Virtual ergonomics in agriculture

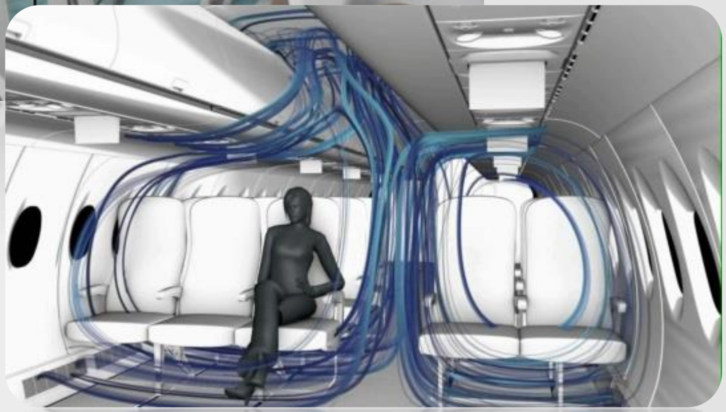
Giuseppe Di Gironimo

UNIVERSITY OF NAPLES FEDERICO II

giuseppe.digironimo@unina.it

IDEAinVR

Interactive Design and Ergonomics Applications in Virtual Reality



Giuseppe Di Gironimo

University of Naples Federico II
Joint Lab IDEAS

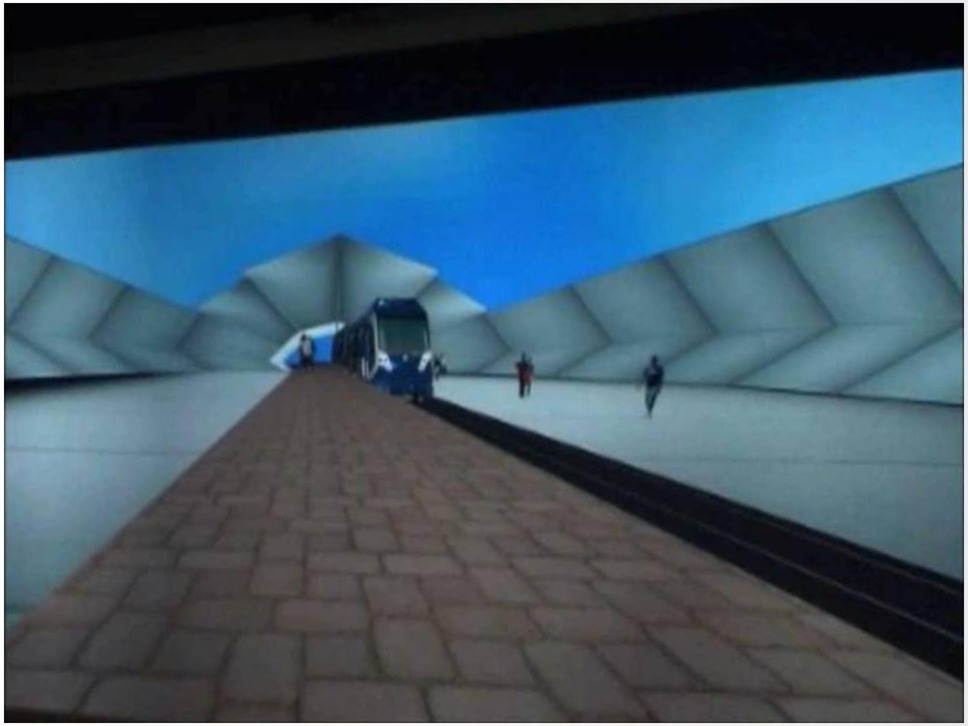
giuseppe.digironimo@unina.it

- ✓ …methods and techniques that allow the design team to simulate human-product interaction when the product is still "immaterial".

CAD model +

- ***Material, textures, shaders and lights***

Collaboration with ESI Group



Collaboration with AnsaldoBreda

giuseppe.digironimo@unina.it

CAD model +

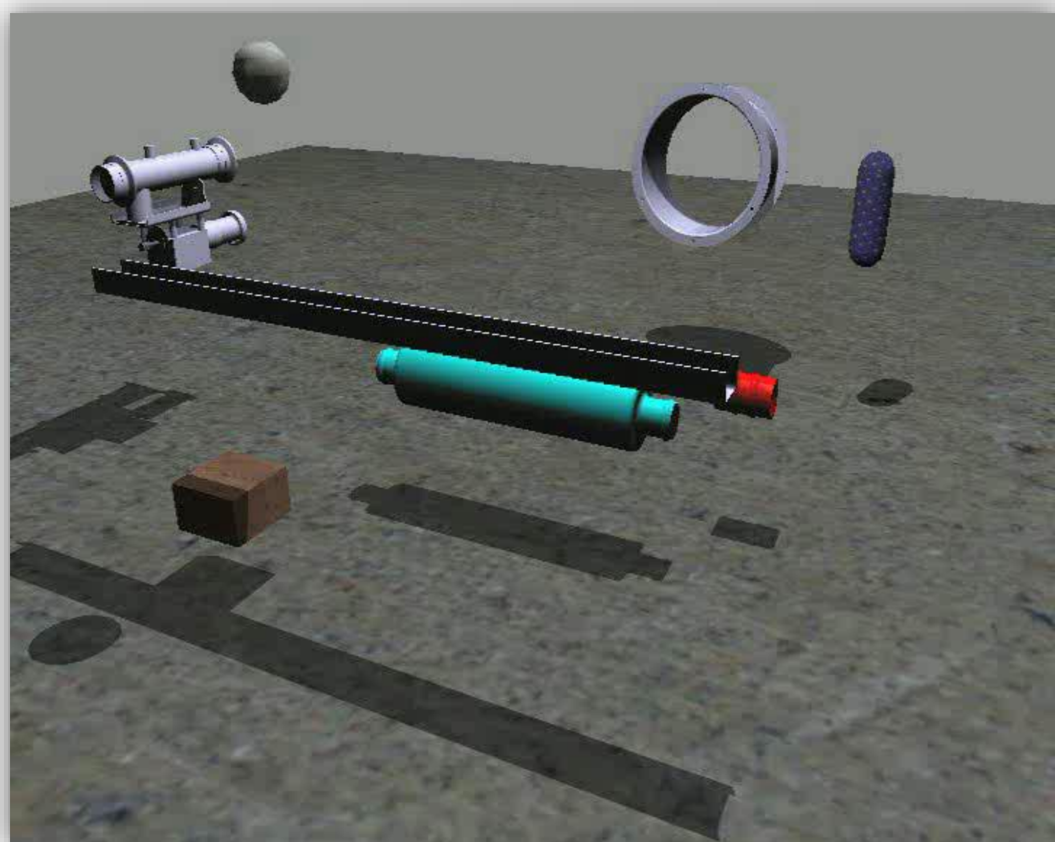
- *Material, textures, shaders and lights*
- ***Kinematic behaviors***
  - ***Direct***
  - ***Inverse***

Collaboration with Firema Trasporti

CAD model +

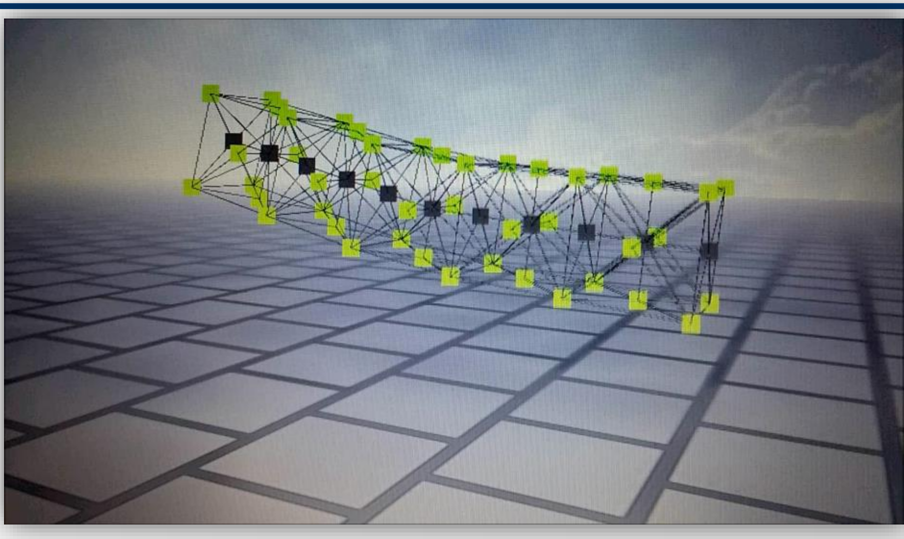
- *Material, textures, shaders and lights*
- *Kinematic behaviors*
  - *Direct*
  - *Inverse*
- ***Dynamic behaviors***
  - ***Rigid body***

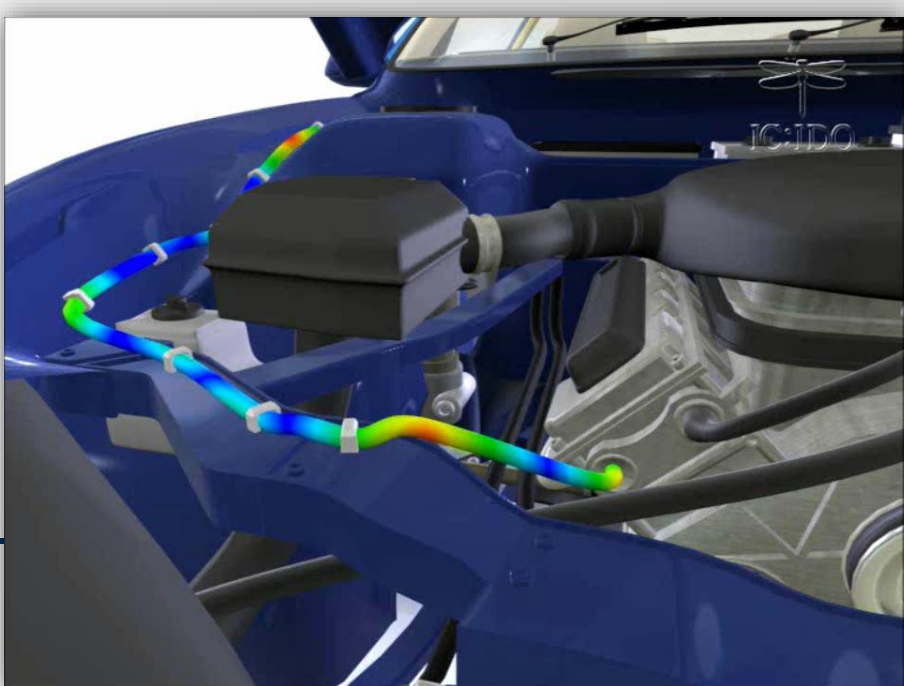
Collaboration with CIRA



CAD model +

- *Material, textures, shaders and lights*
- *Kinematic behaviors*
  - *Direct*
  - *Inverse*
- ***Dynamic behaviors***
  - *Rigid body*
  - ***Deformable body***





Collaboration with Fraunhofer IGD

Collaboration with ESI – IC:IDO

CAD model +

- *Material, textures, shaders and lights*
- *Kinematic behaviors*
    - *Direct*
    - *Inverse*
- *Dynamic behaviors*
    - *Rigid body*
    - *Deformable body*
- ***Sensitivity to collisions***
    - ***Detection***
    - ***Gliding***
    - *Avoiding*

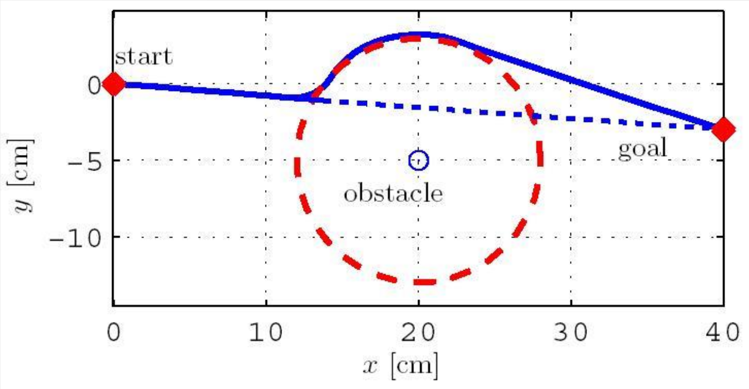
Collaboration with Firema

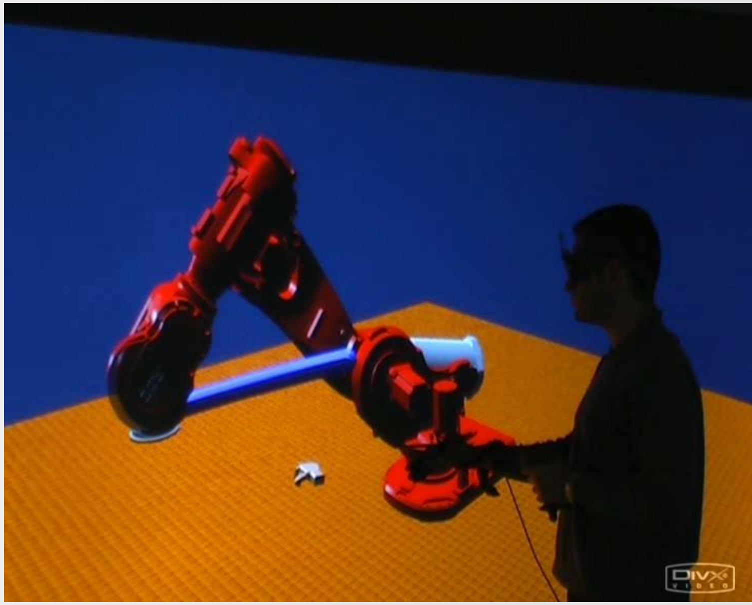
giuseppe.digironimo@unina.it

CAD model +

- *Material, textures, shaders and lights*
- *Kinematic behaviors*
  - *Direct*
  - *Inverse*
- *Dynamic behaviors*
  - *Rigid body*
  - *Deformable body*
- ***Sensitivity to collisions***
  - *Detection*
  - *Gliding*
  - ***Avoidance***

Collaboration with PRISMA Lab – prof. Siciliano





Virtual Prototype

…if compared with **traditional design methods**, engineering design using intuitive 3D interaction techniques in VR increases its contribution to...

- ...styling
- ...ergonomic performance
- …product quality
- …product lifecycle
- ...a product's commercial competitiveness through product differentiation

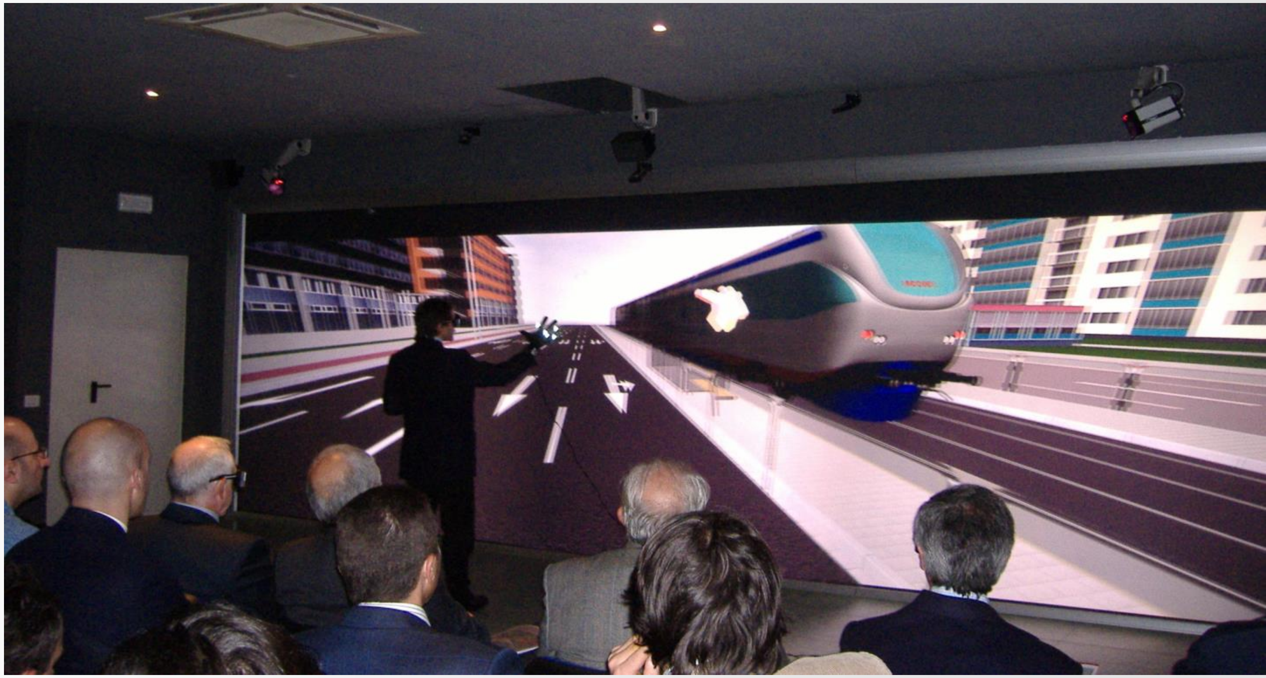
Collaboration with Piaggio Aero Industries

VRTest Laboratory

Main Goal: build an integrated system that allows designers and engineers to visualize the new products and simulate their main performances

Main Tasks:

- Styling
- DMU and PMU correlation
- Ergonomics simulations
- Virtual Serviceability
- Digital Plant
- Marketing and Sales



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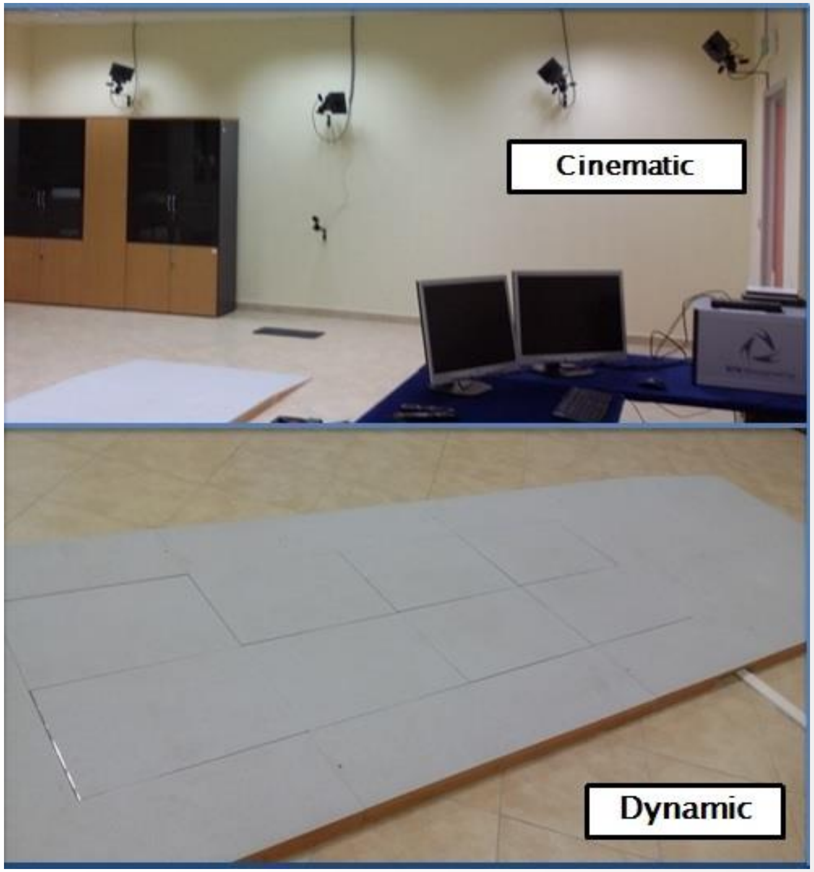
CESMA-MARTE: Advanced Measures in VR

- Virtual Design Review
- Styling
- Concept Design
- Ergonomics
- Virtual Maintenance
- Virtual Manufacturing
- Virtual Training
- Post-processing of CAE data
- Virtual Marketing
- Cooperative Design

ErgoS - Advanced Measures on Ergonomics and Shapes

Integrated system for cinematic, dynamic, inertial and electromyography measurements on human body



Infared digital cameras	10
Sensor resolution	2048×1088
Acquisition frequency at maximum resolution	340fps
Maximum acquisition frequency	2000fps

Number of platform	8
Weight and Size Single platform	28Kg, Sensitive area 60x40cm Minimum height 5cm
Capacity for each sensor	Up to ±2000 N

ErgoS - Advanced Measures on Ergonomics and Shapes

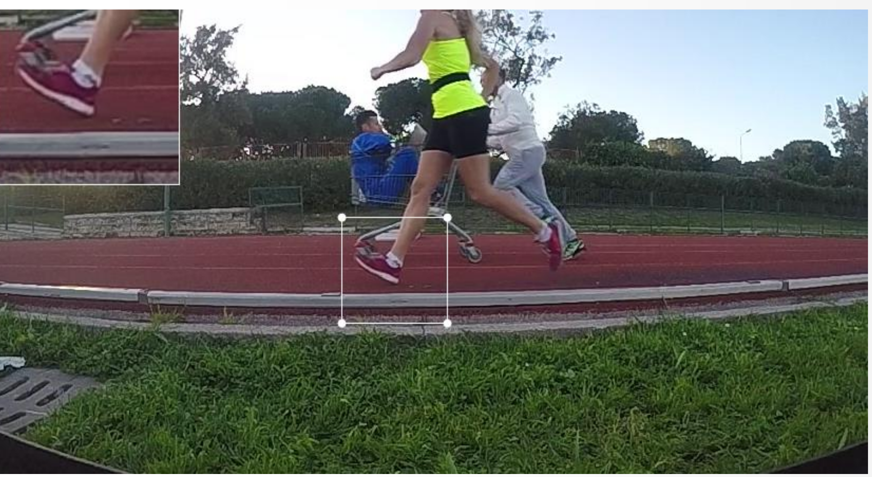
Integrated system for cinematic, dynamic, inertial and electromyography measurements on human body

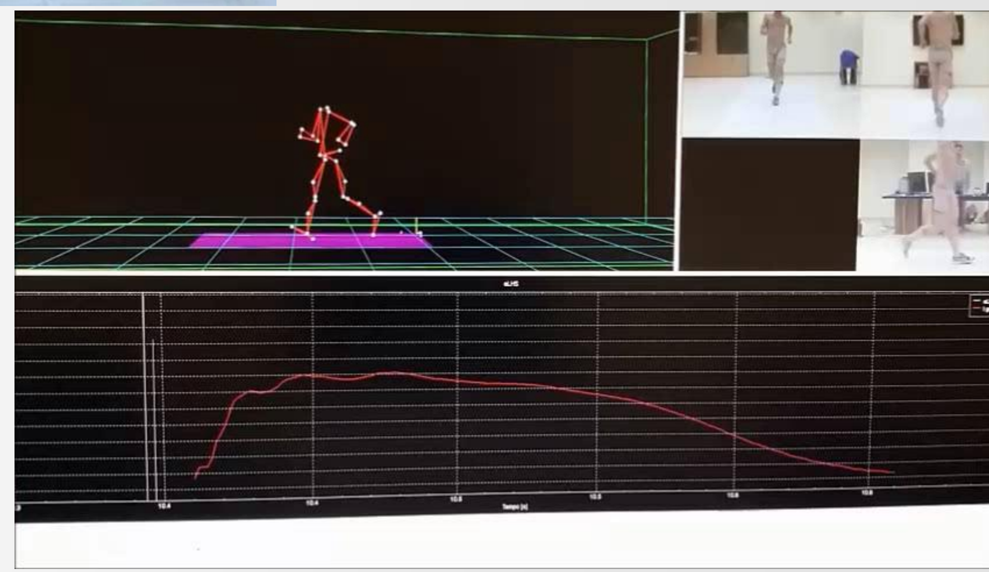
Number of probe	16
Weight	9 g
Frequency	Up to 4 KHz

Size	78x48x20mm
Weight	62gr
Frequency	Up to 200Hz
Data trasmission technology	Bluetooth® Zig Bee

Internal project: Race Walking

Evaluation of the illegal Flight Phase





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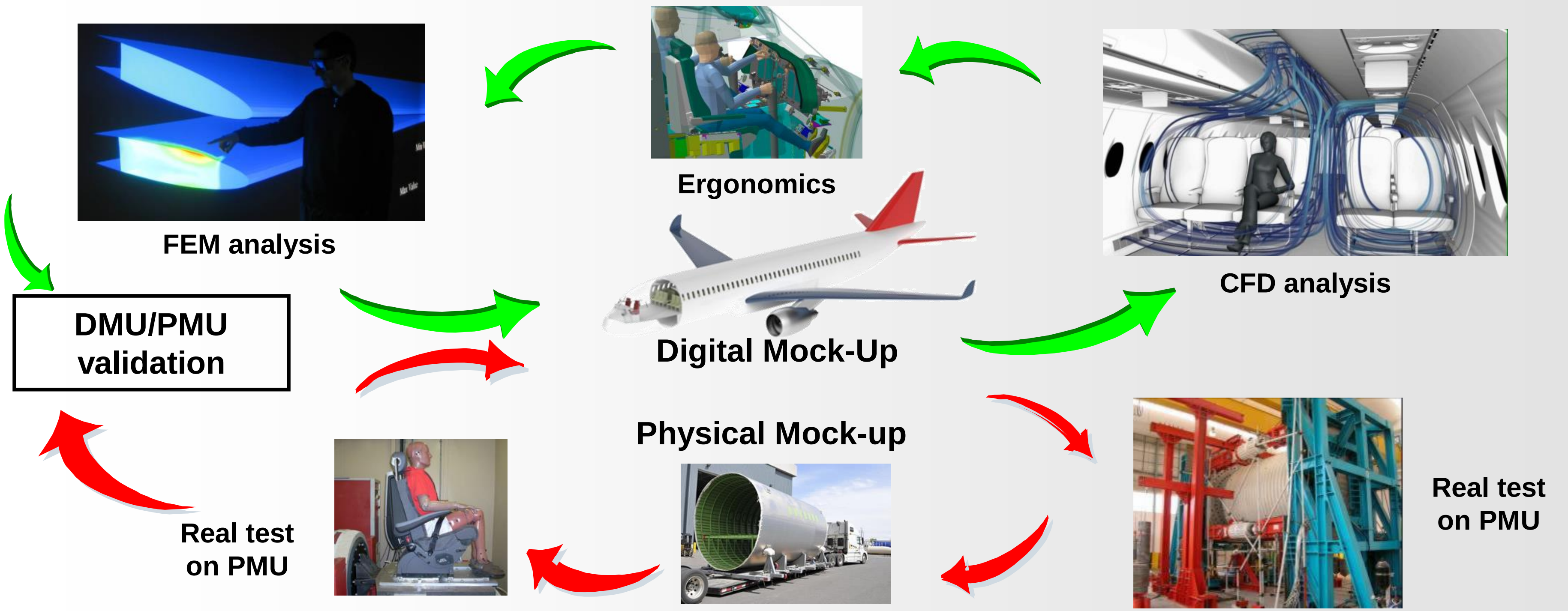
Cooperative design in VR

- Critical review of projects (***design review***) certainly is one of the most crucial stages of product development with digital simulation tools .

- The number of critical reviews of a product is proportional to the complexity of the project, because equally numerous and complex data coming from ***different simulation environments*** must be analyzed and critically evaluated.



giuseppe.digironimo@unina.it

- Introduction and Aims
- International Standards for the design of tractor cabs
- Tractor’s virtual prototyping – Top-down approach
- Ergonomic analyses and optimization
  - *Identification of critical driving tasks*
  - *Virtual simulations through digital human models*
  - *Definition of an Ergonomic Evaluation Index (EEI)*
  - *Test campaign*
  - *Ergonomic Improvement of tractor’s cab model*
- Conclusions

- The increasingly intensive use of agricultural tractors pushes users to require ***improvement of ergonomics*** of driver cabs and usability of controls.

- Several researches in literature have demonstrated that increasing comfort does not always require a very expensive and impressive change of the model. Even minor changes using ***re-design*** within vehicles could improve comfort.

- This presentation illustrates a ***re-design approach*** based on the use and the management of heterogeneous product information, advanced virtual prototyping tools and digital human models, for the re-design and the ergonomic optimization of an agricultural tractor’s driver cab.

International Standards for the design of tractor cabs

- **At the end of last century**, standards on agricultural tractor's driver cab concerned only the seating accommodation dimensions, with particular reference to the distances among seat, pedals and steering wheel.

- **Nowadays**, due to the evolution of the design techniques, the scenario is changed and several rules and standards were studied and created to improve the quality of the tractors but especially to increase the driver's safety.

- There are **62 ISO standards** specifically for agricultural tractors.

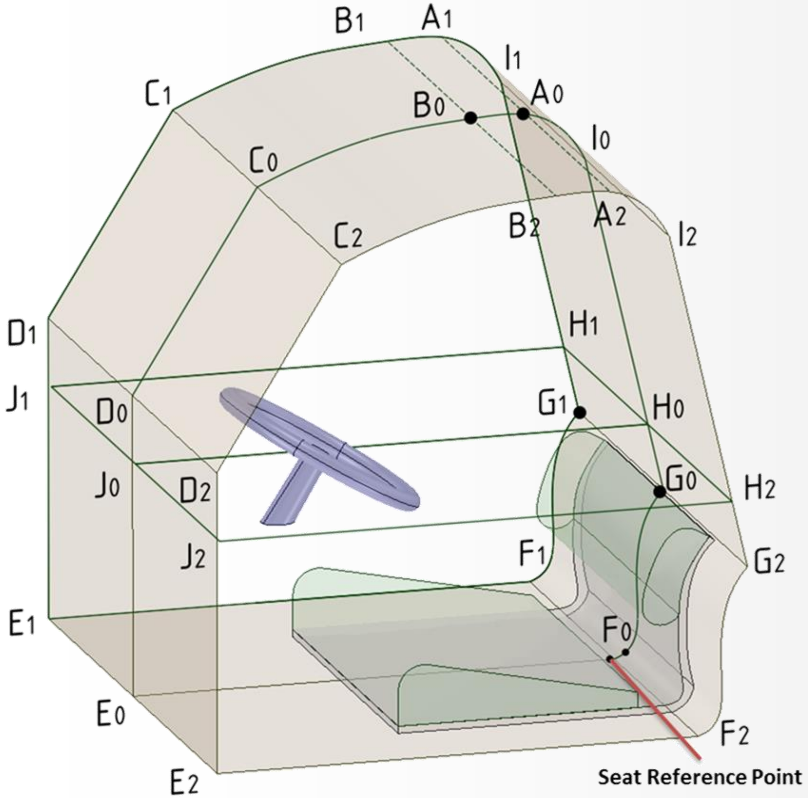
- The most important international organization for tractor's standards is the **Organization for Economic Co-operation and Development (OECD)** which provides a common set of test procedures for tractors in three areas: ***performance***, ***driver's safety***, and ***noise measurement***.

giuseppe.digironimo@unina.it

International Standards for the design of tractor cabs

OECD rule N. 4 (“Testing of the strength of protective structures for agricultural and forestry tractors - static test”)

Survival Cell dimensions

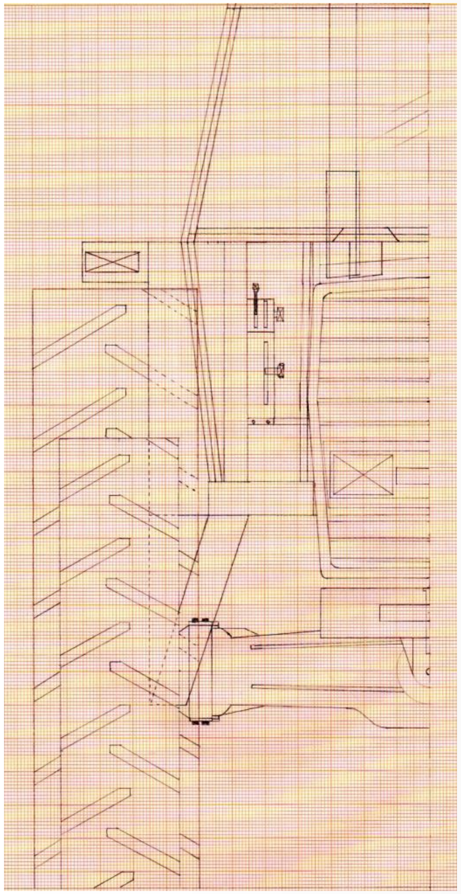


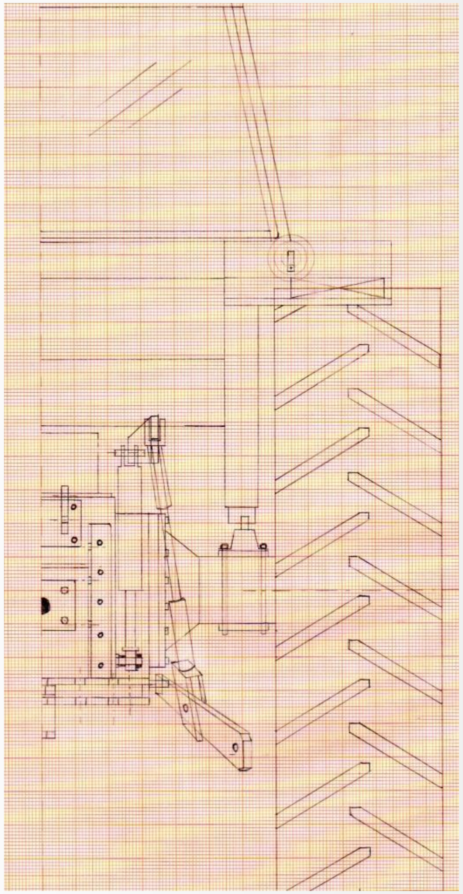
Dimension	mm	Comment
A1 A0	100	Minimum
B1 B0	100	Minimum
F1 F0	250	Minimum
F2 F0	250	Minimum
G1 G0	250	Minimum
G2 G0	250	Minimum
H1 H0	250	Minimum
H2 H0	250	Minimum
J1 J0	250	Minimum
J2 J0	250	Minimum
E1 E0	250	Minimum
E2 E0	250	Minimum
D0 E0	300	Minimum
J0 E0	300	Minimum
A1 A2	500	Minimum
B1 B2	500	Minimum
C1 C2	500	Minimum
D1 D2	500	Minimum
I1 I2	500	Minimum

Real tractor

Tractor's virtual prototyping – Top-down approach

Starting from manual measurement on the real model, photos, sketches and technical drawings, the layout of the CAD assembly prototype was realized



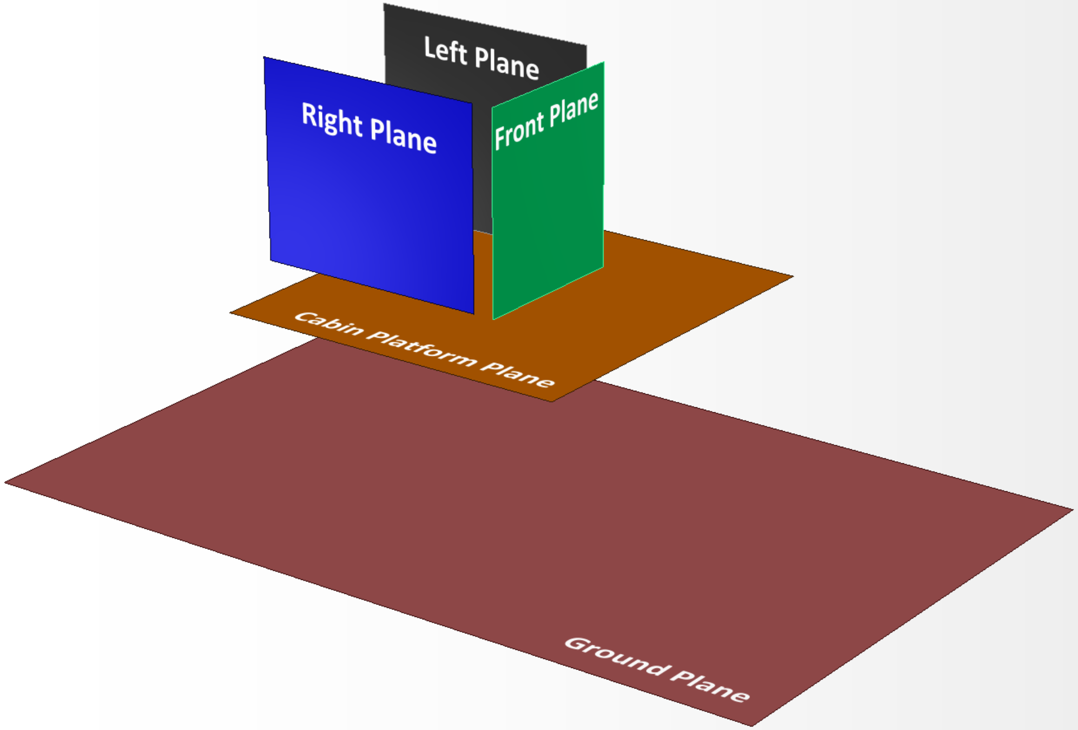


Frontal and rear views of the tractor

giuseppe.digironimo@unina.it

Tractor's virtual prototyping – Top-down approach

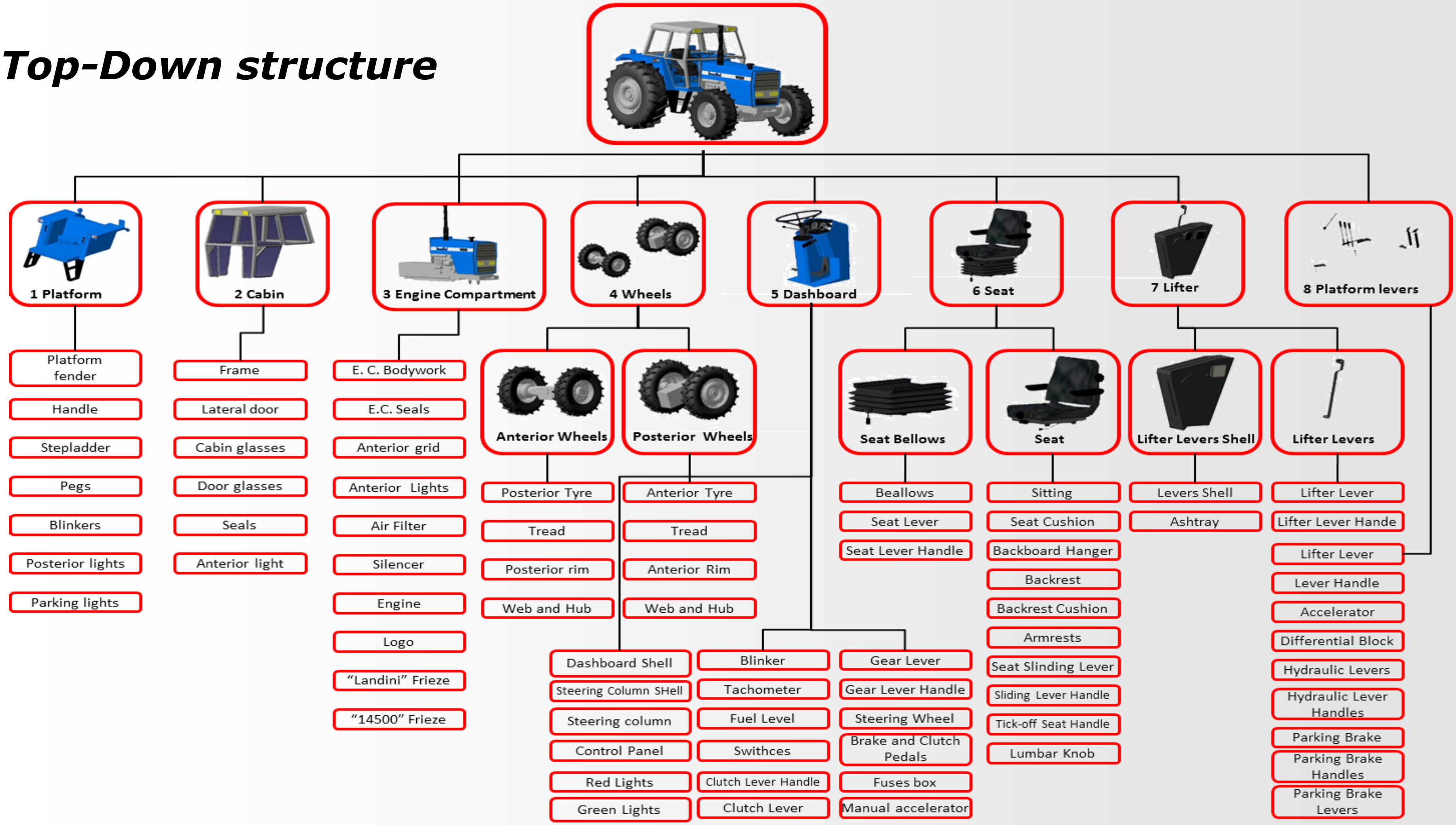
As the case study is composed by many elements, the structure of the assembly was defined starting from a ***Top-Down approach*** according to parameters that identify safety, ergonomic and comfort constraints.



Datum Planes used for the CAD modeling

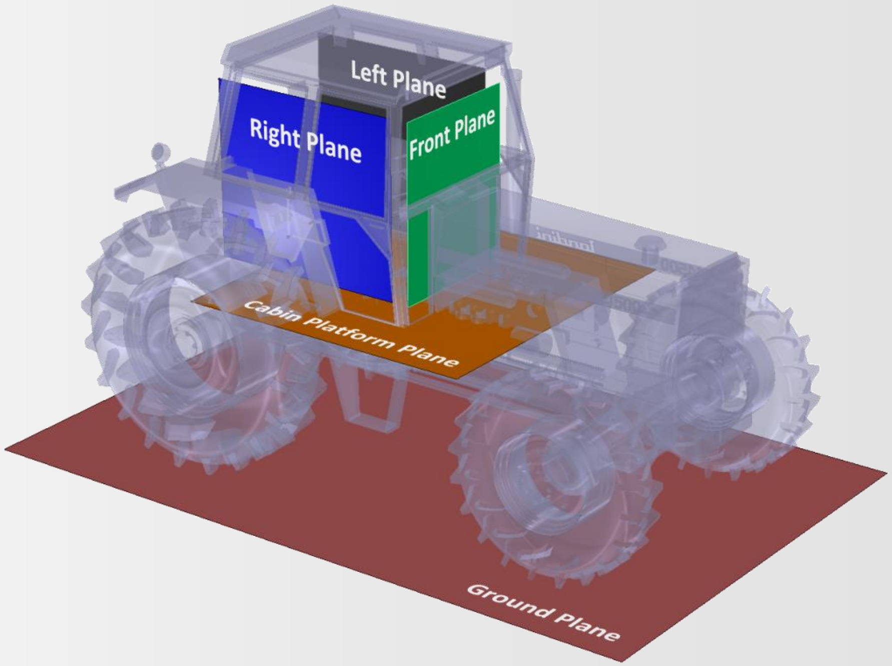
Tractor's virtual prototyping – Top-down approach

Top-Down structure



Tractor’s virtual prototyping – Top-down approach

Final virtual prototype of the Landini 14500 tractor



The extensive work to perform the CAD modeling through a top–down approach assures to perform automatic changes to the defined geometries, drastically reducing re-designing times.

Procedure for ergonomic optimization of the driver cab

	Phases	*Tools*
1.	Identification of critical driving tasks, as regards to ergonomics	***Direct interviews*** ***Questionnaire***
2.	*For each task*: Identification of critical situations as regards to: visibility, reachability, postural comfort	***Virtual simulations through digital human models***
3.	Changing of features parameters and updating of the 3D assembly structure	***CAD***

Phase 1: Identification of critical driving tasks

Customers' judgments on the real tractor have been collected in order to identify the most critical driving tasks perceived by the users as regards to usability

Non-dangerous devices - ND	*Dangerous Devices - DD*
1. Seat suspension handle	1. Primary clutch pedal
2. Lumbar adjustment knob	2. Gear lever
3. Seat sliding lever	3. Brake pedal
4. Seat height lever	4. Parking brake lever
5. Seat tilt lever	5. Power take-off lever
6. Manual accelerator knob	6. Secondary clutch lever
7. Accelerator pedal	7. Power take-off motion lever
8. Ignition key	8. Lift lever 1
9. Light switch	9. Lift lever 2
10. Directional light switch	10. Lift locking lever
11. Differential gear lock pedal	11. Services levers

Some devices in the driver cab correspond to potentially dangerous actions.

"Non-dangerous Devices - ND" → *weight (Hn=1)*

"Dangerous Devices - DD" → *weight (Hd=1.5)*

Phase 1: Identification of critical driving tasks

Customers' judgments on the real tractor have been collected in order to identify the most critical driving tasks perceived by the users as regards to usability

Questionnaire:

- ***10 skilled tractor drivers*** of different percentiles [5th – 95th]
- They were asked to assign a ***score***, from 1 to 5, to evaluate the usability of the devices.

  1: very easy to use; 2: easy to use; 3: little difficult to use; 4: difficult to use; 5: very difficult to use

- The score assigned to each device was than amplified with the corresponding ***weight***.
- The ***critical range*** is between

  3 (for a *Non-dangerous device little difficult to use*)
  7.5 (for a *Dangerous Device very difficult to use*)

Customers' judgments on the real tractor have been collected in order to identify the most critical driving tasks perceived by the users as regards to usability

Critical devices

Device	*Mean Score*	*Weighted Mean Score (WMS)*	*Normalized WMS*
1. Power take-off lever	5	7.50	1
2. Parking brake lever	4.5	6.75	0.9
3. Services levers	2.5	3.75	0.5

- ✓ The results of the survey highlighted that only three devices are critical because present a Weighted Mean Score (WMS) between 3 and 7.5.
- ✓ The survey allowed to highlight, in a qualitative way, what are the control devices in the cabin that skilled drivers perceive as ***"difficult to use"***

Phase 2: Virtual simulations through digital human models

In order to improve the usability of the critical control devices, we need to understand why those devices are perceived as "DIFFICULT TO USE"

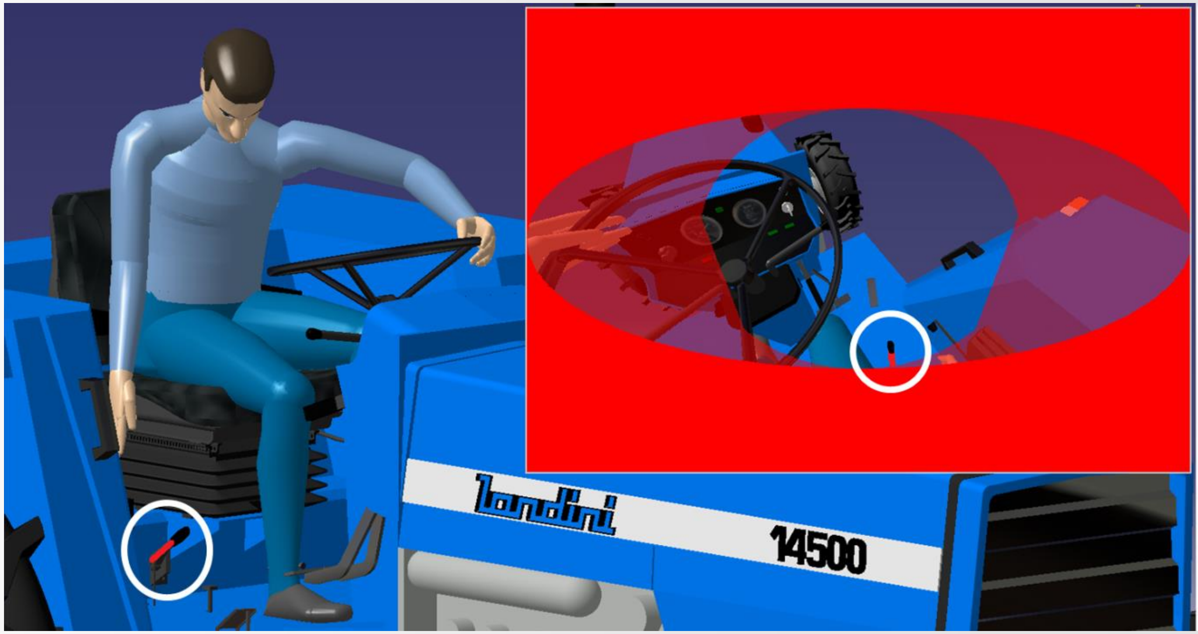
Usability

- Objective characteristics
  - → *Visibility*
  - → *Reachability*
  - → *Postural comfort*
- Subjective characteristics

Phase 2: Virtual simulations through digital human models

Visibility analyses

- The three tasks were simulated in virtual environment.
- The software allows to see the simulation of a task with the eyes of the manikin, highlighting the field of view of both eyes



✓ All tests returned positive results

✓ The dissatisfaction of the real drivers with the use of critical devices cannot be adduced to the lack of visibility

giuseppe.digironimo@unina.it

Phase 2: Virtual simulations through digital human models

Reachability analyses

- Once the manikin has been opportunely constrained inside the driver cab, using the inverse kinematic algorithm it was possible to verify the reachability of the critical devices, also computing a reach envelope surface.
- Even if in order to reach the devices, the driver has to incline the trunk and to extend the hands, the reachability is satisfied.

✓ All tests returned positive results

✓ The dissatisfaction of the real drivers with the use of critical devices cannot be adduced to the lack of reachability

Phase 2: Virtual simulations through digital human models

Postural analyses

Ergonomics' Evaluation Index" (EEI index)

$$EEI = (P + R) / 2$$

P index: Postural Score Analysis tool

R index: Rapid Upper Limb Assessment analysis tool

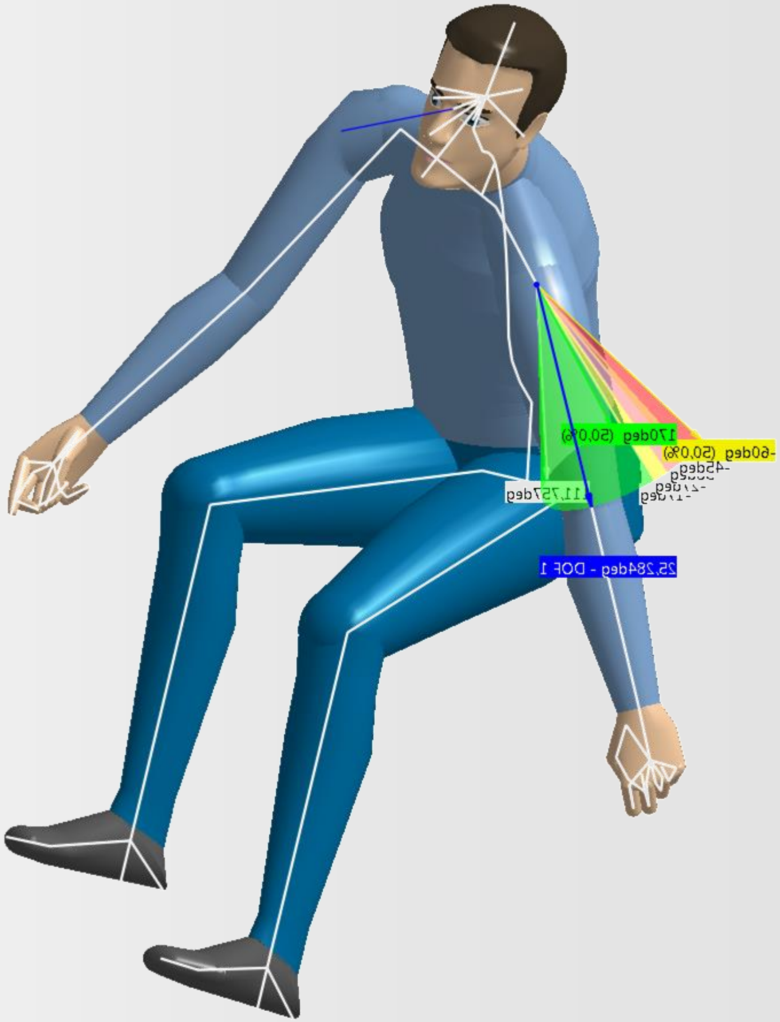
giuseppe.digironimo@unina.it

Phase 2: Virtual simulations through digital human models

Postural analyses

The evaluation of P index needs the preventive knowledge of:

- the angles that have to be examined (“***favorite angles***”),
- their comfort range.

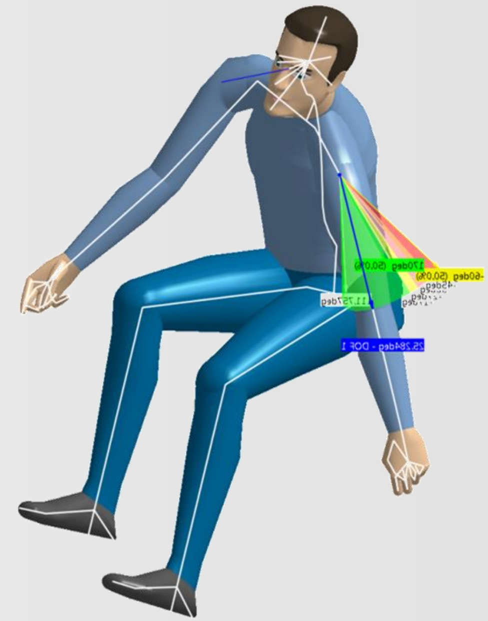


Phase 2: Virtual simulations through digital human models

Postural analyses

2nd Test campaign

3 skilled drivers (5^{th}, 50^{th}, 95^{th})



AIMS:

a) to determine the segments and ***the favorite angles*** of the drivers that are most involved during the activation of the critical devices

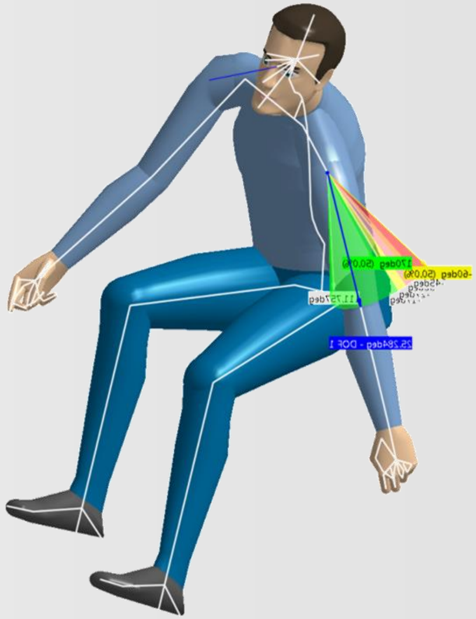
This aim was reached through a visual observation of photos and videos captured during the tests. As result we individuated: the full spine, the left arm and the right arm, and the relative adjacent joints angles, for a total of ***9 favorite angles****.*

Phase 2: Virtual simulations through digital human models

Postural analyses

2nd Test campaign

3 skilled drivers (5th, 50th, 95th)



<u>AIMS:</u>

b) to qualitatively evaluate ***the comfort range of the favorite angles*** in order to implement them in the Human Posture Analysis module of Delmia.

We obtained this aim asking the drivers to:
Assume a driving posture; Move only one joint at a time along all the possible ranges, leaving all other joints locked. Stop the motion when an uncomfortable angle is reached.
In this way we could qualitatively measure with manual tools the comfort range of the favorite angles (φi) related to a tractor driving posture.

Phase 2: Virtual simulations through digital human models

Postural analyses

Running the *Postural Score Analysis* tool, the P index can be obtained through the following formula

$$P = \frac{1}{100} \times \frac{\sum_{i=1}^{n}[100 - p(\varphi_i)]}{n}$$

"*n*" is the number of favorite angles taken into account (n=9 in our case);

"*$p(\varphi_i)$*" is the score related to the favorite angle φ_i. It can range between 0 (worst) to 100 (best).

P ranges between 0 (optimal posture) to 1 (critical posture).

Postural analyses

EEI index evaluation

	P index	*R index*	*EEI*
Power take-off lever	0.81	0.86	0.83
Parking brake lever	0.65	0.86	0.75
Services levers	0.35	0.43	0.39

- *The EEI score can range between 0 (optimal posture) and 1 (critical posture).*
- *EEI less than 0.5 can be considered acceptable.*

giuseppe.digironimo@unina.it

Phase 2: Virtual simulations through digital human models

Postural analyses

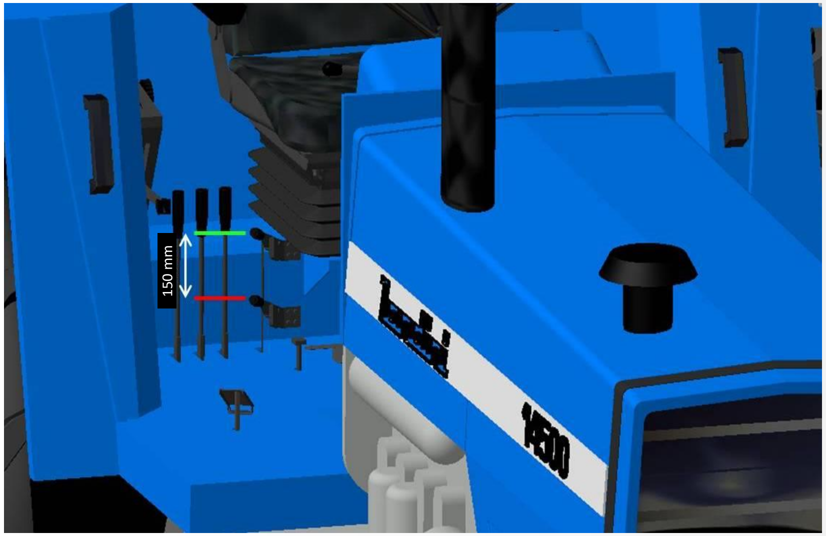
The results of the virtual simulation confirm the qualitative results obtained from the experimental test conducted with real drivers.

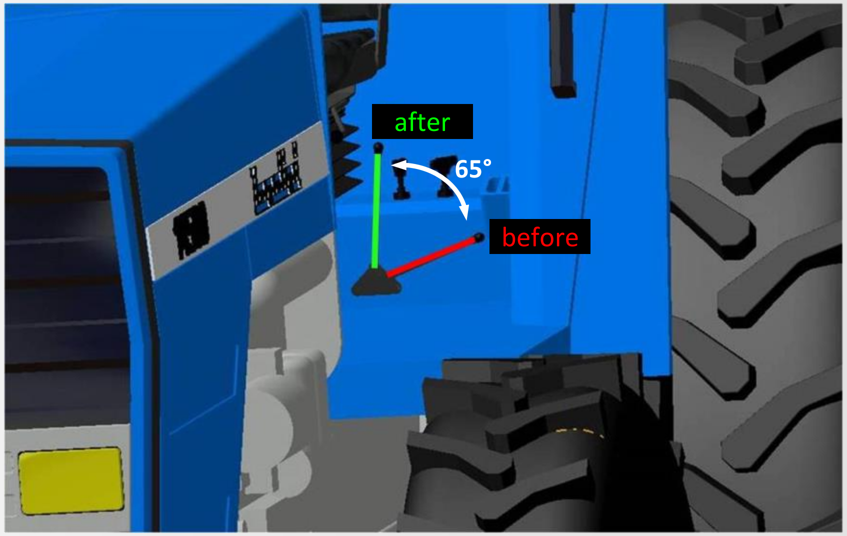
*The **dissatisfaction of the real drivers** with the use of critical devices can be completely adduced to the **non-comfortable postures** that they have to assume to reach the devices.*

Phase 3: Ergonomic Improvement of tractor's cab model

Changing of features parameters and updating of the 3D assembly structure

	P index	*R index*	*EEI*
Power take-off lever	0.81	0.86	0.83
Parking brake lever	0.65	0.86	0.75
Services levers	0.35	0.43	0.39





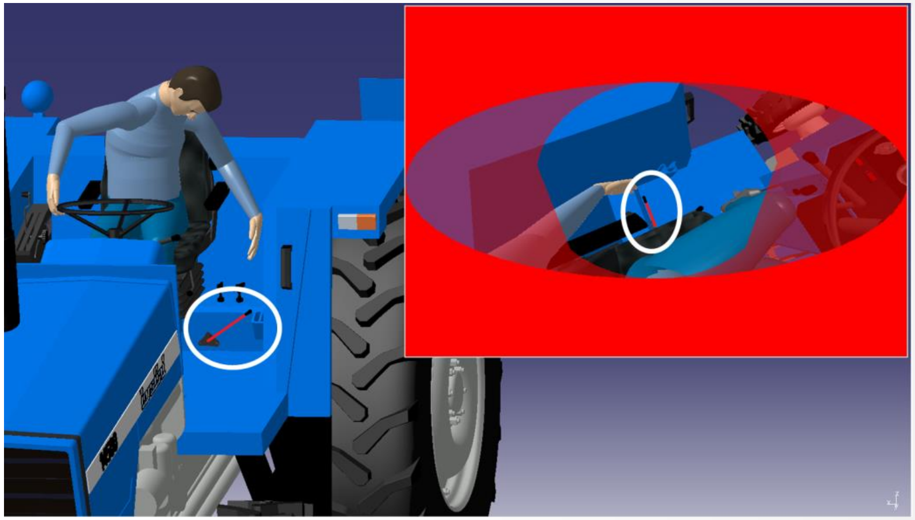
In order to decrease the flexion value of the driver spine, the height from the floor of both the devices was incremented.

At first we adjusted the flexion angle of the spine until the obtaining of EEI scores lower than 0.5. Then, with the reach envelope surface activated, he have lifted the devices until they were inside the reach envelope surface.

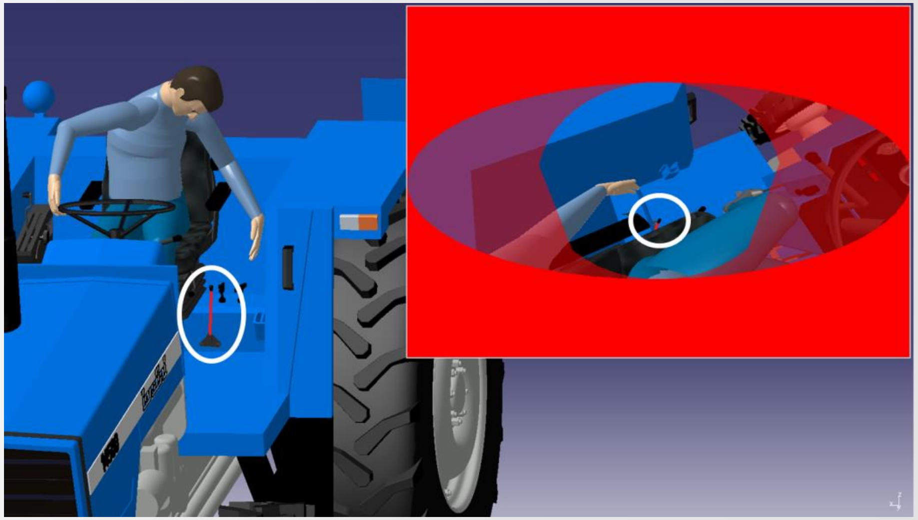
giuseppe.digironimo@unina.it

Phase 3: Ergonomic Improvement of tractor's cab model

Checking of visibility performance



Before change



After change

Using the field of view of the manikin's eyes, we have checked that visibility didn't perform worst after the repositioning of the devices.

giuseppe.digironimo@unina.it

Phase 3: Ergonomic Improvement of tractor's cab model

	P index	*R index*	*EEI*
Power take-off lever	0.81	0.86	0.83
Parking brake lever	0.65	0.86	0.75
Services levers	0.35	0.43	0.39

Before change

	P index	*R index*	*EEI*
Power take-off lever	0.09	0.29	0.19
Parking brake lever	0.14	0.43	0.27

After change

After the design modifications, the values of the ergonomic indexes were improved, and the EEI values became acceptable (lower than 0.5)

VR can give advantages….

…before

- ✓ This research has illustrated the tools and the methodological approach adopted for ***the redesign and the ergonomic optimization*** of an agricultural tractor's driver cab.
- ✓ The research has illustrated how to realize an experimental test with real persons in order to obtain the ***database for the driving posture of an agricultural tractor***.

…after

✓***Virtual training*** of operators

giuseppe.digironimo@unina.it

… un detto cinese
molto diffuso nella comunità della RV!

“Tell me and I’ll forget

show me and I’ll remember

involve me and I’ll learn”