Assistance to the maintenance in residence of the handicapped or old people

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Abstract—**The maintenance in residence of handicapped or old people is an alternative to the hospitalization which answers the current tendency of reduction of the number of hospital beds. It poses two major problems: the safety of the people and their autonomy. To answer it, the AMaDom project combines two approaches: Remote monitoring, for safety and functional substitution for autonomy. A system of remote monitoring of patient in residence makes it possible to the people to remain at home while profiting from a medical supervision remotely and thus of a good reactivity in the event of urgency. In this project functional substitution is ensured by a robotized assistant of handling of objects. The assistant contributes to the integration of a person with reduced mobility in a usual environment.**

The originality of the project lies in the combination of an integrated system of remote monitoring with robotics. The capacities of mobility of the robot ensure, according to the phases or user's needs': a more robust detection of the alarming situations, a more robust transmission of alarms and ambulatory data of the patient towards the domestic station, a decision-making help after alarm and above all, a visual and auditive contact in the event of alarming situation between patient and a distant medical operator. The paper presents the state of works of the project for remote monitoring and functional substitution and develops the interest of making co-operate both services.

Index Terms— **Remote monitoring, physiological data, actimetry, functional substitution, mobile arm, Human machine co-operation, control mode.**

I. Introduction

The maintenance at home of the disabled and/or old people takes an increasing importance as an alternative to hospitalisation or placement in specialised institutes. The number of persons with reduced mobility is presently increasing, specially because of the lengthening of the life expectancy and also because of the saving of persons badly injured in accidents. INSEE study of October 2000 indicates that about 2.3 millions of persons in France, living at home, receive and allocation or another income because of their handicap, their advanced age or any health problem. More than 5 millions of persons have a regular help to accomplish certain daily living tasks and need a constant monitoring. Two times on three the help is give, by the persons'family. Difficulties are of different intensity depending on the nature, the origin and the gravity of the injuries. Women suffer more of motor deficiencies and men suffer more of sensorial deficiencies. Age is a worsening factor: motor deficiencies affect two third of person of more than ninety years old. More than 650 000 disabled people live in specialised institutes. According to INSEE, these persons suffer at different deficiency levels:

- motor (13.4%)
- sensorial (11.4%)
- organic, for example respiratory or cardiovascular (9.8%)
- intellectual of mental (6.6%)

More precisely, about 1% of the population suffer of important motor deficiencies (tetraplagia, paraplegia, hemipleagia).

The maintenance at home poses two major problems: the safety of the people and their autonomy. They are generally solved by the constant presence of a third person. The project aims at proposing a solution to decrease this presence, but only in its utility aspect. The purpose of it is not to remove any human presence around the disabled and/or old person. Decreasing this presence is a clearly expressed wish, in a quite comprehensible will of intimacy. To make possible maintenance at home, the project is interested in two aspects: remote monitoring for safety and functional substitution for autonomy. We understand by functional substitution the assistance for usual tasks of manipulation thanks to a semi-autonomous mobile arm manipulator, remote controlled by the disabled and/or old person.

In the literature no project approached the problems of the maintenance in residence by combining the remote monitoring with robotics. The literature survey will thus approach separately the remote monitoring for security and functional substitution for autonomy

In the context of remote monitoring, we can cite pilot experiences done in Israel, Norway, Canada, Germany like Philips Heartcare Centre [1] and France : experiments of France Telecom research and development for dialysed patients, old persons, Biotel system exploited by SAMU-92 [2], fall detection developed by the team of Grenoble [3] They offer very interesting experimentation fields, which have permitted to obtain technical solutions for remote monitoring.. However many scientific and technical points are still to improve for example:

- Reduction of the rate of false alarm to avoid useless interventions. A solution is based on a multimodal fusion of vital physiological parameters such heart rate measured on the patient, actimetry which measures patient activity and patient localization inside the residence.
- Reliable and protected transmission of physiological data and actimetry of the patient towards the residence station.

In connection with lack of autonomy, many handicapped people (tetraplegic, myopathes, confined to bed people...) have great difficulties, even an incapacity to seize current objects (glass, deliver, quill, etc.). Robotics proposed three configurations for functional substitution : a robotized arm fixed on a desk like AFMaster [4]), a robotized arm fixed on an armchair (Manus [5], [6]) or a robotized mobile arm (MOVAID [7], HTSC project of Amiens [8], ARPH [9]). Up to now, one can note that only Manus arm fixed on an armchair remains marketed. This configuration presents nevertheless two important limits of use when the person is confined to bed or that she wears a collar and wants to collect an object with ground. An arm manipulator embarked on a mobile basis offers a response in these two situations. Up to nowhe projects carried out in this field did not succeed. The field of research remains open. It is necessary in particular to improve the coordinated control of the mobile arm and the interaction between user and robot.

The project can be divided into three steps: remote monitoring, functional substitution and combination of these approaches in order to propose a global response for the maintenance in residence.
First section describes the whole of the system with its functionalities and its devices. The end of the section underlines the contributions of the combination of the two approaches, remote monitoring and functional substitution. Second section provide current results obtained in remote monitoring and next one results in functional substitution. The last section describes works in progress.

II. Principle and Originality

In order to avoid any ambiguity, we define the following terms which will be used in the paper.

Patient device: Ambulatory device placed on the person for acquiring physiological and actimetry data
Residence station: System of treatment of data provided by patient device and then of transmission from the patient residence to the remote monitoring centre
Remote monitoring centre: Distant place for decision making by medical specialists typically SAMU in France.
Mobile arm: Mobile robotized arm
Control station: Station in residence which allows the control of mobile arm by a human user; in our case a disabled person.

A. Remote monitoring

The person in residence profits from two services. First emote monitoring is presented in figure 1. The principle is to measure certain physiological data and the activity of the person. According to the value of these measurements, an alarm is transmitted to the *Remote monitoring centre* which makes or not the decision to intervene.

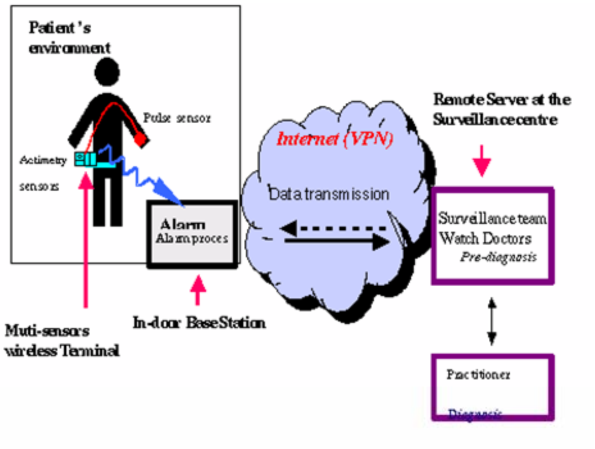

Fig. 1. Principle of remote monitoring of patients in residence.

The system is generally composed of two fundamental elements:

- *Patient device* placed on the patient permanently recording his physiological data - mainly heart rate-, his actimetry eventually supplemented if the health of the patient requires it by sensors for the recording of an electrocardiogram (ECG) or an uninterrupted ECG (Holter) and by a sensor of oxygen saturation rate.
- *Residence station* which receives signals from *patient device*, analyses data in order to generate an alarm after identification of an emergency. The alarm is transmitted to *Remote monitoring centre* for decision making.

B. Functional substitution

The second service is functional substitution for usual object manipulation. It concerns motor disabled people unable to move in the residence. The principle is illustrated in figure 2.
The assistant is composed of :

- a mobile base with two drive wheels
- a 6 dof manipulator arm MANUS carried by the mobile base (figure 3)
- a pan-tilt camera. The camera plays different parts: video feedback for user, perception for automatic control mode and remote monitoring

- a bidirectional audio system (loudspeaker and microphone)
- a *Control station* for the control of the mobile arm by an user. The station is composed of a man-machine interface and a wifi transmission link to communicate with mobile arm.

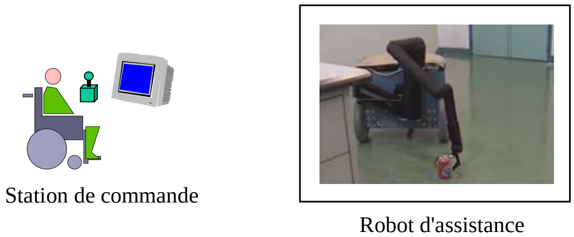

Fig. 2. Principle of the functional substitution.

When disabled person needs an object, mobile arm is sent to seek the object in another part of the residence. Thanks to its own capacities of mobility, perception and seizure, it is able to bring back this object.

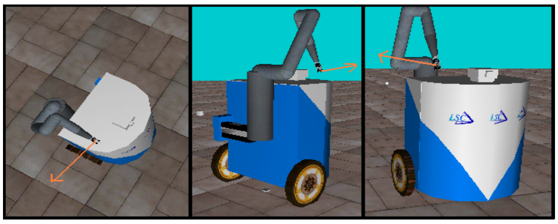

Fig. 3. Views of mobile arm

In the facts this task is carried out by a human machine co-operation. The robot must be able to move while avoiding obstacles and locating. It is remote controlled by the control station of the user which is typically a personal computer. Various control mode are at the disposal of the user.

C. Co-operation between Remote monitoring and functional substitution

The original idea of the project is to combine remote monitoring and robotics to supplement or improve the services of maintenance in residence. Indeed the capacities of mobility of the robot allow according to needs: to confirm alarm, to remotely ensure an audiovisual contact in the event of alarming situation and to allow functional substitution for the seizure and the handling of objects. To our knowledge, such an approach of co-operation between an ambulatory system of remote monitoring and a mobile robot equipped with means of perception has never been proposed. The modular concept makes it possible to adapt the system to the real needs for the person: remote monitoring alone, functional substitution alone, or both in co-operation which can be illustrated by the following scenario. An alarm is set on by the residence station. The distant operator of remote monitoring centre is alerted. He tries to take contact with the person by usual means of telecommunication in order to ensure himself of the validity of alarm. He does not obtain any response. At the beginning, he orders the mobile robot to seek the person in her residence and then to establish an audiovisual contact with her. It is not a false alarm. The distant medical team specifies the diagnosis using the remote monitoring data and the audiovisual data -image and sound- provided by the robot, defines the means of intervention necessary and starts the intervention. While waiting for the arrival of assistance, audiovisual contact is maintained with the person. This scenario illustrates the contribution of robotics to the service of remote monitoring. Reciprocally the measurements acquired by the system of remote monitoring can be used to adjust functional substitution constantly with the needs for the person. Indeed, as seen before the user has at his disposal different control modes for the control of the mobile manipulator arm. The person makes the decision of the better mode to be used. However it would be interesting of proposing a control mode related to the state of the person. The sensors of the remote monitoring system can be used by the functional substitution system for decision making.

III. Remote monitoring

The INTERMEDIA team takes part of the “département Electronique et Physique” belonging to the GET/INT Institute which has both educational (Engineer schools) and research missions. Their technical works and platform realisations were performed thanks to the RNTS project TelePat[1] partnership by taking into account medical and user-centred requirements. In addition the GET/INT team, through one task of the TelePat project, developed more deeply its research on the "telecardiology" part which can be seen as a subset of a televigilance system, namely for cardiac persons: an ambulatory cardiac monitoring system must be able to produce an automatic alarm based on an automatic electrocardiograms (ECG) signals segmentation and identification of pathological ECG waveforms (arrhythmias, pre-infarctus or vascular accidents signs).
The following section describes the state of works developed by Intermédia-INT laboratory. As said above, The system is generally composed of two fundamental elements:

- *Patient device* placed on the patient permanently recording his/her physiological data
- *Residence station* which receives signals from *patient devic*e, analyses data in order to generate an alarm after identification of an emergency. The

[1] TelePat: French acronym of "Remote monitoring for Patients in Residence", this project is funded by the French RNTS program and acts from Nov 2003 till July 2006. The partnership is composed by all organisations mentioned in this paper authorship. TelePat extends works performed in the MEDIVILLE project (French ACI program).

alarm is transmitted to *Remote monitoring centre* for decision making.

The Patient's device - also denominated wearable terminal - (Fig. 1 & 4) includes an acquisition chain of the various physiological signals, their possible pre-processing in order to eliminate the power-line interference signal (50 Hz) and the various measurement noises, such as ones generated by frictions or displacements of the sensors laid out on the patient's body. The latter type of noise is generally a factor limiting the use of such systems in ambulatory mode because the patient is often moving, even if slightly. In our system, the noise problem was solved in the acquisition stage of the portable device [10], of the pulse, by applying a digital noise subtraction filter to the different sensors signals, movements, attitude and namely the pulse signal (heart rate) where the performances of signal acquisition could be very appreciably improved when the patient performs movements : the noise reduction processing developed by [10] achieved to reduce the variations of pulse measurement lower than 10%, even 5%, which remains in conformity with the recommendations of the Health Professionals.

Fig. 4. Real-time and experimental wearable personal terminal for televigilance [10], equipped of sensors for heart rate (on ear) and actimetry (inside), with the in-door reception base-station: various physiological values on the blue display after fusion processing performed within the base-station.

The design of sensors and embedded treatments has led to the realization of a remote wearable monitoring terminal, equipped with actimetry and physiological sensors, indicating the attitude of the patient (vertical/horizontal positions, activity) and his heart rate (pulse measurement); these sensors specific to the recorded physical data type are, either integrated in the terminal (actimetry), or externally fixed for instance in the case of the sensor of pulse placed on the ear or at the wrist according to the blood stream properties of the considered patient (comparative studies carried out within the laboratory, fig.4).
Data generated from the different sensors are transmitted, via an electronic signal conditioner, to a micro-controller based computing unit, embedded in the mobile terminal fixed on the patient's waist. Additional accelerometry sensors to measure the fall impact are currently under finalization to refine, to even carry out a more secure identification of any fall.

Still in TelePat project, in order to reinforce the secure detection of patient's fall event, it is also envisaged to couple measurements coming from the terminal-patient with that of the system GARDIEN [11] allowing the patient's localization by Infra-red sensors fixed on specific places of the rooms (walls and ceiling). This coupling is currently under development and is located within the in-door reception base-station.

The "Residence station" – also called local base-station - carries out for instance one or more filtering process on received signals to improve their signal-to-noise ratio and their quality, to estimate the patient's health tendencies (slow or abrupt variations of its heart rate, to prevent risks of bradycardia…), it carries out the fusion of the various physiological and actimetric values in order to calculate an alarm or emergency index, then retransmitted through a secure VPN link to the remote server of the medical control station.

The data retransmission from the local base-station towards the TelePat centralized server –also called *Remote monitoring centre*- was implemented on an IP network offered by the PERCEVALE project managed by INT. The remote TelePat server connection to the PERCEVALE network authorizes an open access on the outside world (no firewalls), which will make possible in the long term an access from other domestic-patient stations outside to INT (e.g. to simulate a televigilance service deployment with several patient's in-door base-station to manage by a medical centre). In that respect it is crucial to guarantee a minimal QoS between in-door base-stations and the remote medical supervision center: [11] proposed, for large scale deployment of televigilance servers grid, an innovative model of intelligent QoS management, the WS-DSAC concept (Web-Servers DiffServ Admission Control): WS-DSAC computes in real-time the load sharing between several servers in grid to allocate optimal resources in case of high and simultaneous emergencies load.

IV. Functional substitution

The mobile arms make it possible to extend the zone of action of the operator and can be used in an environment not structured. The Manus arm, developed in Holland, is marketed since ten years. It is conceived to be embarked on an electric wheelchair. It is an arm with 6 degrees of freedom with a grip at its end which can seize an object of 1,5 kg. It is controlled thanks to a 16 key keyboard. This configuration showed its effectiveness since 150 Manus arms are currently in service in the Netherlands. In France, one counts only about thirty Manus, primarily thanks to the action of the AFM. The absence of an institute specialized in the provision and the follow-up of this aid and the fact that the majority of the technical innovating assistances are not refunded in France explain this difference.

Two limits appear for this type of system. For confined to bed people, the aid becomes inoperative. Moreover, it is sometimes impossible to collect an object on the ground, for example when the person carries a collar preventing it from seeing on the level of the ground right beside her armchair. A solution consists in embarking a Manus arm on a mobile structure. This configuration is more flexible than the two preceding ones. It is also more delicate to work out. Two situations are possible. Either the robot is in the field of vision of the operator and the control is carried out with a direct visual feedback or the robot is out of the visual field of the operator who must remote control it. Until now the research projects based on this configuration did not reach a phase of pre-industrialization. The principal problem underlined by the authors is the difficulty in controlling a complex system by a handicapped user.

The LSC is developing a functional substitution system being inspired by the third configuration presented above: a manipulator arm embarked on a mobile base called ARPH (Robotics Assistance for the Persons Handicapped persons. From the beginning of the project, in 1994, the AFM (French Association against Myopathies) was actively involved of our specification and design. In the following we present the state of ARPH project. Our works articulate around two complementary axes. The first one, centred on the user, aims at supplying him an assistance according to his wills and his residual capacities. it deals with the cooperation between the user and the machine to reach the wished objectives. Two imperatives are become obvious. First of all, leave the person free of its choices at all the levels by an appropriation rather than by imposing operating modes then, mitigate the limits of the technical assistant thanks to the human intervention. To answer it, we developed three types of modes of command.

The first one is the manual mode. it gives to the user the control of all the degrees of freedom of the system. Its main defect is its difficulty of use for the person. In the second mode, the system executes automatically the mission wanted by the operator. The first defect of this mode is to forbid the operator to act by itself. While it is often an expressed wish. The second defect results from the difficulty proposing a totally autonomous system without equipping the environment and by staying in acceptable costs. We thus opted for the definition of the third type of modes mitigating the defects above. It consists in sharing the control of the mission between the operator and the system. We called them shared modes. Some are proposed to the user. A first shared mode consists in assisting the operator for the avoiding of the obstacles being on the road followed by the robot. The operator gives the direction to follow, the robot takes care to avoid the obstacles. A second shared mode, called mode camera, is based on the control of the movement of the mobile base. A camera, directional in site and in azimuth, is embarked. Here, the operator pilots the orientation of the camera and the robot moves in the direction. Another version of this mode is possible by using the function of follow-up included in the camera. it consists in following automatic movement of an object by keeping it constantly in the center of the image. Once the object chosen by the operator, the camera follows it and the mobile base moves in its direction. Besides modes of command proposed to the operator, the man-machine cooperation man is based on a good understanding of how machine operates by the operator. In robotics, several works use the model of human operator divided in three levels of behaviour (based on the skill and knowledge, governed by rules) proposed by Rasmussen([12] By trying to match the functioning of the machine on this model we approached the question under another angle by referring to the works of Piaget on the adaptation of a child to his environment ([13]) According to Piaget, the intelligence is above all adaptation which can be decomposed into two additional processes. The first one is the assimilation which consists of the generalization of pre-existent schemas. Concretely, by their nearness of appearance or situation, new objects can be likened with pre-existent schemes and to see themselves attributing meanings which contribute furthermore to an extension of the behavioural knowledge base. The second, the accommodation, consists of the differentiation of the pre-existent schemes and requires a more important cognitive investment. In the project ARPH, we studied the means to allow the user to adapt itself to a new tool by assimilation rather than accomodation process in order to limit the workload of the user[14]. The studies on the morphology of the system showed that by supporting an anthropomorphic placement of the visual frame by report to the end effector frame (position of the feedback camera with regard to the manipulator arm), user develops an adaptation rather from assimilation type. Other studies concerning morpho-functional aspect, for example the visuo-motor anticipation mechanisms showed that by reproducing the human behaviour, here also the user adaptation is done rather by assimilation.

A cooperation can settle down only between two entities, here human operator and mobile arm which possess appropriate capacities of autonomy. So, the second axis of our works concerns the autonomy of the mobile arm.. Seizure of an object, remotely, to manipulate it, distinguishes two phases: approach and seizure itself. The approach is carried out mainly by the mobile base which carries the arm. If the phase is automatic, it is necessary to define at first the path to be followed, it is planning, then to follow the path while correcting locally if necessary, it is navigation. The latter uses the localization to check that the followed way is that envisaged. Planning establishes a graph of visibility starting from a priori knowledge of the environment and chooses the best trajectory, in the sense of a function of cost to be defined, thanks to the algorithm A^*.

Navigation is based on the fusion of two behaviours: follow-up of trajectory and avoidance of the obstacles. This second behaviour is possible thanks to measurements of ultrasound sensors. The fusion is done by a fuzzy controller.

Lastly, the localization is essential for an automatic displacement of a point to another. We use a hybrid metric localization. Dead reckoning provides a robot positioning continuously but with a increasing error. So, regularly a method based on video data corrects robot position by reinitialising dead reckoning [15]. Another work deals with symbolic localization.

For the seizure phase itself, the problem is more complex. The movement of the end effector of the manipulator arm depends on commands sent to the arm and on those sent to the mobile base. This redundancy of the degrees of freedom allows to impose constraints on the way of realizing a task. We are interested in the concept of manipulability, introduced by Yoshikawa [16] and developed by Bayle [17]. This concept allows to hold the remote arm far from its singular positions and so to ensure it sufficient ability for manoeuvre all the time. Another direction based on multi-agent approach is in progress.

V. Future works: Remote monitoring and robotics cooperation

As seen before, the co-operation of both services which are remote monitoring for safety and functional substitution for autonomy presents two major interests. In our case, a mobile manipulator ensures the functional substitution for object manipulation. More the mobility of the robot allows the capability to check if an alarm is true but also the degree of gravity of the alarm. By remote controlling the robot, the distant medical team establishes a audiovisual contact with the person at home.

The co-operation poses problems of different nature. The first one is at ethic level. It relates to the intrusion of a mobile object able to perceive and to act in the intimate environment of the person. A sociological study must establish up to what point the intrusion is bearable and which are the limits to be respected.

The other problem is the remote control of mobile robot by the distant medical operator. The usability depends on several factors: control modes, feedback and interface. Current works aims at finding the good compromise for reducing complexity without limiting the intervention capability. The only difference with the case seen in § IV "*the robot is out of the visual field of the operator*" is that the user is not present in residence but is located at *Remote monitoring centre*. He uses Internet for communication with the constraint that Internet is not a deterministic medium. A semi-autonomous robot mitigates this disadvantage. When the Internet offers a good quality of communication, the distant operator orders the remote robot. If there is a degradation of communication, the robot can automatically continue the task in progress.

VI. References

[1] www.Philips.com

[2] Baer M, Ozguler A, Penela J, Fletcher D, Chauvin M. La Biotelevigilance Dans Le Departement Des Hauts De Seine : 13 Années D'expérience 2nd World congress on telemedicine. TOULOUSE 22, 24 March 2000. Communication orale

[3] N. Noury, A. Tarmizi, D. Savall, P. Boissy, P. Barralon, G. Virone, P. Rumeau, 'A smart sensor for the fall detection in daily routine', SICICA2003, Aveiro, July 2003

[4] M. Busnel, R. Gelin and B. Lesigne, "Evaluation of a robotized MASTER/RAID workstation at home: Protocol and first results", Proc. ICORR 2001, Vol. 9, pp. 299-305, 2001.

[5] H. Kwee, C.A. Stanger, "The Manus robot arm", Rehabilitation Robotics News letter, Vol. 5, No 2, 1993, H. G. Evers, E. Beugels and G. Peters, "MANUS toward new decade", Proc. ICORR 2001, Vol. 9, pp. 155-161, 2001

[6] H. G. Evers, E. Beugels and G. Peters, "MANUS toward new decade", Proc. ICORR 2001, Vol. 9, pp. 155-161, 2001

[7] P. Dario, E. Guglielmelli, B. Allotta, "MOVAID: a personal robot in everyday life of disabled and elderly people," Technology and Disability Journal, no 10, IOS Press, 1999, pp. 77-93.

[8] F. de Chaumont, L. Delahoche, C. Cauchois, B. Marhic, C. Drocourt : "New man computer interface for the Manus using a standard joystick" - AAATE, pp. 606-612, sept.. 2005.

[9] P. Hoppenot, E. Colle, "Mobile robot command by man-machine co-operation - Application to disabled and elderly people assistance," Journal of Intelligent and Robotic Systems, Vol. 34, no 3, pp 235-252, July 2002.

[10] J. L. Baldinger, J. Boudy, B. Dorizzi, J.-P. Levrey , R. Andreao, C. Perpère, F. Delavault, F. Rocaries , C. Dietrich , A. Lacombe, ''Tele-surveillance System for Patient at Home: the MEDIVILLE system'', Congrès ICCHP 2004, Paris, Juillet 2004.

[11] F. Steenkeste, H. Bocquet, M. Chan, B. Vellas. Remote monitoring system for elders in a geriatric hospital. Promoting Independence & Quality of Life for older persons : an international conference on aging Arlington 2 – 4 December 1999 (USA).

[12] J. Rasmussen. "Skille, Rules, and Knowledge; Signals Signs, and Symbols, and Other Distinctions in Human Performance Models" - IEEE Trans. on syst., man and cyb (SMC), vol. 13, n°3, p; 257-266, May/June 1983.

[13] Piaget, J. (1936). *La Naissance de l'Intelligence chez l'Enfant.* Paris, Lausanne : Delachaux et Niestlé.

[14] Yves Rybarczyk, Omar Ait Aider, Philippe Hoppenot, Etienne Colle : "Remote control of a biomimetics robot assistance system for disabled persons" - AMSE, special issue - bioengineering applied to handicap rehabilitation, pp.47-56, 2002.

[15] Omar Ait Aider, Philippe Hoppenot and Etienne Colle: " A model-based method for indoor mobile robot localization using monocular vision and straight-line correspondences" - Robotics and Autonomous Systems, vol. 52, p. 229-246, 2005.

[16] T. Yoshikawa: "Manipulability of robotic mechanisms" - International Journal if Robotic Research, Vol. 4, n°2, pp. 3-9, summer 1985.

[17] B. Bayle , J.Y. Fourquet, M. Renaud : "Nonholonomic mobile manipulators: kinematics, velocities and redundancies" - Journal of Intelligent and Robotic Systems, Vol.36, N°1, pp.45-63, Janvier 2003.