Robotic Nursing & Caring – Study Example: Robotic Nursing Assistant (RoNA) System

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Abstract— **Nursing robots are getting into elderly people life gradually because of the huge assistance they can provide both to patients and nurses. In this paper we emphasize fundamental matters about developing healthcare robots, starting by defining nursing robots, featuring the functions a caring robot can perform, and the level of artificial intelligence (AI) integration in such robots. This document also describes the features and benefits of a Robotic Nursing Assistant (RoNA) System developed at Hstar Technologies Inc. and highlights the benefits commonly associated with traditional safe patient lifting methods, in addition to improved patient and clinical staff satisfaction, reduced incidence during patient lifting and clinical maneuvers, RoNA offers as well advantages in : mobility and maneuverability, telepresence support, patient safety, employee injury, worker compensation, and premature retirement reduction and staffing and equipment needs reduction.**

***Index Terms*—nursing robot, patient safety, healthcare robot, RoNA system, robotic IT.**

I. Introduction

The number of elderly people in the world who are 65 years old or more is continuously increasing, in fact it is predicted that by 2050 the aged population will triple and reach 1.5 billion in the world (United Nations, Department of Economic and social Affairs). Many older adults wish to age at their own place, however, performing so is not easy and faces several complexities such as medical condition and physical disability which leads to putting pressure to clinical and aged care facilities, we hence look for innovative (and perhaps more complex) approaches to facilitate life for them and for effective management of their demands. Robotic nursing is one of the solutions for that and it is showing optimistic results regarding the years to come.

Unlike humans, robots are quicker to train, cheaper to maintain, easier to refuel and repair and never get bored or tired of performing repetitive tasks. They could be designed to help the elderly, disabled or chronically sick people leading to a decrease in need for caregivers and care facilities. Despite all these benefits, robotic nursing faces some difficulties which impede the rapid integration of this newly designed technique of assistance to both patients and nurses. The main challenge consists of finding algorithms to program robots with a reliable set of ethics. We hence discriminate two types of nursing robots; the first one consists merely on mechanical tasks achievers with approximately a null set of ethics (due to its needless), the second one are autonomous robots (autonomous in a social context and not technical) which may include a set of ethics for undertaking simple tasks requiring slight human-robot interaction.

In section II of this literature we will be dealing with robotic nursing and caring providing in subsections the definition of robotic nursing, the functions a caring robot can achieve, and the level of A.I. integration i.e. which level of human-robot interaction could we reach? Section III takes as example a robotic nursing assistant (RoNA) system developed at Hstar technologies Inc. and highlights the benefits commonly associated with traditional safe patient lifting methods, in addition to improved patient and clinical staff satisfaction, reduced incidence during patient lifting and clinical maneuvers, RoNA offers as well advantages in : mobility and maneuverability, telepresence support, patient safety, employee injury, worker compensation, and premature retirement reduction and staffing and equipment needs reduction.

II. Robotic Nursing and Caring

A. *Definition of robotic nursing*

Many terms have been associated to nursing robots, for instance: nursebot, carebot, robot nurse ...etc. but all of them refer to the same machine. Robotic nursing is the use of autonomous mobile robots mainly designed and programmed for performing tasks related to nursery aiming to assist (but not replace) nurses in hospitals, care facilities or even homes for a better prevention, and rapid treatment and medical care of people especially elderly and physically disabled ones. In the actual meantime, robot nurses are generally used for performing several routine tasks such as collecting blood sugar and pressure levels.

B. *Functions of nursing robots*

Caring robots are now getting humanized more and more, whether in the appearance, hence the term humanoid robot, or in the functions, we itemize here below the four main ways nursing robots could assist elderly and chronically ill people [1]:

- Making up for cognitive decline (for example, reminding patients to drink, take a medicine or attend an appointment). Elderly people often need to take multiple medications and noncompliance often frequently leads to problems.
- Enabling patients and caregivers to interact more effectively, thereby reducing the frequency of personal visits required.
- Collecting data and monitoring patients, some emergencies (such as heart failure and high-blood sugar levels) could be avoided.
- Assisting people with domestic tasks – many give up independent living because arthritis leaves them unable to cook, clean or use the washing machine or the microwave.

Other tasks could also be achieved inside healthcare facilities by robots, like developing an autonomous mobile robot for in hospitals and elderly houses used for transporting and delivering meals, laundry, drugs and documents… etc., throughout the facility hallways. The robot is fit with appropriate space to carry desired stuff to desired staff or locations compensating the lack of nurse personnel and saving time for nurses in carrying out activities more related to patients. The robot's software contains a two-dimensional built-in map of all the facility making it able to discriminate between the free space and obstacle space. Using an algorithm for static (e.g. walls) and dynamic (e.g. humans) obstacle avoidance, the robot will be able to ovoid collision and safely navigate in the facility.

This robot has got an on-board camera used for the detection of moving obstacles (particularly walking humans). It detects objects that move in the vicinity of the robot by block-based motion estimation. In the method, an image is firstly divided into small blocks, and then the motion of each block is searched by comparing two consecutive images. If the motion between matching blocks is significantly large, the block in the current image is classified as belonging to moving objects.[2] In addition to the camera, multiple ultra-sonic sensors are used for the detection of obstacles. If for example a gurney is being pushed by somebody from the behind of the robot, the sensors automatically detect it, and the robot goes aside letting the way for the gurney to pass.

C. AI integration in robotic systems

The primary challenge in developing nursing robots is the issue of programming a machine with a reliable set of ethics. A nursing robot will have to make complex decisions vis-à-vis its patients on a daily basis. Its role consists of advising patients in order to assist in improving the health of human beings, and hence, the need of having an ethical system that will allow it to properly carry out medical schedule while treating patients with respect. For instance, a robot that is programmed for reminding patients to take their drug needs to know how to react if the patient refuses. On one hand, refusing the medicine could be harmful for the patient. On the other hand, the patient may be refusing of legitimate reasons that the robot may not be aware of. For example, if the patient feels that the medication that he is taking sickens him, then insisting on administrating it could be fatal for him. This leads to the conclusion that a nursing robot alone cannot replace a human nurse in the actual meantime. Furthermore, what if the patient agrees to take the medicine but then forgets afterwards, should the robot stay and watches him out, or is it a violation of privacy? How a robot will be able to interpret this situation in order to call the doctor?

This scenario is an everyday situation that human nurses navigate with ease. The human brain can assess a situation not only based on data that it directly receives through its senses, but it can also logically process other signs, such as the look of a person or the intonation of a response. If there is not enough data to make a decision, a human can figure out which questions to ask in order to receive more information. Humans also have a complicated ethical system that is able to not only weigh the good against the bad, but is also able to make judgments about the degree of benefit of a given course of action. Robots cannot make decisions on such a level. Current technology only allows them to force a "yes" or "no" decision regardless of how much information is available. This is clearly not an adequate system for advanced ethics, so a new approach to decision making must be found.[3]

Integration of AI in robotic systems yields to the use of software components for each module used in the system (computer vision, speech recognizer, speech synthesizer…etc.), yet they appear to us very sophisticated ones, the level if AI integration is still very far from the human one. One of the most popular routing and communication protocol for artificial intelligence is OpenAIR, it is used to allow software components to effectively communicate between them and share real-time information of the robot such as localization, inputted sound, servo motor speed, hardware-software interfacing, and other modules that are used.[4]

The picture bellow depicts an example of A.I. system integration using message protocols and blackboard systems such as OpenAIR protocols and Psyclone.

OpenAIR is a protocol managed by mindmaster.org.

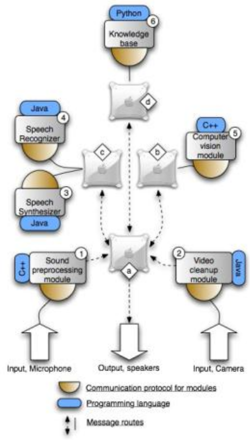

Fig. 1: Explanatory diagram of an AI integration system using OpenAIR

III. ROBOTIC NURSING ASSISTANT (RONA SYSTEM)

A. *Description*

RoNA, depicted in Fig. 1, is a mobile robot developed by Hstar Technologies capable of safely lifting patients with impaired mobility. It is designed to assist nurse personnel in lifting disabled or seriously ill patients in healthcare facilities from bed to bed or bed to gurney and vice versa. This challenging activity results sometimes in musculoskeletal disorders (MSD) among nursing staff, in which this robot could offload this undesirable task of lifting heavy bodies. One of the main causes of medical errors, injuries, and avoidable deaths among patients and disabling musculoskeletal disorders (MSD) among nursing staff is high patient-to-nurse ratios, fatigue on long shifts, mandatory overtime, lack of experienced staff. It is also important to note that the number injured workers in hospitals is significantly higher than the number of injured workers in construction fields, mines and factories.[5] Such a mobile robotic nurse is used to enhance the quality of care of nursing staff. It could offload one of the most physically demanding duties, thereby reducing the potential of self-injury or injury to the patient.

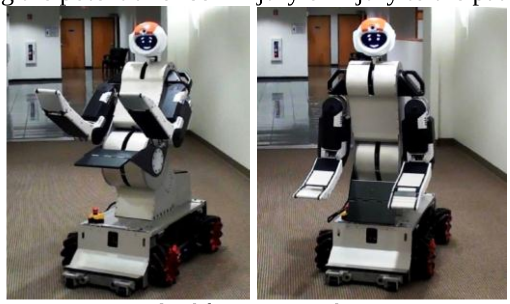

Fig 2. The RoNA prototyped to lift patients weighting up to 500 pounds.

The advantages of using such technology in our modern hospitals are to [6]:

- Increase a nurse's work satisfaction.
- Decrease lifting-related injuries, and extend the years of effective service nurses could render in hospitals.
- Reduce hospitals costs and ameliorate the problem posed by the shortage of nursing staff.
- RoNA works around the clock and never gets tired or injured.
- Staff can spend more time with patients or assist nursing instead of lifting patients together.
- Enhancement of the high-tech hospital.
- Lifting and transporting items weighing < 5kg and providing personal transportation.
- Opening doors.
- Providing alerts and reminders.
- Retrieving information.

B. *Structural Design*

RoNA is an autonomous mobile robot that navigates safely throughout hospital hallways and has got an intuitive interface for robust human-robot interaction as well as a sophisticated telepresence system. Fig. 2 shows a block diagram of a system framework for telepresence based control and direct control of RoNA.

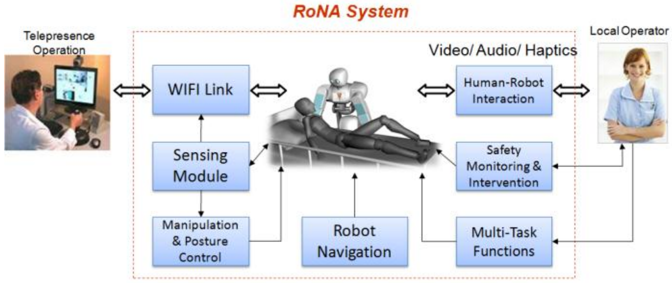

Fig. 2: Block diagram of a system framework for telepresence based control and direct control of RoNA.

Humanoid Upper Torso Design: A series elastic actuation (SEA) mechanism is developed to provide a target performance of RoNA upper torso lifting using three SEA model i.e. electric powered compact rotary SEA, hydraulic transmission electric power SEA and worm drive electric powered SEA. A final design of the RoNA upper torso is illustrated in Fig. 3.

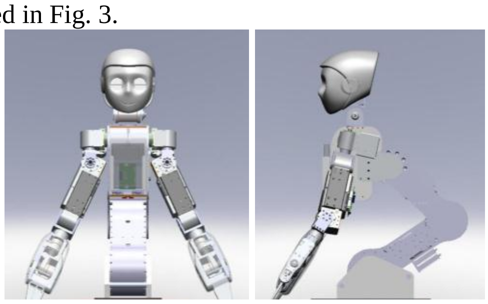

Fig. 3: The RoNA upper torso design.

Robot Actuation Design: Using a Worm Series Elastic Actuator (WSEA for upper-torso via two different types :

- One large WSEA for each arm provides the primary lift capability of the shoulder.
- Three small WSEAs form the lower shoulder and elbow.

With a torque capacity of 678 Nm, the small WSEA has around 50% lower strength of the large one. As shown in Fig. 4 below, these two actuators are very compact for their size. It is used throughout the RoNA torso.

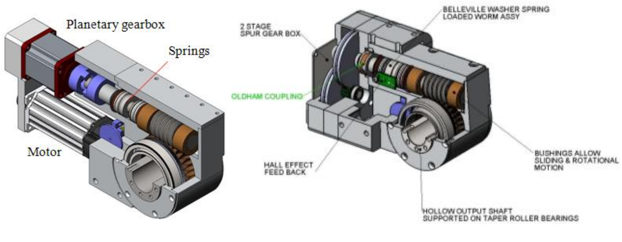

Fig. 4: Detailed view of the large (left) and small (right) WSEAs.

Upper Arm: The RoNA upper-arm unit comprises three of the smaller WSEA actuator modules arranged in a serial kinematic chain to form the lower shoulder and elbow, each with a cable-pass through the center of its rotation, allowing for easy routing of the power and control cables to the lower-arm unit (Fig. 5).

Lower Arm: The RoNA lower-arm (Fig. 6) will be the primary contact surface when lifting a patient. Therefore, it should be compact, safe, and ergonomically designed. The load requirement is low relative to the upper-arm. However, the lower-arm unit requires increased force-fidelity and physical compliance to allow RoNA to safely guide its arms under a prone patient.

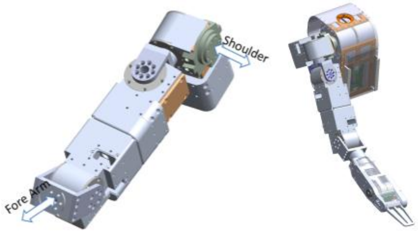

Fig. 5: The assembled upper arm with small WSEAs (left) and entire RoNA arm (right).

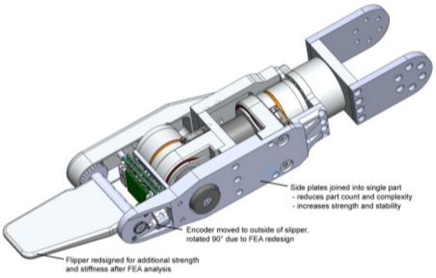

Fig. 6: The Hstar RoNA lower-arm unit with two Harmonic Drive SEAs.

Head Design: RoNA has a 5 DOF expressive head to facilitate human-robot interaction and provides visual feedback to a telepresence operator. The head has a controllable pan-tilt neck, pan-tilt eyes, and eyelids. Two webcams sit behind the eye shells. Fig. 8 (left) shows an assembly diagram of the RoNA head. This entire mechanism was housed inside an amiable head being designed to give the robot an empathetic and approachable look. (See Fig. 7 (right)).

Lower Torso Design: The lower torso is a relatively simple construction with the actuators providing the actuation and feedback.

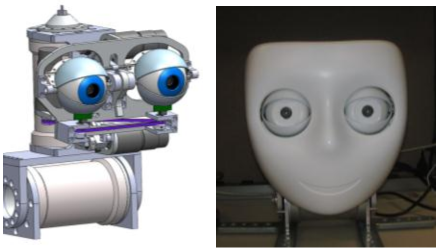

Fig. 7: The RoNA head design with 5 DOFs. Left picture shows the overall head design and the right picture shows the RoNA head with face assembled.

Chest Unit: The RoNA chest-unit is the structural mounting point of the two manipulators, lower-torso, and head (Fig. 8).

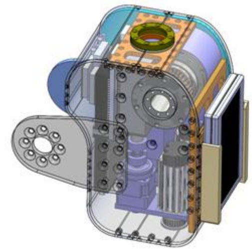

Fig. 8: The RoNA chest design.

Mobile Platform: In the tight and constrained environment of a patient's room, a small platform footprint and holonomic control will be essential. A holonomic platform is able to move laterally, diagonally, and rotate within its own footprint. A modified Segway robotic mobile platform was integrated into the RoNA system (Fig. 9).

Fig. 9: Segway RMP400 Omni with 8" diameter mecanum wheels.

Control System: The RoNA system employs a layered behavior-based control system to provide autonomous and semi-autonomous capabilities. The layering scheme provides increasingly higher levels of abstraction from the physical robot hardware.

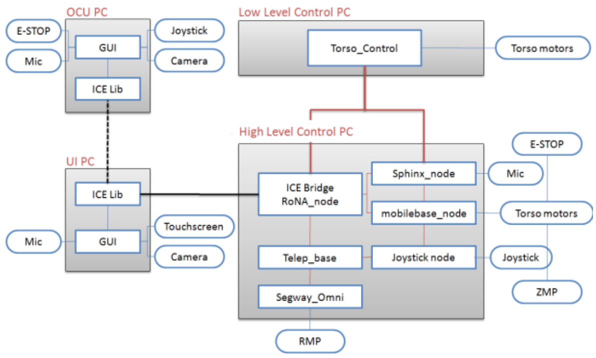

Fig. 10: A system block diagram for the RoNA control.

RoNA utilizes a distributed and networked computation and data management system. Fig. 10 describes the block diagram for the RoNA system control. The OCU (Operator Control Unit) PC is a windows laptop equipped with a microphone, two joysticks, and an emergency stop button. The GUI presents the robot state to the user, and communicates via the ICE middleware to the UI PC on the RoNA robot. The UI PC is a windows computer responsible for the touchscreen interface on the robot, and the robot's side of the telepresence connection with the OCU. It also acts as a proxy for two control computers. The High Level Control PC is a linux PC running ROS and is responsible for coordinating all high level control functions. Local feedback, voice control, computer vision, and interfacing to the various subsystems are all handled by this machine. The Low Level Control PC is a real-time linux PC solely responsible for driving the SEA arms. It accepts directions and returns status to the High Level Control PC via ROS.

Human – Robot Interaction: An in testing feature of RoNA is the ability for a remote doctor to interact with and attend to a patient in the hospital environment. RoNA's socially expressive interface can be used to enhance this physician-patient interaction and dialogue. This RoNA subsystem will utilize two primary components: An Intention Agent that runs on the physicians PC, and the Attention System that runs on RoNA.

Fig. 11 presents the RoNA remote GUI design for telepresence operation. In our initial design, The following GUI components are for remote OCU GUI design;

- Remote video display module
- Base motion control module
- Robot Arm/Torso control module
- Remote robot camera and robot face expression control module.
- Local patient information module.
- Local doctor video module.
- OCU configuration module.
- Remote RoNA location map module.
- Microphone/speaker volume control module.
- Communication link monitoring module.

Fig. 11: Overall design of the RoNA remote OCU GUI module.

Gravity Compensator: This compensator is design to facilitate positioning of RoNA system to the hospital bed or wheel chair for lifting procedures. As shown in Fig. 12, the gravity compensation controller is consisted of one internal velocity controller and one external force controller. The internal velocity controller is optional; it is added for the consideration of patient safety because the velocity loop makes the control system more stable.

The gravity compensation modular reads the robot joint position and velocity in real time and calculates the required joint torque to compensate gravity and arm dynamics, and feedback the torque offset to the external force controller.

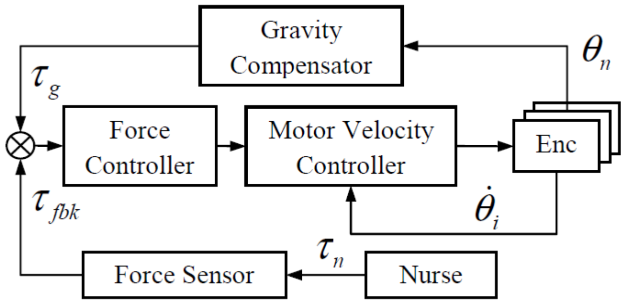

Fig 12. The gravity compensation controller

Based on the torque error, the external force control loop calculates the desired velocity to drive motor to provide the desired torque to compensate gravity and arm dynamics.

B. Lifting Simulation

A simulation of lifting a patient on computer helps asses the trajectory planning and also theoretically verify that if each actuator is strong enough to actuate RoNA to lift 500 pounds. The simulation also can help in mechanical design by determining numerous design specifications, such as the required output torque for each joint and the geometric dimension for each actuator.

Fig. 13 shows a sequential screenshot of RoNA lifting up a patient model. For simplicity, in this simulation path planning simulation in joint space is performed. Notice the simulation started while the patient model is already onto the RoNA forearm. It is also assumed that patient cannot actively move and only subjected to the gravity during the entire lifting.[7]

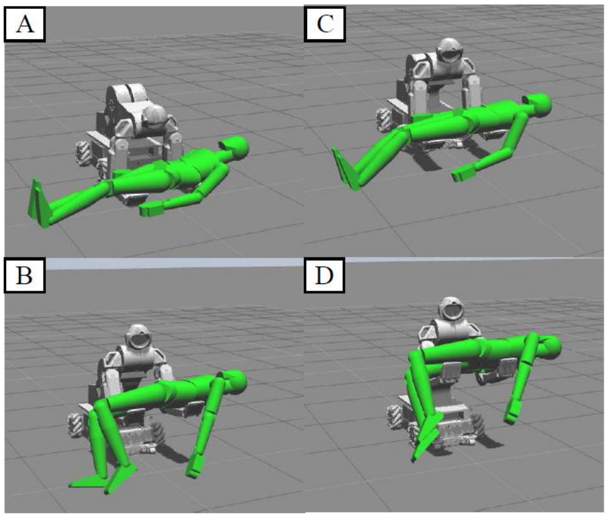

Fig 13. RoNA lifts a patient model in simulation.

ACKNOWLEDGMENT

The author gratefully thanks in particular Yi-Je Lim, Chief Operating Officer & Business Partner at Hstar Technologies Inc. for providing all necessary materials for conducting the research and kindly permitting the use of photos Robotic Nursing Assistant (RoNA) system.

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