCW4950 Mini PC eCW512L	eCW4950 : 625 € eCW512L : 456 €
Centralized Server	1		
Ethernet Switch	1	Needs at least a port for the server and one for each Kinect.	

What is our choice of computers and configuration
[J.S.Newton, T.Ridene, Internship report, 2013]

Appendix 2.3 Proposed Config 2 : Wiring and Sofware

Wiring needs

Materiel	Meters	Requirements	Price per meter
Ethernet cables	(variable)	The cables have to be able to connect 4 Kinects to a switch and the server to this switch	< 1€
USB extenders	(variable)	Depending on the location of the Kinects and their allocated mini-PCs, USB extenders may be needed	--
Other	--	--	--

[J.S.Newton, T.Ridene, Internship report, 2013]

Software

Materiel	Software required
Embedded PCs	Linux OS, libfreenect drivers, OpenNI / Windows 7 OS, Kinect SDK *(Proposed configuration includes UBUNTU)*
Centralized server	Windows 7 OS, Kinect SDK,
Network : switch	We need a synchronization between data issued from the 4 embedded PC and acquired by the central server – a kind of TimeStaming process

[J.S.Newton, T.Ridene, Internship report, 2013]

53

Thank You for your Attention

54