Biomechatronics Recovery Systems For Persons With Disabilities

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Abstract

An exoskeleton is a mechatronic system which has the goal of to ensure an extra strength when muscles of humans are affected and don't achieve the driving force necessary. As structural exoskeleton are used orthotics and the prostheses. The orthosis is a medical device which is applied at the level of a body segment in the goal of prevention or correction the gap that segment. The prosthesis is a medical device which makes part of the biomechatronics field and which deals with the substitution a segment of the human body. In this paper it illustrate how to design a structural exoskeleton.

Keywords

exoskeleton, locomotion, robotics, mechatronics, orthosis**.**

Introduction

The purpose of this work is to present various mechatronic systems which have an important role in the rehabilitation of humans with different disabilities such as: the paraplegia, the spastic paraplegia, spastic diplegia, hemiplegia.

In nowadays there is a big category of mechatronic systems used for rehabilitation human subjects. The exoskeletons part of mechatronic systems used in psychotherapy and training for different categories of human subjects: [1].

The body is the mechanism which must be controlled. The body is controlled with the help of human brain. If the human muscles are affected and can't achieve in totally driving force necessary, attaches an exoskeleton which will to provide an extra strength: [2].

Generally the term of "exoskeleton" is used to describe a device which increases the performance of carrier, while the term of "orthosis" is used to describe a device which prevents or corrects the malfunctions of certain areas. So, the objective of basic of using orthosis is maintaining and/or functional recovery of body segment at the level which is applied: [3].

Exoskeletons and orthotic systems have classified in four categories: series-limb exoskeletons, parallel-limb exoskeletons for load transfer, parallel-limb exoskeletons for torque and work augmentation and parallel-limb exoskeletons that increase human endurance: [3].

Over a century, technologies and scientists have developed this field of exoskeletons and orthotic systems for rehabilitation of humans with various deficiencies. The advances in this field have been truly impressive, but there are still many challenges associated with exoskeletal and orthotic design that have yet to be perfected: [3].

A challenge in the field of exoskeletons is a lack of underlying mechanisms that are responsible for control of movement in humans and how those interact with a robotic device in parallel with the human subject. It is impossible to know how various design, sensing and control choices should be made in order to maximize the performance of the human subject while minimizing the interference with the subject preferred movement strategies: [4].

In nowadays disabilities which appear at the level lower limb, upper limb and the procedures of rehabilitation of gait are based on recovery through physiotherapy. The use of such exoskeletons for the rehabilitation of people with disabilities improves first the procedures of rehabilitation and second it obtains the motivation and the independent from human subject: [5].

Lower limb robots are wearable devices that can be classified according to their particular application as assistive devices: for human impaired movement or for human power augmentation. These robotic devices might take the form of exoskeletons, orthoses, prosthetic devices or soft robots. In last year are developed many platforms for rehabilitation of gait, but few were looking at successful. Because of this were developed rehabilitation robotics exoskeleton and the benefits of this are many. A robot exoskeleton allows the achievement of training by rehabilitation more consistent following the progress of humans regarding the movement: [5].

This robots of rehabilitation are use when the humans are suffering by different pathology such as the paraplegia or presents muscle problems which prevent the achievement of gait. These exoskeletons were developed to replace therapist manual assistance increasing the amount of stepping, practice while decreasing therapist effort: [6].

This paper presents first of all an introduction about the development exoskeletons and what means a device by type exoskeleton, in the second it is presented the conceptual structure of an exoskeleton and finally it is presented the concept of parallel robot with applications in biomechatronics.

The structure of an exoskeleton

The conceptual structure of an exoskeleton is presented in next image: compliant harness, exoskeleton thigh, exoskeleton shank, payload, exoskeleton backpack frame, power supply, powered hip, powered knee, powered ankle and exoskeleton foot: [7].

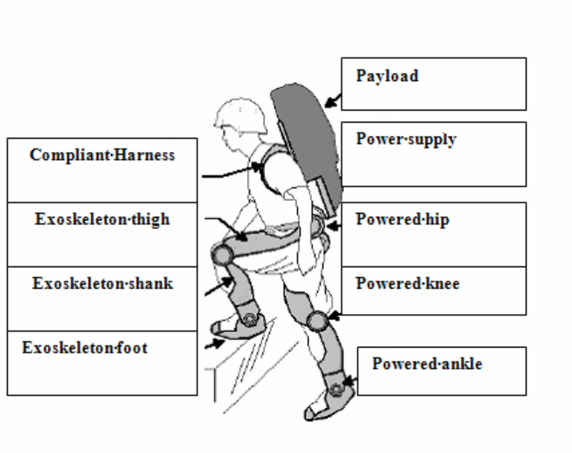

Figure 1: Conceptual sketch of a lower extremity exoskeleton

The developed structures are different through the way of materialization, but can be included in these categories with representation generalized: [8].

- The anthropomorphic structure made by elements and kinematic couplings engines according with the human body structure.
- The non-anthropomorphic structure which follows the development of directional of a features depending with the purpose followed.
- The pseudo-anthropomorphic structure is developed around of human body structure without to contain all degrees of freedom of this.

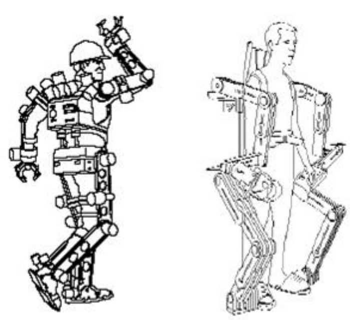

Figure 2: Structures for an exoskeleton

where: a) anthropomorphic structure and b) non-anthropomorphic structure

Values for geometric parameters corresponding degrees of freedom of human kinematic chain are presented in table 1: [8].

Table 1.Geometric parameters corresponding biomechanics of the human body

	Human Parameters	**Experimental version**	**Military experimental version**
ankle-flexion	14.1°	45°	35°
ankle-extension	20.6°	45°	38°
ankle-abduction	—	20°	23°
adductie-ankle	—	20°	24°
knee-flexion	73.5°	121°	159°
tibial-flexion	32.2°	121°	125°
tibia-extension	22.5°	10°	—
tibial-abduction	7.9°	16°	53°
adductie-tibia	6.4	16°	31°
external rotation	13.2°	35°	73°
internal rotation	1.6°	35°	66°

Case 1:
Based on this information on human biomechanics can develop the structure of an exoskeleton: [8].

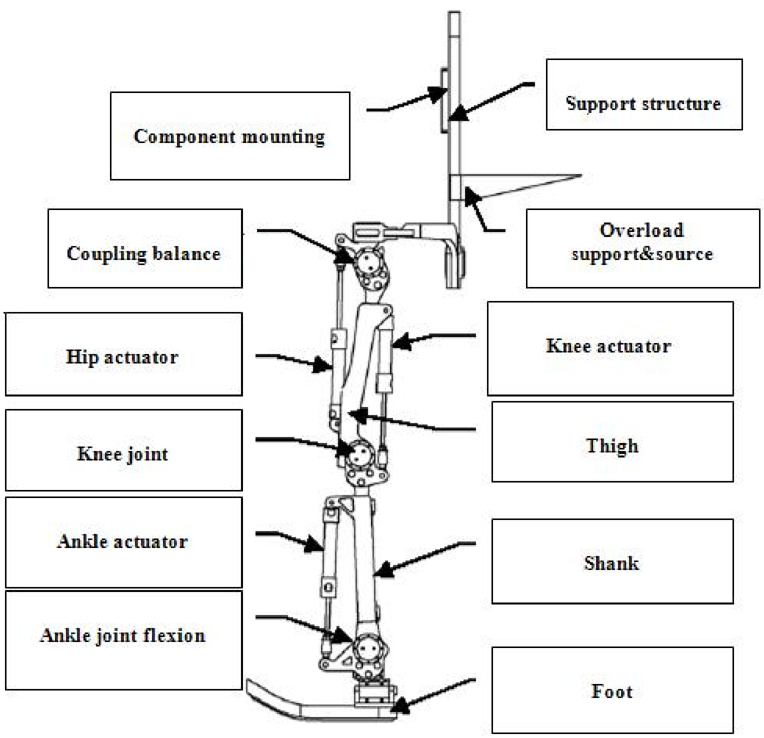

Figure 3: The structure with components subsystems

The design of an exoskeleton take in consider some criteria such as: the system table, the compensation of gravity forces, the ensuring of a big number of degrees of freedom, the safe operations and perception from humans, the safe reliability for all operations, the complexity relatively low and low cost, the simple evacuation, the low maintenance: [8].

Case 2:

Another type of exoskeleton very frequently used is the equipment MIT-MANUS. This mechatronic system is based on mechanism design whose characteristic point can attach subject's hand. The subject may impose a movement of robot or the robot can move subject's hand in horizontally scheme: [8].

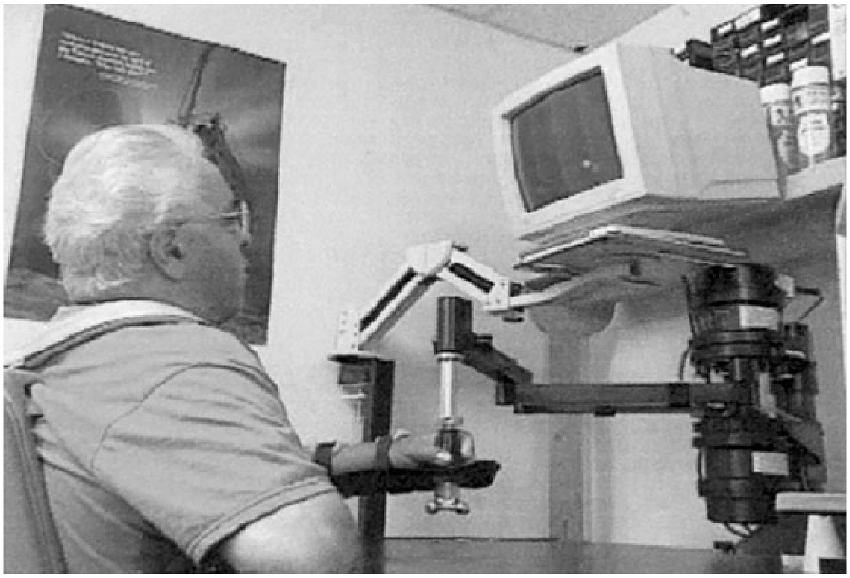

Figure 4: MIT-MANUS system used for rehabilitation

Case 3:

The mechatronic system MIME (Mirror Image Movement Enhancer) is an exoskeleton which incorporates a robot PUMA 560 for control of human hand in some movement. The movement can be made in 3D. This system is for subjects with different disabilities as semipareza: [8].

Figure 5: The system MIME

Case 4:

The mechatronic system ARM Guide is an exoskeleton which has the goal to assist a subject in execution of movement. The system has three degrees of mobility. The human hand is attached in the point S, a orientable support. An actuator M can assist the subject in performing movement R.

The movement R, P and Y is made on base of optoelectronic transducers. A force sensor is attached of interface robot subject. The system is balanced static by two counterweights: [8].

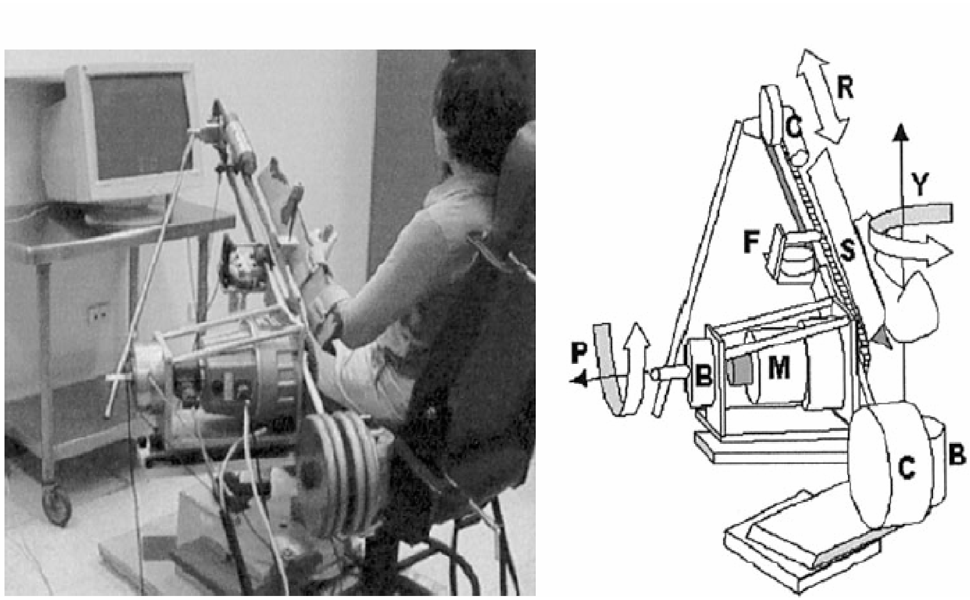

Figure 6: The system ARM Guide

Case 5:

The system MGT (Mechanized Gait Trainer) is a mechatronic system which has one actuator. An induction motor which is connected by planetary gear to two elements of supporting. The two points of supporting execute an ellipsoidal movement: [8].

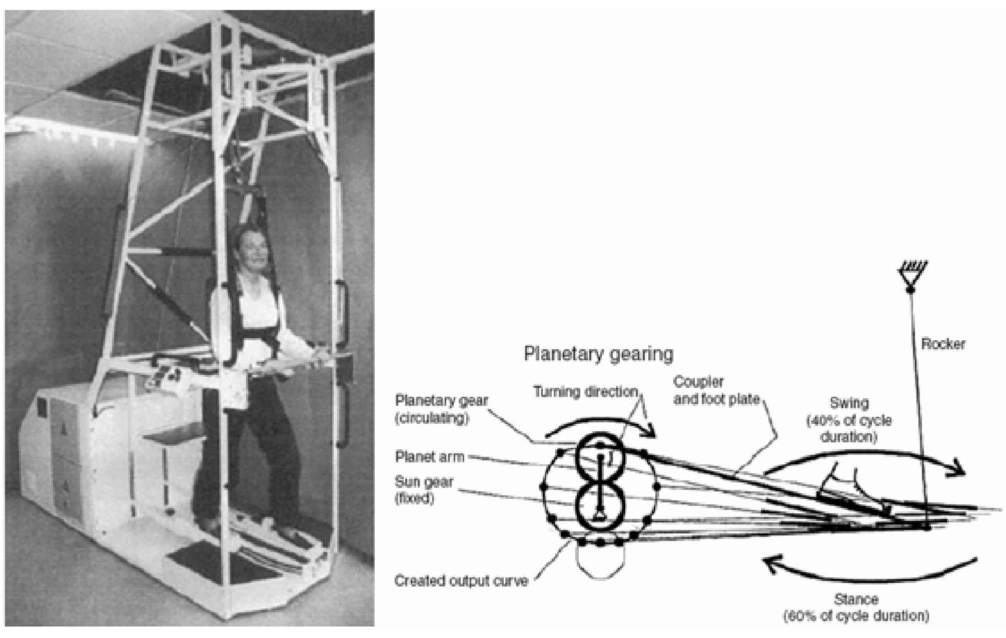

Figure 7: The system MGT

Case 6:

The system Lokomat is an exoskeleton for subjects with disabilities. A scheme kinematic structures is presented in the figure below: [8].

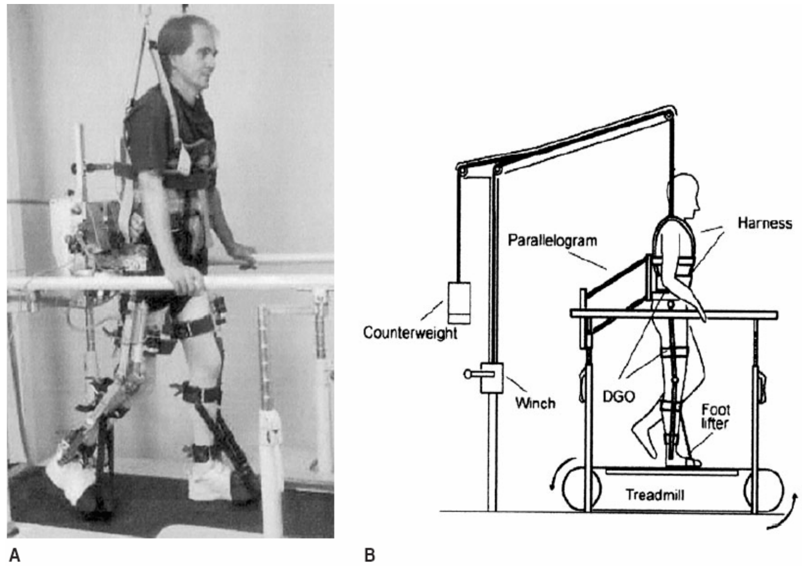

Figure 8: The system Lokomat

"Mechatronic philosophy" and parallel robot design

The parallel robot has applications in generating of solutions for biomechatronic systems for subjects with disabilities.

Parallel robot belongs through concept, design and applications to the mechatronic product class designed using the principles and procedures of the "mechatronic philosophy". The V design model-V design cycle is currently recognized and accepted in the field of mechatronic design. The V design cycle is presented in the figure below: [9].

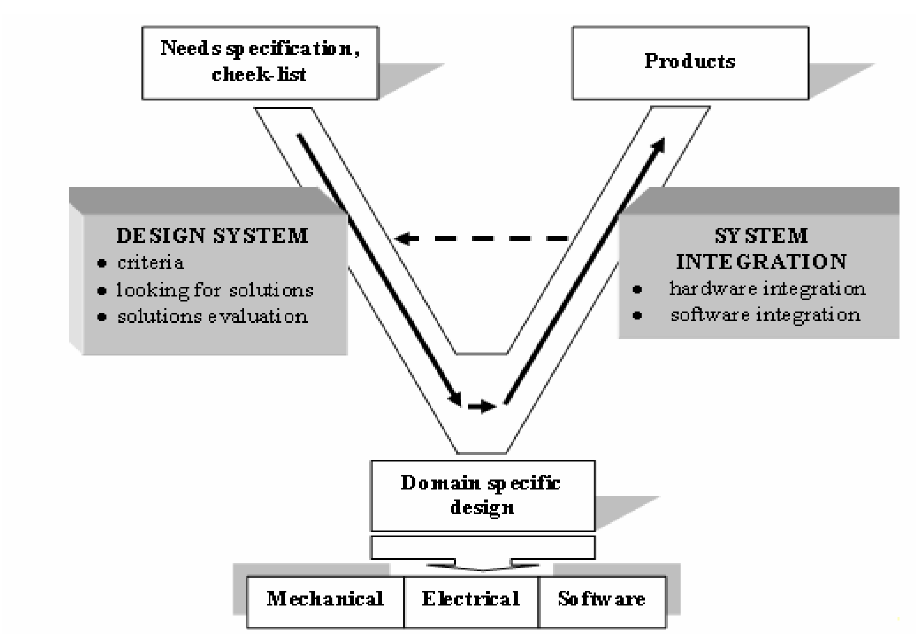

Figure 9: Mechatronics design and V design cycle

The systemic approach and the methods for developing new ideas play a key role in this growth.

Taking a decision in the design process can be greatly simplified by the system decomposition according the system function. Patterns development is achieved by evolving from abstract to concrete, from simple to detail: [9].

Figure 10 shows a case of system decomposition for a parallel robot in correspondence with the previously facts: [9].

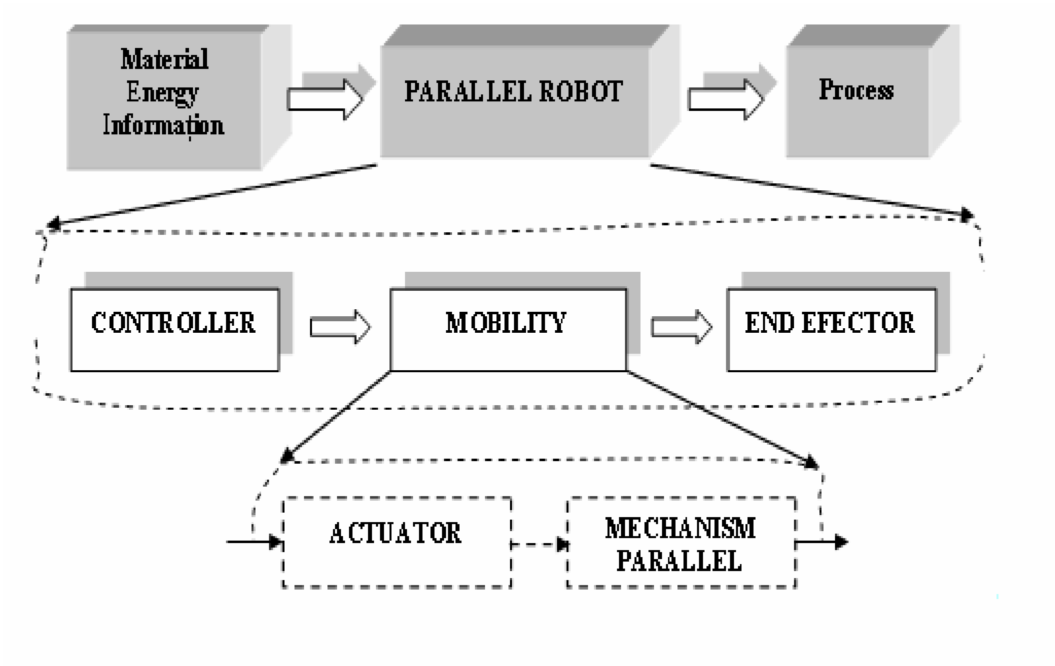

Figure 10: Decomposition of the robot system based on the function to be performed

The development of the parallel mechanism will ensure the mobility function for the robot system. The conception of several structural variants, which will be further dimensionally synthesized, according to a given application corresponds to the incipient stage in the system design and has to be based on a well defined simple and rapid model. One can use the kinematic connections method to solve this question: [9].

The aspects which must addressed as specification for project are obtained like individual construction or group. All this is in checklist which must analyzed in project stage. In order to ensure the success of medical robot must answered compulsory the following questions: [9].

1. Meets the parallel robot the fundamental requirement of safety?
   - Is the control efficient?Can be controlled the end effectors in all possible configurations?
   - The workspace is secured that must to be excluded any unwanted events?
   - Is provided the sensitivity at the end effectors?
   - Is provided the protection from electromagnetic interference with change of surgical systems?
   - The work programme of robot allows the intervention of human operator during an intervention in order to take and to coordinate the action?
   - Are provided the safety features in case of defects? What happens with the system if the supply with energy discontinues? How can distinquish a hardware error by a software error? How fast can the software to answer at external events?
   - Exist the possibility to avoid of singular points? Can the human operator to coordinate to avoid single points? Exist the possibility to warning the close of characteristic point by singular points?
2. The structure is compact? The parallel structure don't affects the brightness of the operating room? The volume attached of robot don't affects the useful space of the operating room? The robot structure allows a simple reallocation, fast with minimum cost of this for different applications?
3. What is the efficiency in the training program, cost, time for learning for new human operators?
4. The structure is easy of sterilized?

The main requirements for medical robot are presented in figure below: [9].

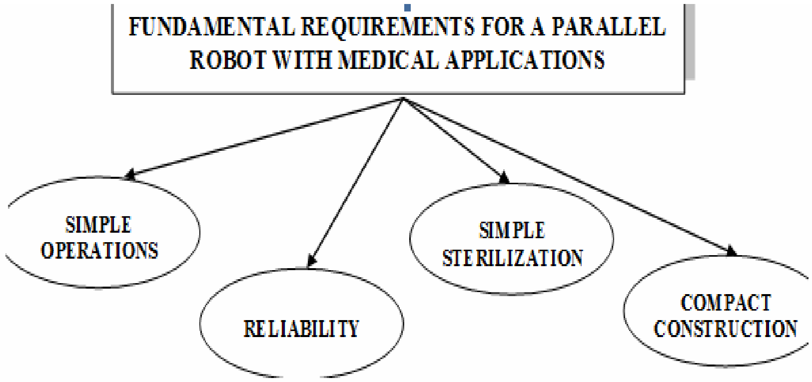

Figure 11: Fundamental requirements for a parallel robot with medical applications

Conclusion

Parallel robots have received special interest due their advantages over conventional serial mechanisms: high rigidity, high load capacity, high velocity and high precision. Parallel robot is a mechatronic system and requires to be designed in the spirit of mechatronic philosophy. The V design model V design cycle is adopted.

The use of a parallel robot in a given application requires careful analysis of the structure and of the indispensable parameters. Numerous applications of parallel robots in medical field bring this field closer to mechatronics. As robots are by their own nature mechatronic systems designing a parallel robot according to mechatronic design philosophy is a logical decision that allows general systemic approach.

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