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Ergonomic Design Knowledge Base

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Abstract: - The ergonomic and aesthetic aspects of the products are more and more important, especially when the utility goods for every day use are being designed. In general, computer-aided design tools do not assist designer with higher level advice when dealing with ergonomic appropriateness and aesthetic appearance of design. Designers have to relay on their own knowledge and experiences or ask for help human experts in this specific field of design. Unfortunately, such experts are quite rare. The alternative way that can be taken to overcome this bottleneck is to apply some intelligent computer programs with expert knowledge. This paper presents the proposed architecture for the consultative intelligent computer system for supporting the aesthetic and ergonomic design. Emphasize is given to the knowledge base of the sub-system responsible for the ergonomic design aspects. The ergonomic design rules and recommendations are presented.

Key-Words: - intelligent advisory system, expert knowledge, knowledge acquisition, production rules, hand tools

1 Introduction

In the last decade, the application of the intelligent systems for supporting various phases of design process is becoming more and more important [1]. The effectiveness of the system depends mainly on the quality of the knowledge base and the appropriateness of the system's inference engine. The domain knowledge can be collected in different ways:

- by studying relevant literature and standards,
- by studying relevant projects,
- by interviewing human experts.

When the knowledge is acquired, it has to be organised and arranged in a way that allows the inference engine of the system to access and use this knowledge effectively. For that purpose the appropriate formalism for the knowledge representation has to be chosen. In the field of design, production rules are the most commonly used formalism for encoding knowledge, as they are quite similar to the actual rules used in design process [2].

This paper will present a development process of the knowledge base for the ergonomic part of the intelligent advisory system for supporting aesthetic and ergonomic design, that we named Oscar.

2 Short presentation of Oscar

Like many other intelligent systems, Oscar is being developed in order to support designers when dealing with aesthetic and ergonomic aspects of design. The system is composed out of two sub-systems that can be applied in two different modes. We can namely use them independently from each other, or simultaneously and interdependent on the same design project [3]. The proposed structure of the system is presented in Figure 1.

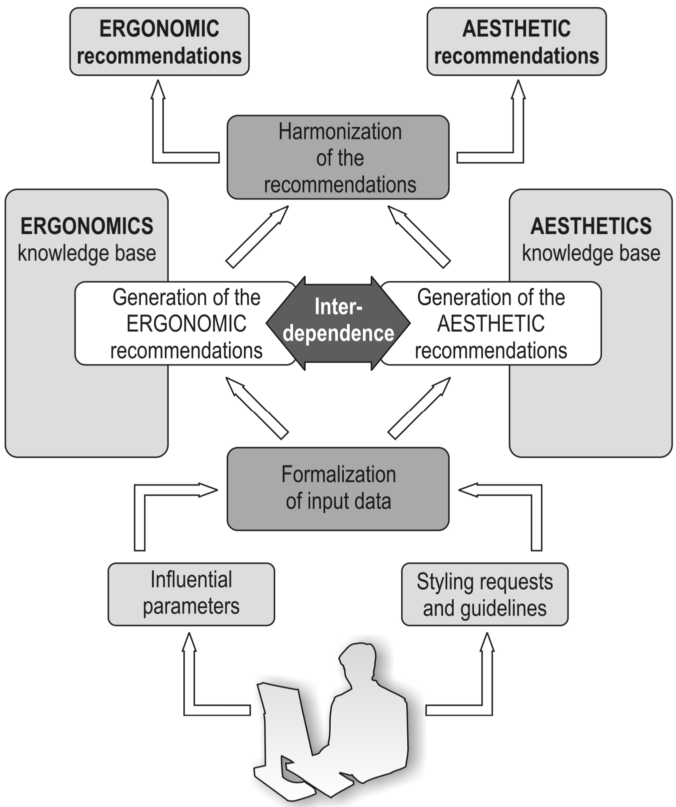

Fig. 1. The architecture of the proposed intelligent system.

At the beginning of the work the user is asked to present some facts, influential factors, requests and guidelines regarding specific design case to the system.

After the information is presented to the system, the data processing can take place. During this phase the user can expect some more questions to give the additional information, in order to ensure an adequate solution. In the simultaneous mode, the task of the inference engine is also to synchronise and harmonise derivation of the recommendations for aesthetic and ergonomic design, which are presented as the results at the end of the data processing.

3 Development of the knowledge base for the ergonomic design sub-system

3.1 *Step 1*: Knowledge acquisition

Because the knowledge and data related to the ergonomic design are very extensive, we have decided at the start to limit our research on the field of the hand tool design. When dealing with the hand tool ergonomics, static and dynamic anthropometry of the human hand needs to be taken into consideration [4].

In our case, the anthropometric data have been searched and collected from various sources, such as books, handbooks, standards and internet. This data need to be considered and reflected in the ergonomic recommendations [5].

The important part of the knowledge acquisition process was also an exact specification of the global hand tool ergonomic design goals [6-8] that need to be followed by the designer of the hand tool to meet health, safety and efficiency requirements. Here is the list of some goals that were recognised as the most important ones:

- consider the anthropometrical data to define dimensions and configurations;
- maintain wrist in the neutral straight position;
- avoid tissue compression;
- reduce the excessive forces;
- protect against vibrations, heat, cold and noise;
- ensure the task could be performed at the appropriate height;
- reduce the static load;
- consider cognitive ergonomics.

In continuation, the hand tool ergonomic design knowledge base is presented in terms of detail description of the above goals associated with the recommendations how to carry them out at design phase.

3.1.1 Appropriate dimensions and configurations

In order to define the appropriate dimensions and configurations of the hand tools the anthropometrical data are transformed into ergonomic recommendations [9]. Table 1 presents some of the "anthropometrical recommendations", which are presented graphically in Figure 2.

TABLE 1: ANTHROPOMETRICAL RECCOMENDATIONS.

Parameter	Value
Handle cross - section	Round or oval
Handle diameter - power grip	min. Ø 32-45 mm
Handle diameter - precision grip	min. Ø 7-15 mm
Handle length	min. 100 mm
Handle length - with gloves	min. 114 mm
Pistol grip handle angle	80°
Grip span (pliers, cutters etc.)	63-89 mm
Grip curvature (pliers, cutters etc.)	13 mm

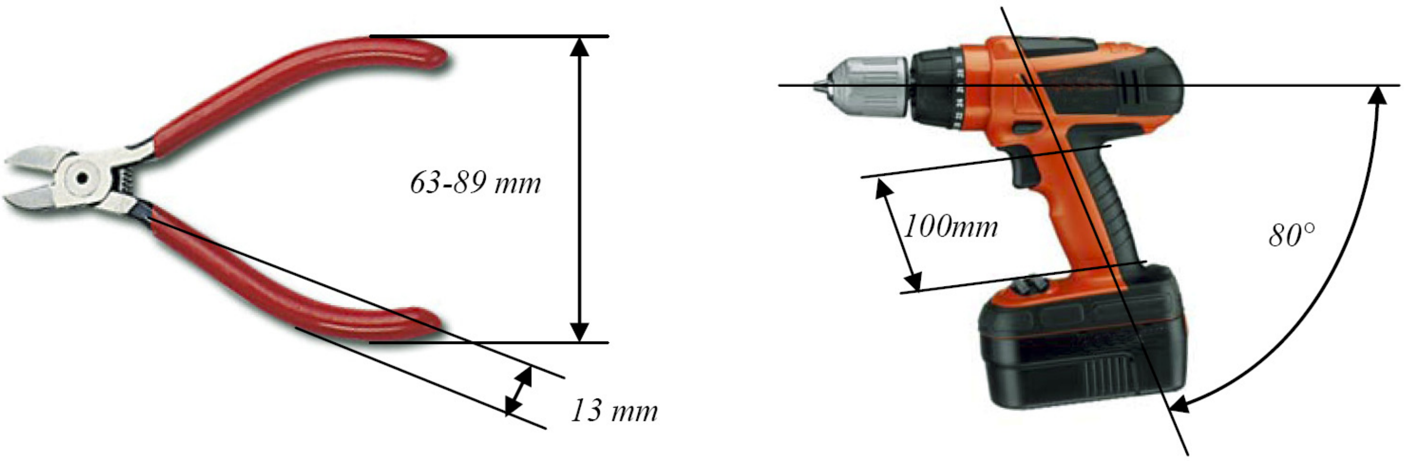

Fig. 2. Graphic presentation of the anthropometrical recommendation.

3.1.2 Maintain wrist in the neutral straight position
All movements of the wrist, especially those cases in extremes of these movements, in connection with repetitive finger actions or prolonged forceful finger exertions, place extensive pressures upon the flexor tendons passing through the carpal tunnel. This may cause inflammation of tendon sheath and pressure upon median nerve and in consequence even serious injuries. Bending the wrist, while performing the task, which requires repeated rotation or twisting of the forearm, can also stretch and pull the tendon connection at the elbow. Repeated stress at this connection can cause irritation and swelling, leading to so called tennis elbow. When the wrist is straight, tendons can slide easily through the sheath.

Recommendations:

- Use pistol grip for tools, which are used on vertical surfaces. The type of the grip used depends on the work piece height.
- Use inline grip (cylindrical grip) for tools, which are used on horizontal surfaces. Again, the type depends on the work piece height. For example, for the horizontal work piece in a femur level, the pistol grip is suitable.
- Use deviated handles, which maintain the straight wrist for tools for specific tasks.
- Provide adjustable handles for tools which work in several different positions.
- Use power tools instead of traditional tools for tasks which require highly repetitive manual motions.

3.1.3 Avoid tissue compression
Local pressure upon tissues of a palm or fingers may cause loss of circulation, damage nerves, leading to tingling of fingers; or damage tendons or muscles, leading to pain and difficult hand movement. This unsuitable pressure is caused by insufficient handle length (thickness) or hard surfaces on handles.

Recommendations:

- Use handles of adequate length (thickness) that span the entire hand.
- Use padding to soften the handle surface.
- Use contoured handles which spread the pressure over a large area.

3.1.4 Reduce the excessive forces
Exertion of high finger forces, either prolonged or repetitive, can stretch and in turn fray tendons. This kind of damage can make it difficult for the tendon to slide through the tendon sheath, which can lead to further irritation and swelling. Irritation and swelling can lead to restriction of the tendon movement through the sheath, eventually causing so called trigger finger. Especially combination of both repetitive and prolonged motions can lead to permanent disorders, and carpal tunnel syndrome. Excessive forces may also overload muscles and create fatigue and potential for injuries. Highly repetitive tasks which may not use so great force can also cause irritation.

Contact with sharp edges of tools or bending the wrist greatly increases the hazard associated with the use of forceful finger exertions. Repetitive bending and loading of the elbow may lead to the tennis elbow disorder.

Recommendations:

- Use power grips and avoid the use of forceful pinch grips with straight fingers. One can exert more force with the power grip than pinch grip.
- Use the appropriate grip size. To generate the most grasping force, design objects to a size that permits the thumb and forefinger to overlap slightly.
- Reduce resistance of tool activators (triggers, trigger lockers etc.).
- Use the alternative non-mechanical triggers (vacuum, optical etc.).
- Increase leverage within the tool. Add more fulcrums. Extend lever arm.
- Improve tool balance. Reduce tool length. Locate heavy masses such as motor, battery, etc. as close as possible to the wrist.
- Where relatively large force is needed to activate the tool (hydraulic or pneumatic power tools) use trigger levers for more fingers instead of single point trigger to spread the activating force.
- Avoid sharp edges on triggers and handles.
- Add the second handle located near the front end of the tool to spread exertion between two hands. In this way the control of heavy tools and tools operating with large torque is also improved.
- Increase contact friction on handles. Use non slip, nonporous and slightly compressible materials.
- Use a collar where the force is applied coaxially to the handle. It may reduce the grasping force.
- Use the expanding springs to prevent the constant need of opening handles.
- Use the power tools instead of traditional tools for tasks which require high excessive motion.

3.1.5 Protect against vibrations, heat, cold and noise

Local vibrations may cause circulation disorders, white fingers or other serious CTDs. Enhanced noise may increase fatigue and stress; and may cause problems of hearing. Hand may be affected by vibrations in range of 1,5-80 g and 8-500 Hz.

Recommendations:

- Improve the overall tool design taking into account the natural frequencies to decrease vibration distribution from the motor or other source of vibrations into other connected parts and handles.
- Use isolation mounts such as springs and rubber silent blocks between individual parts.
- Use damped tool handles.
- Use damping materials on a handle surface.
- Use heated handles where needed.
- Cover hot parts of the tool such as motors etc.
- Clean and adjust power tools periodically.
- Remark: sound (noise) is a consequence of vibrations, actually vibrations transferred from the tool into an air and than into human ears; therefore same recommendations can be used analogously for decreasing the level of noise.

3.1.6 Ensure the proper height for the task

Working in position that implies the elbow raised and maintained above the shoulder height for prolonged periods can trap nerves and blood vessels under the bone and muscle, which leads to numbness and tingling in the hands, and can fatigue the muscles of the shoulder and upper arm.

Recommendations:

- Design tool handles and other features to fit in the proper working height level.
- Reduce muscle exertion and improve control over the tool.
- For heavier manual work with the heavy power tools, design the tools for use at the hip level, with the tool close to the body and the angle between the upper arm and forearm in range of 90°-120°.
- For precision work with lighter tools, design the tools for the use at the elbow level and higher.
- Use extended poles for work above the head.

3.1.7 Reduce the static load

Holding the same position for a period of time can cause pain and fatigue. The primary problem is the time of duration which can be increased by high force or awkward posture.

Recommendations:

- Reduce the weight of the tool.
- Use tool supports.
- Improve tool balance. Reduce tool length. Locate heavy masses such as motor, battery etc. as close as possible to the wrist.

3.1.8 Cognitive ergonomics

Cognitive ergonomics deals with a mental interrelationship between the human and the artefact. The goal of this ergonomic sub-discipline is to prevent mental overload and misunderstanding when operating the tool.

Recommendations:

- Use red colour for switch buttons or for warnings and dangers.
- Use vertical switches with the following meaning: up-ON, down-OFF
- Turning a dial to the right increases the speed, torque or power.
- Use numbers: 1-slow....10-fast.
- Use the right hand to operate the trigger and other controls.

3.2 *Step 2*: Encoding the knowledge

After the acquisition phase, the collected knowledge needs to be encoded into the knowledge base in form that can be used within the intelligent system. As argued in the *Introduction*, the production rules [10] were chosen as the most suitable formalism for presenting knowledge in the Oscar system.

Following the basic structure of the production rules, the rules dealing with ergonomic design aspects have the form:

IF *Fact 1 has Value 1*
AND/OR *Fact 2 has Value 2*
AND/OR …
AND/OR *Fact n has Value n*
THEN Apply one or more:
Design Recommendation 1
Design Recommendation 2
...
Design Recommendation m

Different combinations of the facts and their values determine different list of ergonomic design recommendations. Table 2 shows some of the facts used in production rules and their corresponding values.

TABLE 2: SOME ERGONOMIC FACTS AND POSSIBLE VALUES.

Group	Fact	Value
Tool description	type	tool, hand tool, equipment, work place, …
	use style	handle, horizontal direction, grip, …
	contact surfaces	grip, palm push button, foot, …
	weight	low, medium, high
	material	steel, steel casting, plastic, rubber, …
	mechanical vibrations	horizontal direction, all directions, …
	acoustical vibration	none, low, medium, …
User	sex	male, female
	age	18 - 55
	estimated size	average, large, …
	left or right hand use	both
	protection equipment	safety gloves, safety shoes, helmet, …
Work environment	estimated location	construction place, office, vehicle, …
	work conditions	dust, humidity, darkness, …

Considering the data presented in the Table 2 and ergonomic design recommendations discussed in the previous section, we can construct the actual rules. Here is for example a simple rule for maintaining wrist in the neutral straight position:

IF *Type* is *Hand tools* for specific tasks
AND *Contact surfaces* are *Grips*
THEN *Use deviated handles*

3.3 *Step 3*: Result presentation

When the data processing stage is finished, the results have to be presented to the user. Both, textual and graphical presentation of the proposed design recommendations are anticipated to be used. Figure 3 shows graphical representation of the ergonomic recommendation, which is the result of the rule presented on the left hand side.

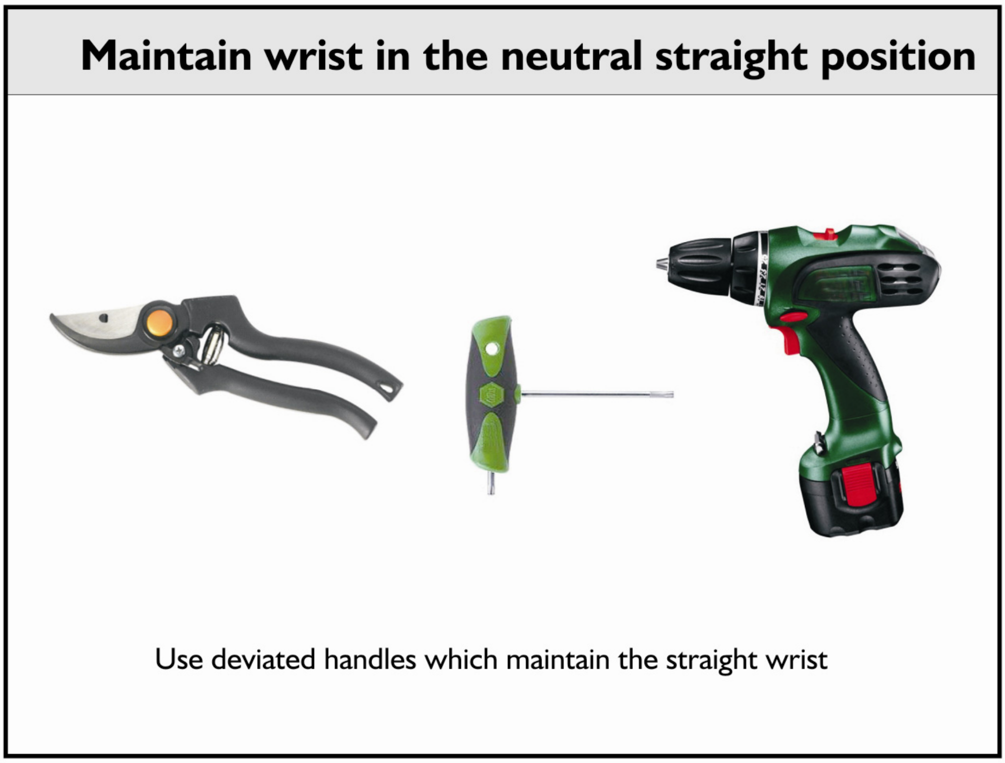

Fig. 3. Graphic presentation of the ergonomic recommendation.

4 Conclusion

The knowledge base is the key foundation of every intelligent computer system. Therefore, a lot of attention has to be dedicated to development of the knowledge base.

In this paper, we present the knowledge base for intelligent consultative advisory system, meant to propose design recommendations considering the ergonomic aspects of design.

The most important development phases are discussed, starting with the knowledge acquisition, followed by the selection of the appropriate representation formalism and actual encoding of the rules. A clear presentation of the proposed design recommendations is also very important. Thus, we decided to use graphical presentations for that purpose.

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