Research on cervical traction equipment based on neural network control system

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Abstract

Traction therapy is an important method for treatment of cervical disease, according to the characteristics of cervical physiological and pathological, give the cervical period loading and load shedding can get better therapeutic effect in the process of traction. We should precise control of the traction in order to ensure the safety and efficacy of traction therapy. Therefore, this paper studies a cervical traction control system based on fuzzy expert and neural network. In order to eliminating the systematic errors of PID neural network control algorithm, we have introduced the variables C of systematic deviation, greatly improve the control precision, the PID neural network algorithm has been improved, so that it can meet control requirements of the equipment. Found the linear relationship between C and traction on the study of variation of C. The greater change rate on the piecewise point lead to the error has been increased due to the load is a periodic piecewise functions. In order to improve the control precision, we have used the control strategy combine expert system and PID neural network, measured the weight of W and C under various operating conditions get a fuzzy expert system. The paper develops the traction control system based on the algorithm of the improved PID neural network and fuzzy expert system, using Visual C#2008 as software development tool and Windows XP as the operation platform. The system achieves the expected targets and realizes the traction control and patient information management.

Keywords: Cervical traction equipment; neural network; control system

1. INTRODUCTION

Neck pain is common. Most of the people experienced neck pain in their life, mainly with neck and shoulder pain, upper extremity pain, numbness, as the main symptoms. With the high prevalence rate and growing incidence rate, as the high recurrence rate, neck pain adversely affect the socio-economic system, family and the health care system. In American, the medical expenses on spinal care, including neck pain, is about 19.39 billion US dollars, which is the second most costly musculoskeletal health care expenses. There is normally no indication for surgery in case of neck pain. Most patients seek for conservative treatment. There are different conservative treatments based on the diversity and complexity of the causes of neck pain. Current research did not find a conservative treatment which is better than the other treatments, and yet to find the gold standard of conservative treatment of neck pain (Chung et al., 2003; Koyama et al., 2005).

Conservative treatment options are personalized, in response to different clinical conditions require, such as acute or chronic neck, pain level, neck activity and whether the pain was accompanied by neurological symptoms. Also, conservative treatment programs change with the patient’s condition. For patients with neck pain treatment strategies developed primarily from clinical experience. The current use of a wider range of practices include manual therapy, acupuncture, traction, cervical exercise therapy, in which manual therapy is the most common use of practices, and shows the most treatment effect satisfaction in patients. Spinal manipulation and mobilization techniques are the two commonly used approach. Their main difference lies in the use of high-speed thrust in spinal manipulation in the spine. The purposes of treatments are to relieve mechanical compression of the nerve, to improve the local microcirculation, restore spinal balance and relieve muscle spasm. However, some may argue that there is lack of evidence on the efficacy of the techniques. Some studies suggest that practices therapeutic effect is limited to only short-term effects. There are studies that some practices, especially the cervical spine movement joints practices may cause cervical basilar artery blockage that induced risk of stroke, and is not recommended. In this way, the scientific nature of the manual therapy, efficacy and safety was questioned (Odebode et al., 2011).

According to the types and the energy of violence, with or without rotation factors, as a common cervical spine injury in clinical, the dislocation of lower cervical spine (which is often refer to 3-7 cervical spine) can result in the total dislocation or semi dislocation of cervical facet joints with unilateral or bilateral as well as the fracture...
of vertebral body, vertebral lamina, and spinouts process; at the same time, it is often accompanied by different severity of spinal cord injury, and even life-threatening. Therefore early diagnosis and treatment, to shorten the time of compression of spinal cord and restoring the effective volume of the spinal canal are very important to create favourable conditions for the recovery of nerve function (Kang and Park, 2015). Yet traction is an important means for relieving the compression of spinal cord, and most scholars believe that axial skull traction is the most simple, effective, safe and reliable device. From traction bow of Crutchfield to Gardner-wells, and scholars have improved or designed many new tools later such as modified Gardner-wells traction, bi-directional traction bed, Odebode-Agaja traction bow and so on (Kinnaird and Jelsma, 2009; Duane, 2004). It is said that the skull traction is still an indispensable clinical means in the treatment of dislocation and fracture of lower cervical spine. It is also said that the skull traction is fast and efficient, cheap and easy. Whether the conservative treatment after unsuccessful closed reduction or the surgery after a failure of closed reduction, the skull traction is still plays an indispensable role in the treatment of dislocation and fracture of lower cervical spine, it’s worthwhile for us to continue to promote or improve. Now the traditional traction method is that the initial weight is 4kg, and X-ray is executed per 30min, if that failed, the 2kg weight traction is increased and so on. If the weight is added to 18kg or time over 24hours not yet reset, a surgical reduction is required. Due to the larger scope of traction, load is aperiodic piecewise functions, the patient have muscle resistance and other reasons in the process of traction, experiments show that the traditional PID control method is difficult to meet the accuracy requirements (Marangoz et al., 2013).

2. MATERIALS AND METHODS

BP network is an error back propagation algorithm by former training multi-layer feed-forward network. This paper also analyzes the results of the process evaluation of the advantages and limitations. On the basis of its limits the research put forward the way to improving the effectiveness of teaching evaluation. And it put forward the process of evaluation that it is not exist in isolation. It can put the evaluation process and the traditional summative assessment together effectively, so as to achieve the sustainable development of teaching, achieve better teaching purpose, the better teaching effect. BP neural network topology includes input layer (input), hide layer (hide layer) and output layer (output layer).

PSO algorithm is a population-based optimization method, called particle swarm algorithm, individuals called particles. Traditional perception quality of teaching is one-dimensional, that is when the property meets the quality of teaching, and the students will be satisfied. And when property does not meet the quality of teaching, the students will be not satisfied. However, the quality of teaching evaluation of this single dimension too monotonous is not able to fully explain the student evaluation (Lei et al., 2015).

Traditional perception quality of teaching is one-dimensional, that is when the property meets the quality of teaching, and the students will be satisfied. When the property to meet, customer is satisfaction. But when the property is not met, the customer can accept. 2.
Expected quality level (O): When the property to meet customer satisfaction. But when the property is not met, the customer is not satisfied. The basic mass (M): When property satisfied, customers think it should be so. But when the property is not met, the customer is not satisfied. No difference in quality (I): Whether property is satisfied, customers will be satisfied or dissatisfied. Rebellious quality (R): When property is satisfied, customer dissatisfaction. When the property is not met, the customer will be satisfied.

Formula is as follows:

\[
\frac{1}{2\pi} \int_{-\infty}^{\infty} e^{-itx} dx = \delta(k) \quad (4)
\]

Equation (1) can be converted into the following form:

\[
f(y,\omega) = f^0(y,\omega) + \int S(y - y', \omega) L \bar{F}(y', \omega) dy' + \rho \omega^2 \int g(y - y', \omega) \bar{J} f(y', \omega) dy'
\]

\[
a f_b^{(a)} f(t) = \frac{1}{\Gamma(1+\alpha)} \int_a^b f(t)(dt)^\alpha
\]

\[
= \frac{1}{\Gamma(1+\alpha)} \lim_{\Delta t \to 0} \sum_{j=0}^{j=N-1} f(t_j)(\Delta t)^\alpha
\]

With \( \Delta t_j = t_{j+1} - t_j \) and \( \Delta t = \max \{ \Delta t_1, \Delta t_2, \ldots, \Delta t_j, \ldots \} \), where for \( j = 1, 2, \ldots, N-1 \), \( [t_j, t_{j+1}] \) and \( t_0 = a \), \( t_N = b \). Active set methods (ASM) are considered as one of the most effective techniques for solving small to medium scale nonlinear problems. In this work we will focus on ASM for solving convex QP problems depicted in (3) in which case the Hessian \( G \) is at least positive semi definite and therefore any local solution of the QP is also a global minimizer. ASM solves system (3) by reducing it into the following equality constrained QP. If \( f(x) \) is defined on the real line \(-\infty < x < \infty\), its local fractional Hilbert transform, denoted by \( f_{x}^{H,\alpha}(x) \) is defined by

\[
H_\alpha \{ f(t) \} = f_{H}^{\alpha}(x)
\]

\[
= \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} f(t)(dt)^\alpha
\]

Traditional perception quality of teaching is one-dimensional, that is when the property meets the quality of teaching, the students will be satisfied. And when property does not meet the quality of teaching, the students will be satisfied. However, the quality of teaching evaluation of this single dimension too monotonous is not able to fully explain the student evaluation. So it can use KANO theory and SERVQUAL theory of university teaching quality satisfaction survey, in order to help the university teachers understand the various needs of the students as well as induction affect students’ satisfaction with teaching quality factors.

The three level BP neural network shown in Fig. (1). Where: N1 is the input layer node. N2 intermediates layer nodes. N3 is output layer node.
The three level BP neural network shown in Fig. (2). Where: N1 is the input layer node. N2 intermediates layer node. N3 is output layer node.

Neck pain is the most common complaint in cervical syndrome nerve root type, which is the patients, can easily locate the area of pain. The onset may be acute, sub-acute, or chronic, and impingement on the nerve roots may be from either osteophytes or disc herniation. The pain characteristic is radiation of pain into the inter scapular area and into the arm. Patients feel continues aching and insidious pain in mild case and paroxysmal sharp pain in the severe cases. The symptoms can be aggravated when the neck is extended backward and can also be aggravated by deviation of the head toward the sick side, cough, sneezing, abdominal pressure (cassava manoeuvre), defecation and urination (Jung, 2016; Myśliwiec, 2014). The traction device (Fig 3) was originally designed for portable intermittent use to accommodate a patient’s daily activities during traction.

For relief, the patient often adopts a position with the arm elevated and flexed behind the head, unlike the patient with shoulder disease who maintains the arm in a dependent position, avoiding elevation or abduction at the shoulder joint. Mostly, the pain radiates downward along the cervical nerve root, it is experienced as a "lightning" or "electric" sensation and is referred to dermatome areas. It is felt mainly in the upper limb, scapula, and the trapezius ridge and is often patients have proximal arm pain and distal parenthesis as X22. The basic algorithm is shown in the following equations (Hoffman et al., 2016; Choi et al., 2015; Chumbley et al., 2015; Gudavalli et al., 2014; Barros et al., 2014):
\[
\varphi_j(\mu_i) = \exp \left( -\frac{(\mu_i - C_j)^2}{b_j^2} \right), \text{ for } i = 1, 2, \ldots, H \quad (8)
\]

In this space, the \( m \)th multidimensional receptive-field function is defined as
\[
\Phi_m(\mu) = \prod_{j=1}^{\bar{m}} \varphi_j(\mu_j), \text{ for } m = 1, 2, \ldots, N \quad (9)
\]

The function can be written in a vector notation as
\[
\Phi(\mu, C, b) = [\Phi_1, \Phi_2, \ldots, \Phi_N]^T \quad (10)
\]

where \( C = [C_{11}, \ldots, C_{1L}, C_{21}, \ldots, C_{2L}, \ldots, C_{N1}, \ldots, C_{NL}]^T \), and \( b = [b_{11}, \ldots, b_{1L}, b_{21}, \ldots, b_{2L}, \ldots, b_{NL}]^T \).

The weight memory space with \( N \) components can be expressed in a vector as
\[
W = [W_1, W_2, \ldots, W_N]^T \quad (11)
\]

The activated weights in weight memory space, which can be written in a vector form as
\[
y = W^T \Phi(\mu) \quad (12)
\]

The state variables and the desired values can be defined as follows:
\[
z_1 = x - y_d \quad (13)
\]

and
\[
z_2 = x - \alpha_d \quad (14)
\]

The following tracking error dynamics is shown as:
\[
\dot{z}_1 = \dot{x} - \dot{y}_d = x_2 - \dot{y}_d = \dot{z}_2 + \alpha_d - \dot{y}_d \quad (15)
\]

The first derivative of the Lyapunov function can be written as
\[
\dot{V} = z_1^T \dot{z}_1 = z_1^T (\dot{x} - \dot{y}_d) = z_1^T (\dot{x}_2 - \dot{y}_d) = z_1^T (\dot{x}_2 - \dot{y}_d) = z_1^T (z_2 + \alpha_d - \dot{y}_d) = z_1^T (z_2 + \alpha_d - \dot{y}_d) = -\lambda z_1^T z_1 + z_1^T z_2 \quad (16)
\]

From (9) and (13), it can be obtained:
\[
\dot{z}_2 = \dot{x} - \dot{\alpha}_d = -M^{-1}Cx - M^{-1}(G_y + d) + M^{-1}r - \dot{\alpha}_d \quad (17)
\]

\( \tau \) is selected as
\[
\tau = -\lambda z_2 - z_1 - F \quad (18)
\]
Then we can get:

\[
V_2 = V_1 + \frac{1}{2} z_2^T M z_2 + \frac{1}{2} z_2^T M z_2 + \frac{1}{2} z_2^T M z_2 = -\lambda_1 z_1^T z_1 + z_1^T z_1 + z_2^T M (x_2 - \hat{a}_1) + z_2^T C z_2
\]

\[
V_2 = V_1 + \frac{1}{2} z_2^T M z_2 \quad (19) = -\lambda_1 z_1^T z_1 + z_1^T z_2 + z_2^T (-C x_1 + C z_2 + \tau - M \hat{a}_1 - (G_g + d))
\]

\[
= -\lambda_1 z_1^T z_1 + z_1^T z_2 + z_2^T (f + \tau) - z_2^T (G_g + d)
\]

\[
(20) \dot{V}_2 = -\lambda_1 z_1^T z_1 - \lambda_2 z_2^T z_2 + z_2^T (f - F) - z_2^T (G_g + d) \quad (21)
\]

The ideal weight \( W \) from (17) and expressed as

\[
F = W^T \Phi(\mu) \quad (22)
\]

Define the estimate of the value of (18) as

\[
\hat{F} = \hat{W}^T \Phi(\mu) \quad (23)
\]

It’s provided by the adaptive weight law. So estimation error of the weight is

\[
\tilde{W} = W - \hat{W} \quad (24)
\]

The positive values \( W_{\text{max}} \) as follows:

\[
\| W \| \leq W_{\text{max}} \quad (25)
\]

The adaptive weights law is defined as

\[
\dot{\hat{W}} = -k G \| \tilde{W} - z_2^T G \Phi(\mu) \quad (26)
\]

By differentiating the yields of \( V \), we obtain

\[
\dot{V} = \dot{V}_2 + tr \left\{ \hat{\Phi}^T G \tilde{W} \right\}
\]

\[
= -\lambda_1 z_1^T z_1 - \lambda_2 z_2^T z_2 + z_2^T (f - F) - z_2^T (G_g + d) + tr \left\{ \hat{W}^T G \tilde{W} \right\} \quad (27)
\]

\[
= -\lambda_1 z_1^T z_1 - \lambda_2 z_2^T z_2 + z_2^T (f - \hat{F} - F) - z_2^T (G_g + d) + tr \left\{ \hat{W}^T G \hat{W} \right\}
\]

The symptoms of cervical syndrome nerve root type may also include pain, numbness, or weakness in different areas of the arm or hand. Although most acute neck pain is a relatively common ailment that usually resolves within a couple of weeks, some neck pain can persist and may be also present in the shoulder or arm. The goals of treatment will be to provide pain relief, to improve range of neck movement, and to prevent long-term disability. The initial treatment focuses on patient education and control of pain and inflammation. The patient should be informed that most patients (70% to 80%) have well to excellent outcomes with conservative management and that most of the pain subsides within several weeks. Over 90% of patients with acute cervical radiculopathy due to cervical disc hesitation will improve without surgery. The purpose of this paper is to discuss non-operative treatments (especially acupuncture) for cervical syndrome nerve root type of patients with neck and upper extremity pain.

3. RESULTS AND DISCUSSION
The MR images obtained in the seven healthy volunteers during traction showed that the length of the cervical vertebral column had increased by 0–3 mm (mean length increase, 1.93 mm). Of the 29 patients, 21 (72%) had complete resolution or partial reduction of the cervical disk herniation and an elongation of the cervical vertebral column of 0-7mm (mean length increase, 2.19 mm), which was not significantly different from that in the volunteers (P>0.917). Eight patients had minimal elongation of the cervical vertebral column (mean length increase, 0.44 mm), which was significantly shorter than that in the healthy volunteers (P<0.001) (Table 1). No patient reported having pain or any other discomfort during either traction device inflation or MR imaging. Of the 29 patients, who had a total of 40 HCDs, 19 had an HCD at one cervical disk level, nine had HCDs at two levels, and one had HCDs at three levels. There were 15 HCDs each at the C5–6 and C6–7 cervical disk levels. There were five HCDs at the C3–4 level, three at the C4–5 level, and two at the C7-T1 level. In the patient with HCDs at three levels, the herniation at one level was reduced but the herniations at the two remaining levels were not. In the nine patients with HCDs at two levels (total of 18 levels), the herniations were reduced at 13 levels and not reduced at five levels. Of the 19 patients with HCDs at one level, 13 had reduced herniations and six did not. Disk herniation was completely resolved in three (10%) of the 29 patients and partially reduced in 18 (62%) (Fig 4).

Figure 4. Experiment result

Eight of the 29 patients had minimal elongation of the cervical vertebral column during traction (mean length increase, 0.44mm; range, 0–1.5mm), however, and no reduction of the disk herniation. The length of elongation of the cervical vertebral column during traction in this group was significantly shorter than that in the healthy volunteers (P<0.02). There was a significant difference in elongation of the vertebral column between the patients who did and those who did not have some herniation reduction (P<0.01). Widening of the facet joint space was observed at MR imaging during traction in two (29%) of the seven healthy volunteers and in five (17%) of the 29 patients (Fig 5). In addition, foramina widening was observed in one (14%) of the seven volunteers and in five (17%) of the 29 patients. Dimpling of the annulus capsule due to the secondary retraction effect of the increased disk length was observed on the sagittal MR images obtained in three (43%) of the seven healthy volunteers and in 12 (41%) of the 29 patients (Fig 6).

A cervical spine model of three dimensional finite element models was set up in accordance with measuring figures of cervical spine by autopsy and three planar finite element units were produced according to three X-ray pictures which showed three kinds of cervical radiant pathological changes of cervical lordships: smaller, straight, kyphosis. 11 kinds of different traction angles from 0 to 30 degrees and 5%, 10%, 15%, 20% weight of body pull were approached to observe the stress distribution of lustra joints, cervical facet joints and changes of vertical distances among cervical transverses.

(1) The stress of normal lustra joints and cervical facet joints was mainly compressive stress which increased from top to bottom, and vertical distances among cervical transverse became slightly narrow at the action of head weight;

(2) when head was in normal or flexion posture, the compressive stress on lustra joints and cervical facet joints could be turned into tensile stress and vertical distances among cervical transverses turned wide ,while in extension posture the stress on them was remain compressive stress and vertical distances turned narrow by traction. The location of maximum stress on the cervical moved downward according to the enhancing of angle. The value of all of them was enlarged with the enhancing of angle and force;
(3) In despite of three kinds of cervical pathological changes, there were the same feature: when head was in normal or flexion posture, the stress of lustra joints and cervical facet joints was still tensile stress and enlarged according to the enhancing of angle and force, the location of maximum stress on the cervical moved downward according to the enhancing of angle.

(4) The therapeutic principle of CSA by cervical traction was that cervical traction withstood the weight of head, turned the compressive stress on lustra joints and cervical facet joints into tensile stress and widened vertical distances among cervical transverses by cervical traction when head was in normal and flexion position;

(5) The suitable traction force were 10%-15% weight of body and angles of cervical traction should be in 0-10 degrees with head was in normal or flexion posture at beginning and the follow selection of angle and force should accommodate to clinical and image diagnoses;

(6) The pathological changes of cervical lordships had little influence on therapeutic effect.

4. CONCLUSION
In this paper, the author studies on cervical traction equipment based on neural network control system. Therefore, this paper studies a cervical traction control system based on fuzzy expert and neural network. In order to eliminating the systematic errors of PID neural network control algorithm, we have introduced the variables C of systematic deviation, greatly improve the control precision, the PID neural network algorithm has been improved, so that it can meet control requirements of the equipment. Found the linear relationship between C and traction on the study of variation of C. Therefore early diagnosis and treatment, to shorten the time of compression of spinal cord and restoring the effective volume of the spinal canal are very important to create
favourable conditions for the recovery of nerve function. Yet traction is an important means for relieving the compression of spinal cord, and most scholars believe that axial skull traction is the most simple, effective, safe and reliable device. The greater change rate on the piecewise point lead to the error has been increased due to the load is a periodic piecewise functions. In order to improve the control precision, we have used the control strategy combine expert system and PID neural network, measured the weight of W and C under various operating conditions get a fuzzy expert system. The paper develops the traction control system based on the algorithm of the improved PID neural network and fuzzy expert system, using Visual C#2008 as software development tool and Windows XP as the operation platform. The system achieves the expected targets and realizes the traction control and patient information management.

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