ADVANCED ASSISTIVE CONTROL STRATEGIES FOR SMART HOSPITAL BEDS

By

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I, Huy Hoang Nguyen, certify that the work in the thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that this thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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2D	:	2-dimensional
ANN	:	Artificial neural network
DC	:	Direct current
DSP	:	Digital signal processing
DV	:	Disparity vectors
FN	:	False negative
FP	:	False positive
G	:	Girth
GaRBF	:	Gaussian radial basis function
GDM	:	Gaussian distribution method
GDX	:	Gradient descent with momentum
H	:	Height
HJB	:	Hamilton-Jacob-Bellman
HSV	:	Hue, saturation and value
IAV	:	Inscribe Angle Variance
IMM	:	Interacting multiple model
LM	:	Levenberg Marquardt
LRF	:	Laser range finder
MLP	:	Multilayer perceptron
NN	:	Neural network
OFV	:	Optical flow vectors
OMPID	:	Optimal multivariable proportional integral derivative
OMNNC	:	Optimal multivariable neural network controller
ONN	:	Optimal neural network
ONNCv	:	Optimal neural network controller for linear velocity subsystem
ONNCω	:	Optimal neural network controller for angular velocity subsystem
OPID	:	Optimal proportional integral derivative
P	:	Proportional
PD	:	Proportional derivative
PID	:	Proportional integral derivative
RBF	:	Radial basis function

RANSAC	:	Random sample consensus
RP	:	Resilient backpropagation
SCG	:	Scaled conjugate gradient
Sen	:	Sensitivity
Spec	:	Specificity
TDD	:	Triangular Diagonal Dominance
TP	:	True positive
TN	:	True negative
UTS	:	University of Technology Sydney
W	:	Width

Abstract

The intention of employing hospital beds is to bring comfort to the hospitalised people and support the clinical staff in patient-care activities. Over many years, hospital beds have been upgraded from simple beds created by crude stretchers to smart beds equipped with various advanced functionalities such as motorised wheels and an intelligent steering system. With these features, patient transportation becomes much easier and safer than before. In addition, the number of manual handling tasks and injuries of nurses in relation to the transfer of patients are significantly reduced.

However, a drawback of the current smart hospital beds is that their steering systems are controlled by human users. In recent years, the increasing number of people being hospitalised (especially obese patients) has led to work overload problems for nurses. Stress, exhaustion and distraction of staff are some of the effects of the nursing work overload problem. These are also major factors causing unpredictable risks for both patient and medical staff during transportation within hospitals.

An integration of an operator-following function not only allows the smart hospital bed to deal with the problem of human control but also creates an innovative solution in terms of patient transport. To achieve this, a 3-stage operator-following control strategy is required for the bed system. In the first stage, the operator is identified by the utilisation of a target detection algorithm. In the second stage, based on the information obtained relating to the operator, operator-following controllers generate desired velocities for the smart hospital bed. In the final stage, a low-level controller drives the bed system to track the desired velocities.

In relation to operator detection, two approaches, consisting of the Gaussian Distribution Method (GDM) and the Artificial Neural Network (ANN), are investigated and developed for the smart hospital bed. Technically, the GDM classifier is based on a threshold condition of a Mahalabonis distance between a testing point and the training data set. On the other hand, the ANN classifier is based

on a construction of a neural network model through a training procedure. The experimental results show that the operator detection performance of the Neural Network - Levenberg Marquardt (NN-LM) method is better than that of the GDM method (92.41% sensitivity and 89.8% specificity vs 91% sensitivity and 88.5% specificity).

In terms of the low-level control, two approaches including an Optimal Multivariable Proportional Integral Derivative (OMPID) control method and an Optimal Multivariable Neural Network (OMNN) control approach are introduced and designed for the smart hospital bed. In theory, the OMPID control algorithm is a combination of a Triangular Diagonal Dominance (TDD) decoupling technique and an Optimal Proportional Integral Derivative (OPID) control design. Meanwhile, the OMNN control strategy combines a two-phase diagonal decoupling technique and an Optimal Neural Network (ONN) control design. Real-time implementation indicates that the OMNN controller drives the smart hospital bed to track the desired velocities with higher accuracy, smaller overshoot, shorter rise time and settling time than the OMPID controller.

From the results obtained from the operator detection algorithms and the low-level control algorithms, an advanced operator-following control strategy is developed for the smart hospital bed. This is a combination of the neural network based operator detection method, the Proportional Integral Derivative (PID) based operator-following strategy and the intelligent multivariable low-level control approach. The Levenberg-Marquardt (LM) learning algorithm is chosen to train the neural network classifier. Two PID controllers are utilised to minimise the distance and angle error between the operator and the bed system. The Optimal Multivariable Neural Network control strategy takes the responsibility of stabilising the overall system under the effect of uncertainties. The experimental results serve to show that the operator-following performance of the smart hospital bed using the advanced operator-following control strategy is more stable and efficient than that of the bed system without the proposed approach.