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Office furniture design for wheelchair user

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Abstract

There are an estimated 1.19 million wheelchair users in Spain. People use wheelchairs for a variety of reasons, the most common one is paralysis from spinal cord injuries. Current estimates indicate there are around 504.000 people alive in Spain with spinal cord injuries. Among other reasons for using wheelchairs are: fatigue from multiple sclerosis, muscle weakness from muscular dystrophy, lower limb spasticity from cerebral palsy, and missing limbs due to amputation. People who use wheelchairs may encounter a variety of obstacles at their workstations depending on their limitations. Some possible accommodations could be adjustable height desk or table for a person who cannot work comfortably at an existing desk, accessible filing system or office supplies, and frequently used materials on most accessible shelves or drawers for a person who cannot reach upper and lower shelves and drawers. This paper presents the graphical design of a workstation for wheelchair users, in this case, technical, anthropometric, ergonomic, aesthetics and scientists aspects have been analyzed. The design of composite structure conduct to explicit safety constraints applied to office furniture requirements kept continuously current and updated as part of innovation. Finally, results are showed in a three-dimensional model.

1 Introduction

Since the beginning of the century, the awareness of society towards the employment disabled becomes a reality. Due to this fact, the need to adapt the workspace to people with limited mobility arises. In most cases, this required adaption of workspaces is made provisionally and based on conventional furniture in such a way that some part of the dimensional limitations or mobility of these individuals is not corrected yet. Therefore, it is believed desirable to design special furniture that matches the real needs of these users.

1.1 Legal framework

Law 31/1995 of 8 November on the Prevention of Occupational Risks (LPRL), which entered into effect three months after its publication on February 10, 1996, aims to promote safety and health of workers through measures and development activities necessary for the prevention of occupational hazards. In this Law shall be emitted a series of rights and obligations of the employer and the employee. To properly comply with this Act, the implementation of the entire manufacturing work derived from that project must follow in a clear-cut way all the items listed in it.

Furthermore, while designing the station office, criteria to minimize the risks to which the future worker is exposed by the use of the designed furniture will be considered, in order to ensure the integrity of workers' health.

- The Law clearly states the role of the National Institute for Occupational Safety and Health at Work, as a guarantee of improved safety and health at work, so does the expertise in the development of legal rules. Compliance or monitoring the displayed parameters in the documents produced by the already mentioned organism on every different field, ensure to reduce many of the risks that may exist in the workplace.

The documents prepared by the INSHT, in this case the Prevention Technical Notes (NTP) of ergonomics in the office area, will be useful for the final design of the post, since that will ensure proper matching between user and furniture, making it an easy task and reducing risk, consequently, complying the law.

In this regard it should be noted for reference

- NTP 232 display screens (VDT): postural fatigue.
- NTP 490 Disabled workers: job design.
- NTP 242 Ergonomics: ergonomic analysis of work spaces in offices.
- NTP 602 The ergonomic design of workstation with display screen: the team.

All these technical provisions are based on strict compliance of the regulation reflected in the corresponding Royal Decrees, which develop and clarify the law mentioned above:

- RD 486-1997 workplaces.
- RD 488-1997 Display screens.

On the other hand, it is necessary to mention the RD 1801-2003, on general safety of the products, whose compliance passes through the application of technical standards in force.

1.2 Context

The modern office furniture has a number of defining characteristics: flexibility, comfort (ergonomic), functionality and aesthetic quality (minimalism). These requirements arise from the needs that must be covered in today's office. That is to say, flexibility to overcome the multitude of tasks and different workers; ergonomics, to ensure that the worker can perform its function comfortably avoiding any injury; functional, to perform tasks correctly; and aesthetically making the environment pleasant and so does work indirectly.

Fig. 1 Office furniture.

The appearance of the furniture is undoubtedly affected by the characteristics of the office or company, fig.1. A clear example is the optimization of office space, which has led manufacturers to design modular positions for subsequent coupling among them, consequently achieving the sought space saving. Thus, the "islands" of posts are a very common image in the office nowadays and they are a feature of this type of furniture.
On the other hand, modern office furniture is usually mainly metallic. The use of profiling is widespread and it gives the cause to perform essential furnishings with a minimal use of material. By this way, the structure is integrated into the set, creating aesthetic products really significant.
Analyzing the production of these companies it is showed that there are several types of configurations of furniture, mainly due to the various functions performed in the same, and above all, the intensive use of the computer or not.
The type of office furniture is influenced by the characteristics of one's job, trying first one to meet the needs of the job. Thus it is possible to find specific furniture:

- *Reception*, it combines a variety of surfaces to promote operability and functionality.
- *Customer*, it has large areas to receive visits and the use of computers.
- *Commercial management*, usually arranged in the form of islands or groups promoting communication. It is mainly focused on computer use.
- *Management*, large work surface for computer work and other tasks.
- *Call center*, designed for exclusive use of computers and telephones so they are small in size.
- *Administrative management*, large size for computer, telephone and other administrative tasks. Modular composition.
- *Director's office*, designed to hold meetings in the post itself.

- Some projects involved are: DEMIUSIR: Development of computer furniture for a wheelchair user (PROMI) ADAPTOFI: Adapted from office ergonomics to workers with problems of seated (IBV-COCEMFE) ADAPREC: Ergonomic Adjustment industrial jobs (IBV-CEAPAT), Development of office furniture for disabled users (HODEMA-IBV).

2 Ergonomic study

This section will initially consider ergonomic risks involved in office work and subsequently applied to wheelchair users.
Criteria for adaptation or ultimate achievement of a post in accordance with the needs of such users are:

- Limitations of scope in sagittal plane
- Limitations of scope in vertical plane
- User lateral mobility (obstacles)
- Mobility front of the user (obstacles)
- The existence of inefficient or awkward postures, which involves risks.

2.1 Musculoskeletal Problems

The Biomechanics Institute of Valencia (IBV) in its publication "Recommendations for the design and selection of office furniture" presents a national survey, which states that 24% of respondents say the neck-shoulder is the most affected part of the body, 19% eyes, 15% lumbar, head 9% and 7% of the dorsal area, see tab. 1.

Zone	% 1rst ill	% 2nd ill	No problems
Head	9	3	82
Eyes	19	14	61
Neck-shoulder	24	10	63
Dorsal	7	9	82
Lumbar	15	7	71
Abdomen	0	0	100
Legs	1,5	1	94,4
Right arm	0	1,5	98
Left arm	0	0,5	99
Right hand	0,5	0	99
Left arm	0	0	99,5

Tab. 1 Musculoskeletal Problems.

Thus, musculoskeletal problems associated with office work, particularly in the computing tasks, are due to the following factors: restricted mobility associated with sedentary work. Poor posture, associated both with the seating (no back support, posture with his back very bent), and the position of the head-neck (bending or twisting of the neck to write or look at the screen, respectively) and the position of the arms and wrists while typing (arms without support, lack of space to support the wrist, ulnar deviation of hands typing).
On the other hand, the sitting position can cause other problems to circulation (numbness in the legs) due to pressure from the seat in the thighs and hamstrings and poor mobility of the legs (this question is to design their own chairs wheels).
Finally, we will emphasize back problems, and that over 80% of the population has an episode of this kind throughout his life. Poor posture and inappropriate furniture can cause this situation.
This pain is one of the most common causes of absenteeism. For example, it is estimated that 16% of U.S. casualties are caused by this trouble. Most decisive factors in the diseases of this type are: duplication of effort (not very pronounced), uncomfortable postures which overload muscles, physical inactivity, stress and dissatisfaction.

2.2 Environmental conditions

In this section you can distinguish those related to lighting and noise.

2.2.1 Lighting

The most common problem in today's office is related to the appearance of reflections on computer screens, associated with the presence of direct light sources, both natural (windows) and artificial. It is necessary to analyze the distribution of light sources in relation to job to avoid such problems, fig.2.

Fig. 2 Light effects

2.2.2 Noise

Standard noise levels in an office are often well below those needed to cause health problems. The main problem is associated with discomfort and interference that occur to concentrate at work or to have a conversation. In this way, conversations taking places around us are the most influencial source of noise.

2.3 Psychosocial Issues

INSHT recommendations in this regard are aimed at preventing the following situations:

- Overload or underload situations.
- The repeatability that can lead to monotony and dissatisfaction.
- The improper pressure of time.
- The social isolation that prevent social contact in the workplace:

2.4 Specific risks and limitations of wheelchair users

- The most common mismatch between the tasks and skills are mainly subject to the following aspects:
- Physical
- Dimensional (scope and gaps)
- Sensory

3 Specifications

One of the main points of any design process is the establishment of specifications, since it is when the requirements of the final product are set out. In order to specify the design parameters in the studied case, some preliminary issues will be considered, such as:

- Anthropometric data of wheelchair users
- Size of the wheelchair
- Restrictions on mobility and range
- Restrictions imposed by the rules

3.1 Anthropometric data

Design can be influenced by two different types of human body dimensions;

- Static dimensions, measurements of the head, torso and limbs in Standard positions.
- Dynamic dimensions, which are measurements taken in working position during the movements.

The CEAPAT, Center for Personal Autonomy and Technical Aids in the technical guide in building accessibility and IBV, Institute of Biomechanics of Valencia collected anthropometric data of the Spanish population in a wheelchair, the dimensions are eloquent and serve to guide in establishing specifications.
In Tables 2 and 3 show dimensional analysis work undertaken by the Polytechnic University of Valencia (UPV) to 99 wheelchair users.

Variables	Mean	S	P5	P95
Weigth	65,1	13,1	43,7	86,6
Heigth	168,9	10,6	151,5	183,6
Waist	91,8	10,9	73,9	109,6
Head-to-ground height	124,3	7,6	111,9	136,8
Head-seat height	77,8	9,5	62,2	93,4
Eye-ground height	112,3	7,3	100,3	124,4
Eye-seat height	65,9	9,3	50,6	81,2
Shoulder-ground height	97,9	6,8	86,9	109
Shoulder-seat height	51,5	8,7	37,2	65,8
Elbow-floor height	69,1	4,8	61,2	77
Elbow-seat height	22,6	6,8	11,4	33,8
knees -floor height	63	4,5	55,6	70,4
Span	158,7	14,8	134,5	182,9
Wide shoulder	44,6	4,6	37	52,1
Wide hips	36,6	4,8	28,7	44,5

Tab 2. Anthropometric data male wheelchair users. Kg and cm units.

Variables	Mean	S	P5	P95
Weigth	57,4	11,1	39,3	75,5
Heigth	162,2	9,1	147,3	177,1
Waist	85,5	10,5	68,4	102,6
Head-to-ground height	120,5	7	109,1	131,9
Head-seat height	73,9	8,4	60,1	87,7
Eye-ground height	109,4	6,8	98,3	120,5
Eye-seat height	62,8	8,2	49,3	76,3
Shoulder-ground height	94,6	5,9	85	104,1
Shoulder-seat height	47,9	7,5	35,6	60,2
Elbow-floor height	68,2	4,8	62,1	76,1
Elbow-seat height	21,5	6,1	11,5	31,5
knees -floor height	62,6	5,3	54	71,2
Span	152,6	10,3	135,6	169,5
Wide shoulder	41,7	3,9	35,2	48,1
Wide hips	35,9	4,1	29,1	42,7

Tabla 3. Anthropometric data female wheelchair users. Kg and cm units.

3.2 Wheelchair measurements

The real importance of the wheelchair is on the limitations of movement that the user may suffer and on the limitations of range, uncomfortable postures and ineffective job performance.
The dimensions of the most relevant wheelchairs and some of the relationships between these and certain design aspects are specified in Figure 3.

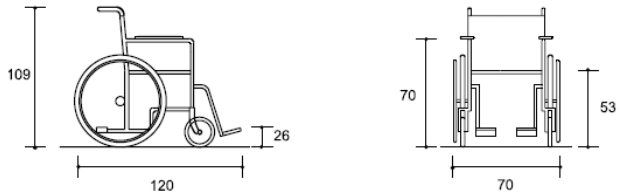

Fig.3 Measures of the wheelchairs

To produce a correct longitudinal displacement, it is necessary that the width between two obstacles which have to pass the user is at least 91 cm or 81 cm. provided that width not longer more than 61 cm. So that there will be no problems with his arms drive. The minimum diameter for a full rotation is 153 cm, see fig. 4.

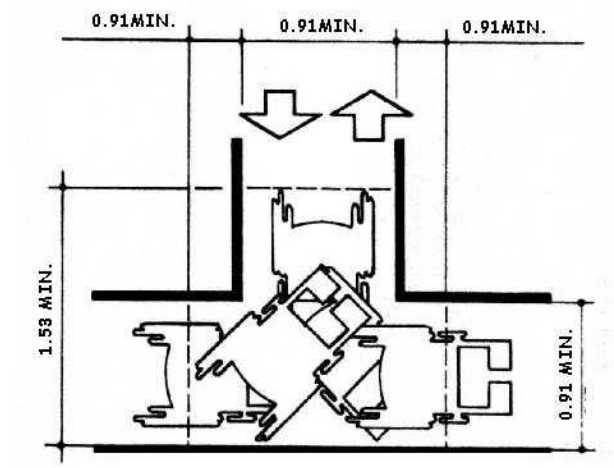

Fig. 4 Longitudinal and transverse size.

3.3 Mobility and range constraints

In matters of range it is combined the features of the vehicle with the users themselves, being necessary to know previously the dimensional static characteristics.
Constraints will condition the design of shelves and storage units.Refering to that, there are a series of charts, prepared by APRODIS (Association for the Development of Persons with Disabilities), which will be useful to understand the baseline design.

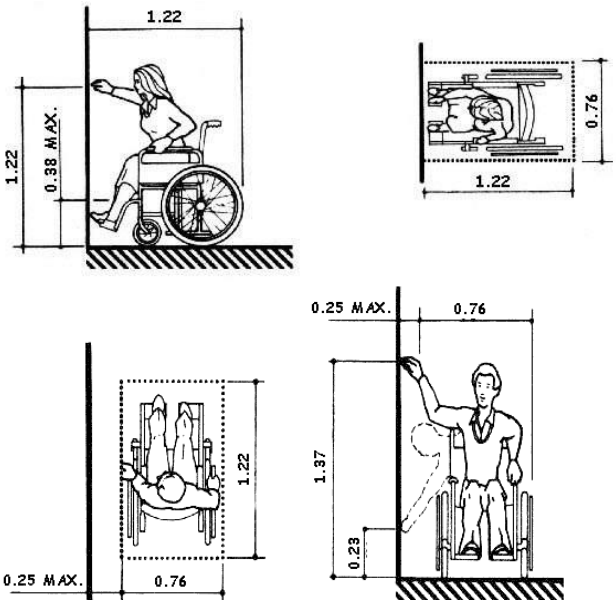

Fig. 5 Range schemes

4 Design

The main objective of this phase is to get the job according to the premises established in the specifications.
The current jobs tend to minimize the overall volume, and to integrate into itselfs as many items as possible to make the development of different tasks easier to users. This integration should be achieved with greater clarity, since the user is more limited in their movements.
It should be tried to have in the same position, regular file system for different user types of auxiliary storage systems, such as trays and briefcase, also adjustable in range, heigh adjustable surface for working in a comfortable way, etc.
At the same time, the structure should be as simple as possible and with minimum volume, to procure the user enough space to move freely in the post. This last aspect is the most important, so that the free space under the dash becomes a priority. This is intended by the "vertical growth" of the workstation, at which top are contained all the elements. The versatility of the post must be due to a simple, modular and adjustable structural design. In this respect, it is pointed out the concept of metal sections included in this idea, which is based on orthogonal profiles with guides on all sides, to introduce structural elements.

Fig. 6 Photorealistic image of the furniture designed

The initial layout is based on an area where it is concentrated most of the structural efforts (pillars on the left) and a single column on the right, giving it enough space to the user to move easily. Stability on the base left single pillar is produced by small square brackets, dimensioned according to mechanical and anthropometric criteria in such a way that it ensures the quiet of the place before efforts, and doese not restrict user mobility.

4.1 Structural elements

The structure of the designed workstation is totally metallic. The items that make up are the profiles or pillars, beams and brackets. The asymmetric configuration is mainly due to specific design needs. The left side of the office table, destinated to accommodate the drive drawers and storage, provides total rigidity. It is composed by four profiles connected by means of six beams (four longitudinal and two transverse). From this group, it comes out a longitudinal bar that ends in a unique profile located approximately 1400 mm of this group. The function of the beam is to provide rigidity in the horizontal plane, the pillar, and therefore the entire board is supported by the brackets, fig. 7.
To mitigate the tendency to roll, two legs (the same angles, as discussed below) are arranged in the bottom of the profile in order to give consistency to the overall position. These brackets hold the board, being anchored to the profiles. That is why it is important to confer rigidity to the post by the stringer.

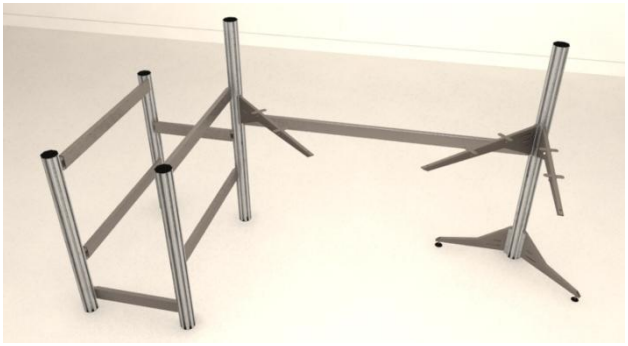

Fig. 7 Structur

Furthermore, the width of a standard board is around 25 mm, and the screw hole of the bracket is placed 35 mm from the joint surface with the board, to the established heights for work, it shall be deducted the approximate 60 mm. In this sense, if the minimum recommended height for computer use is 660 mm, combining the height of elbows P5, 640 would be a good initial height, so the first hole can be located at 580 mm. Setting the ranges of 30 mm (the maximum recommended is 32 mm), and setting from 670 mm, shorter intervals to achieve better regulation, the average is 750 mm at the last hole, giving coverage to the P95, also under the criteria field study.
The height intended to set the board are:
580 - 610 - 640 - 670 - 690 - 710 - 730 - 750
The wiring canalization will be carried out in the post by plastic channel.
For the design of the brackets, due to its pure structural function, it is necessary to address the mechanical requirements. So, the critical reference force is 750 N, as it is the requirement for the board. This mechanical question get surpassed choosing a metallic material such as aluminum or steel safeguards (forwards you will find the development of the material selection and characteristics). One way well studied will also help to support the efforts required.
The Requirements Compliance gets over rules in the sizing of furniture (part of the UNE 527, 1023, and 14,073).

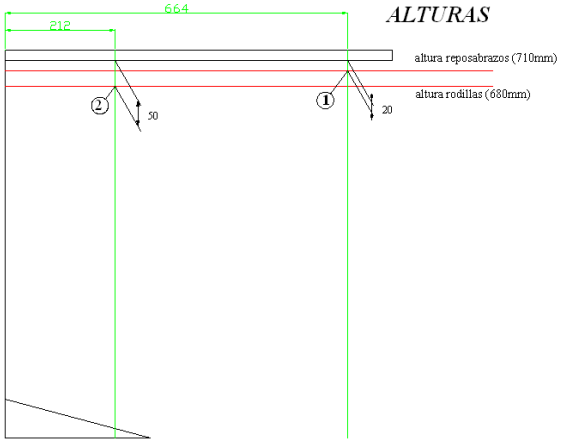

Fig. 8 Squares measures

Figure 8 shows the profile of a hypothetical table, with set dimensions (750mm in height and depth of the work surface). The red lines represent the heights of the P95 for the knees and the armrests of wheelchairs.

4.2 The board

The board has been designed under OFITA criteria. So that it will be mixed with adjustable height and with an asymmetric configuration.
The depth of this in the computer area will be approximately 800mm, deeper than the "administrative" one which will be around 750mm. See fig 9.

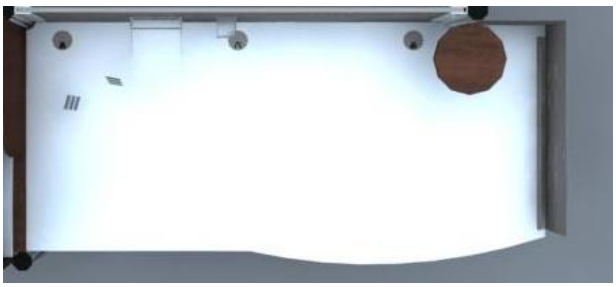

Fig. 9 Image board

4.3 Optional Hand

The extra table is an optional element designed to increase work surface or to change character set. It is designed under lateral coverage criteria and requirements of rotation. The squares are small and attach bolts to support the same main board. Verification has been made of rotation unobstructed.

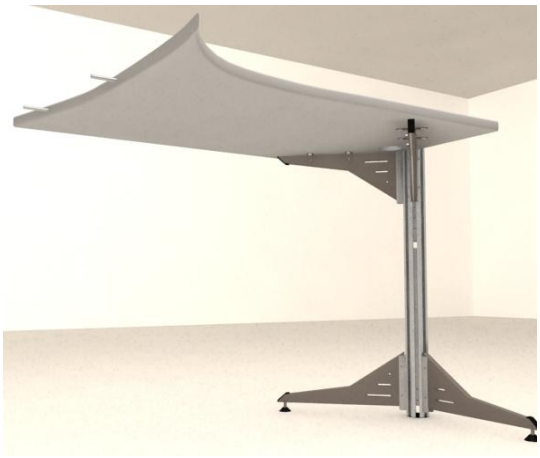

Fig. 10 Optional Hand

4.4 Accessible filing system

Affecting the lateral range width it was taken into account extraction determined under scope, with enough volume for folders and sliding rails anchored, see fig. 11.

Fig. 11 Picture of storage furniture

4.5 Drawers

The drawers are adapted to the trading system by means of binding to two sheets, formed by sliding to three heights. The fixing of the sheet to the rails (top and bottom) allows a front access opening (300mm free).

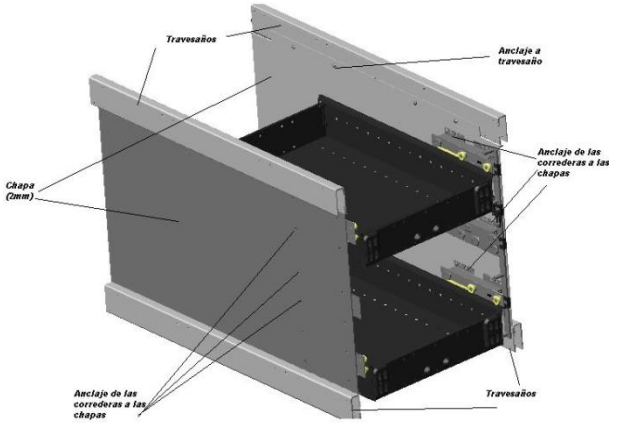

Fig. 12 Drawers

Finally, we must take into account the trim and covering.

5 Review

On the one hand this section describes the pure aesthetic analysis and on the other hand ergonomic simulation.

5.1 Aesthetic analysis

The color range of the stand is based on neutral and subtle (wood, grayscale ...) tones which were chosen based on environmental criteria. The colors are used to convey a sense of elegance, quality, tranquility and sepsis that will help the user to concentrate on the task (mental function). Organic forms present in the object produce spontaneity and lightness. The geometric shapes of the profiles give a sense of softness, ductility and dynamism. The textures are smooth and soft. Moreover, the juxtaposition of volumes that are generated in response to the drawer to the storage unit, the partition and computer placed and on the other hand, the sense of minimalism or potential volume of the structure. The lighting is intrinsic to the object in aluminous elements, which emphasize the lightness of all, while matte surfaces, it provide plasticity.

5.2 Ergonomic Analysis

Simulation has been performed with different situations, one of which corresponds to a 95 percentile male user, by applying the method ERGODIS, it emphasizes the data shown in table 4.

	Distance (mm)
Head-floor	1409
Elbow-floor	746
Size	1713
Knees-floor	680
Heigth of table	770

Tab 4. Data for P95 male.

5.2.1 Range analysis

In the analysis of scope it is easy to assume that the position is comfortable.
The main factors are: increased shoulder flexion (80 °), lateral separation average (70 degrees), mild wrist flexion (15 º) and very slight turn of this one (5 °), combined with a slight twist of the elbow (50 °). The frequency of performance is medium. The load is medium-low due to the steel ball bearings, low friction and weight of the unit.

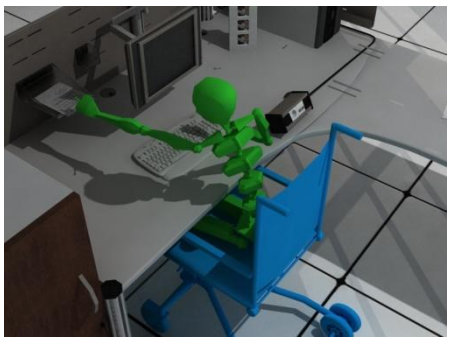

Fig. 13 User-wide simulation

5.2.2 Rating of moves and turns

The wheelchair comes with no problem in the workstation, it does not affect the extra table.
Other important constraint of space under the table is that imposed by the brackets which support the main board. This question is trivial in the case of two teams that are arranged in diagonal, on the main board, since for its design was considered the maximum height on two levels

deep. So that there will not be intersection there. However, to enhance the flexural strength of the board it was required to establish a large square on one side of 0 °, so that these restrictions are violated.

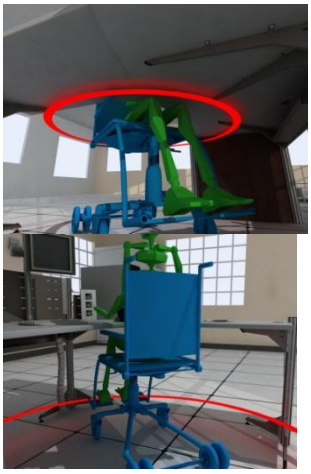

Fig. 14 Rotation analysis

6 Conclusion

The assessment of adaptation has produced extremely satisfactory values, however, there are two positions that could be improved or at least they are worthy of consideration. Aside from that, it means that the space allocated under table is extremely broad in order to an end user was able to move without any restriction.

On the other hand, the surface is large enough to be able to distribute work based on the needs at any time, so that issues of scope and management of the computer, or side table are in the background because with a simple change of the workplace is mitigated any difficulty. In addition, this,what may seem an excuse to justify this, it is reinforced if we look at the technical notes regarding prevention and ergonomics rules, which recommends workspace enough to change positions throughout the day so as not to fall into the "sedentary. " However, planning a modular electrical adaptation solves the problems which could be considered while handling the computer, or enlightenment, etc in an aesthetic and integrated way.

Dealing with imbalances appeared, we can say in defense of the design firm, they pass the to background when you consider that:

On the one hand, the place has enough storage space to house the documents needed for work (and drawer storage unit.) Therefore, the need of more storage space is in subject to saturate the headspace completely.

Another interesting issue is that the drawer has the opportunity to have an intermediate box, so if you need a hanging file folders, simply move the module down to the middle position of the sheet, solving the problems of range.

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