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Applications of Case-Based Reasoning Approach to Promote Well Teaching and Learning in Dynamic System Modeling and Analysis Subject

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Abstract

One of the most widely used well completion challenges to promote well teaching and learning effectively in mechanical engineering education is dynamic system and modeling analysis subject. The learning innovation is that case-based reasoning approach retrieve, reuse, revise and retain solutions to solve previous problems that have been encountered and remembered as cases representation. The purpose of this paper presents an application of case-based reasoning approach to promote well teaching and learning in dynamic system modeling and analysis subject. Both the concept and the proposed model were followed by scaffolding problem-solving in technology-enhanced learning environments via case-based reasoning. A systematic literature review guided by article journals and research related field via electronic database was conducted in kinematic modeling and dynamic modeling for a proposed model of omni-directional wheeled robot. While deriving the robot's instantaneous translation velocity, rotationvelocity and the relative velocity is straightforward, expressing a suitable model to promote well teaching and learning effectively dynamic system and modeling analysis subject. By arbitrarily integrating the technology-enhanced learning environments via case-based reasoning, a proposed model is that alternative solutions can be recommended to the experts for final decision and implications. The proposed model is implemented in a generate idea, implication to solve problems, adaptation knowledge to generic problems are presented.

Keywords:Case-based reasoning, Dynamic System Modeling and Analysis, Problem Solving, Technology-enhanced learning environments

Introduction

Mechanical engineering education aims to promote quality of the problem-solving skills by integrating multidisciplinary studies, and develops intermediate science, technology, engineering, and mathematics (STEM), and real-world problem-solving on social demands to improve future engineering competencies (Jonassen, 1999; 2006).One of the most widely used well completion challenges to promote well teaching and learning effectively in mechanical engineering education is dynamic system and modeling analysis subject (DSMA). Due to its highly learning achievement and applications, DSMA deals with the mathematical modeling of well dynamic systems and response analyses of such systems with a view toward understanding the dynamic nature of each system and improving the system's performance (Ogata, 2004).

Moreover, well are often DSMA applications as mobile manipulators. Li et al. (2009) stated that mobile manipulators is conceptualized as robotic manipulators (orarms) mounted on mobile platforms (or vehicles). Suchsystems combine the advantages of mobile platforms and roboticarms and reduce their drawbacks.Therefore, students learn to analyze besides exogenousdisturbances which may increase the difficulty of referencedynamic tracking control for mobile manipulators, actuator failures (eitherin wheels or joints) might suddenly occur during the motionof mobile manipulators (Kang et al., 2012).

Successfully,dynamic tracking control has been a challengefor studentsto solve in the term of NHMS.

In this paper, researchers proposed the applicability ofCBR as the adaptation knowledge to studythe control of mobile manipulators presents a significantincrease in the single mobile manipulatorcase.This will impose a set ofkinematic and dynamic constraints on the position and velocityof coordinated mobile manipulators in the term of non-holonomic mechanical systems (NHMS).The well NHMS datasets represent a tremendousamount of knowledge to idealize the relationships between kinematic modeling and dynamic modeling by eliminating the relative motion.

The purpose of this paper presents an application of case-based reasoning approach to promote well teaching and learning in dynamic system modeling and

problems in DSMA. Significant work andresearch was not conducted in the context of Thai engineering education using artificial intelligencetechniques to mine data and build predictive systems thatwould maximize the output of the wells.Currently to characterize the study phase, Case-based reasoning (CBR) is an excellent technique to promote students use maximizes the value of historical data enabling better decisionsregarding well a set ofkinematic and dynamic constraints on the position and velocityof coordinated mobile manipulators

analysis subject for undergraduate mechanical technology students at Nakhon Si ThammaratRajabhat University.

Both the concept and the proposed model were followed by scaffolding problem-solving in technology-enhanced learning environments via case-based reasoning.

This paper organized as follows: Section 2 introduces the theoretical background of CBR and NHMS of mobile manipulators; Section 3 presents an application of problem-solving in technology-enhanced learning environment via CBR; Section 4 discussesthe proposed model for application of TELEs via CBR; Section 5 suggestsfurther complements that extend the basic functionality provided by the proposed model.

Theoretical Background

While interest in technology changes has been affected to improve problem-solving skills, students has been lack. Hannafin and Land (2000) described that teachers hold traditional teaching methods, didactic beliefs and use “conventional ways” without sustainable development for student-centered problem solving. For this reason, researchers then analyze research and journals related to dynamic system and modeling analysis, teaching and learning, and technology-enhanced scaffolds for designing problem-solving, implications for real-world engineering education (Sudsomboon&Anmanatrakul,2010; Sudsomboon&Maungmungkun, 2013). CBR is fit to employ as theproblem solving techniquethat uses and adapts the solutions of analogous past problems tosolve new problems(Aamodt& Plaza, 1994; Chang, Lai, & Robert, 2006; de Mantaras, McSherry, Bridge, Leake, Smyth, Craw, et al., 2005; Hsu & Ho, 2004; Kolodner, 1993; Vong& Won, 2010). Case-Based Reasoning (CBR)

CBR is a problem solving method thatuses similar solutions from similar past problems in order to solvenew problems (Kolodner, 1993).One of the main properties of theCBR systemis a subfield of Artificial Intelligence rooted in the works of Roger Schank in the early 80s, ondynamic memory and the central role that the recall of earlier episodes (cases) and scripts (situation patterns) has in problemsolving and learning.

CBR stated as a heuristic human problem solving behavior that has been adapted for computer use. It is based on recall and reuse of specific "cases" and offers techniques for acquiring, representing and managing previous experiences. The CBR cyclehave four-step process of retrieve, reuse, revise, and retain is detailed as shown in Figure. 1.

Insert Figure 1 here

Retrieve: The process of finding cases, and their corresponding solutions, in the dataset or knowledge base that are most relevant to the given case. Reuse: The process of mapping the most common solution from the knowledge base for the given case. The reuse process also allows for adaptation of the most common solution, as needed, through the use of rules or "if statements" incorporated into the system. Revise: The process of testing the new solution. If the new solution is successful, the process moves directly to retain. If the new solution does not work as expected or needs additional fine-tuning, the solution is further adapted to achieve the desired result.

Retain: The process of storing the new case and its final solution in the knowledge base for future use in the case-based reasoning process. The benefit of CBR resides in its potential for developing a learning system that learns as new cases are solved. Learning occurs as a natural by-product of the process (Aamodt and Plaza, 1994). It is important to propose that CBR guide to solve problems effectively. For the application of mechanical engineering, each time a new solution is generated and a problem is solved, the experience is stored through the retain process to be used later on in solving similar problems. On the other hand, when the proposed solution to the problem fails, the reason for failure is identified and retained in order to avoid the same failure in the future. Analysis of NHMS for mobile manipulators

In the recent years, mechanical systems with holonomic constraints are traditionally treated by eliminating dependent variables from the motion equations. However, this elimination is not applicable to systems with non-holonomic constraints. For the applications of control engineering, there are many systems that are subject to both non-holonomic and holonomic constraints. In case of the non-holonomic systems, depending on whether the non-holonomic constraints are presented at a kinematic or dynamic level.

The existences of NHMS namely non-holonomic constraints (NHC) have received increasing application of their industrial systems like the motion planning and control of mobile manipulators are designed to perform high-speed and high-precision operations. A first systematic study of NHC, focusing motions needed for these operations,was characterized by a wide range of changes of positions and velocities(Li,Ge, &Ming, 2007; Venkatraman, Ortega,Sarras, & van der Schaft, 2008).

However, NHC as a nonlinear dynamics effects and dynamic couplings become dominant for such motions. Also, kinematic consideration of the dynamics model may interfere control processes. The work industrial systems are to perform is achieved via sophisticated control algorithms, which are required to be stable and high performance(Wang, Miao, Liu, &Chen, 2013). The precision control demands can be met when control algorithms are based upon full nonlinear dynamic system models. According to Brockett's theorem (2003), stated the NHC with restricted mobility

cannot be stabilized systems to perform configuration in the mobile manipulators. Hence, the control design in this study conceptualized as feedback control of dynamic model in non-holonomic mechanical systems (NHMS) is a challenging problem, and arises from the fact affected that a system for stabilization by a static time invariant feedback. With most recently researches were done by the assumption of known dynamics, which has been carried out to control mobile manipulators, includinginput–output feedback linearization,and nonlinear feedback control. Because ofdynamic uncertainty, adaptive modern controls systems have been proposed for motion control ofmobile manipulators (Tan, Xi, & Wang, 2003; Yamamoto, &Yun, 1996; Lin, &Goldenberg, 2001).

However, inanalyticalmethodology, environmental uncertainties arise in mobile manipulator motions which cannot affect the system stability and performance. In this paper, under NHC uncertainly, the most significant fact from the control design perspective is that they do not merge into a dynamic system model. This is because the dynamic models are based upon classical results in dynamics, i.e. Lagrange's equations with multipliers (Wang, Miao, Liu, &Chen, 2013; Bloch, Baillieul, &Krishnaprasad, 2007) and their modifications or Kane's equations. Also, the NHC equations represent tasks put upon system motions and they can be differentialequations of orders higher than one or two, and be non-integrable (Xu, Zhao, Yi, & Tan, 2009).

The tracking control strategy reliesupon two dynamic models: a reference model, which is a dynamic model of a system with arbitrary orderdifferential constraints and a dynamic control model. The reference model serves as a motion planner,which generates inputs to the dynamic control model(Xiao,& Zhang, 2013).

Moreover, the importance of NHMS constraints that originates from other than kinematic sources have beenrealized. These include (Cheng, Su, Tsai, & Nguyen, 2012; Tang, Miller, Krovi, Ryu, &Agrawal, 2011; Xu, Zhao, Yi, & Tan, 2009):

Constraints that arise through feedback control of a mechanical or biological system, such as an "intelligent" being imposing a constraint;

Constraints that are kinetic in nature (such as determining the equations of motion of a system subject to constant total energy, momentum, or other first integrals or constants of the motion);

Constraints imposed mathematically, without regard to their physical realizability.

Aplication of problem-solving in technology-enhanced learning environment via CBR

This section presents the concept and the proposed model, followed by scaffolding problem-solving in technology-enhanced learning environments (TELEs), the proposed model for application and constructing of problem-solving in the knowledge domain via CBR; finally implications are presented.The proposed model for this paper is a systematic literature review guided by article journals and research related field via electronic database.

The data was conducted by a systematic review as follow as: (1) searching the research related field, (2) selecting research journals, (3) extracting/monitoring data, and (4) data synthesis with validation/modification to evaluate the results (Kim &Hannafin, 2010; Nussbaum, 2008).

Scaffolding problem-solving in technology-enhanced learning environment via CBR

By reviewing principles of problem-solving approaches, it is evident that will be applicable for all types of problems and problem-solving contexts. Conceptualization of problem-solving approached appropriate for students that are neither situated in a specific context nor influenced by domain-specific learning tasks. To effective learning, researchersmotivate students know problem solving as situated, deliberate, learnerdirected, activity-oriented efforts to seek divergent solutions to authentic problems through multiple interactions amongst problem solver, tools, and other resources.

In this paper, researchers define the referee journals of a redundantly actuatedomnidirectional mobile manipulator with kinematicconstraints entitled: Modeling and Adaptive Fuzzy Control for an Omni-Directional Wheeled Robot (Lin, Juang, &Chen, 2013; Xu, Zhao, Yi, & Tan, 2009) as shown in Figure 2 .

Insert Figure 2 here

A. Kinematic modeling From Figure 2, about the research showed the derived of kinematic modeling was completely. Lin, Juang, and Chen (2013)proposed that the descriptions of a Swedish wheel mounted on a mobile robot with local coordinate frame {R} $(G-X_RY_RZ_R)$, where point A is the wheel center and other geometric parameters are defined as follows. α is the angle of vector $\overline{GA}$ relative to X_R axis, and β is the angle between $\overline{GA}$ and main wheel axis. The distance from G to wheel center A is l, and the main wheel's radius is r. And $\dot{\varphi}$ and $\dot{\varphi}_{sw}$ are respectively the rotation speeds of the main wheel and the passive roller contacting with the flat floor.

The corresponding velocity of wheel center A is $r\dot{\varphi}$ along the tangential direction. Thus, the wheel center A's velocity component along the contact roller's axis is $r\dot{\varphi}\cos\gamma$ .Assume that the robot's instantaneous translation velocity in terms of local frame {R} is $[\dot{x}_R\ \dot{y}_R]^T$, and the rotation velocity about Z_R axis is $\dot{\theta}$. Then the wheel center A's velocity vector can also be computed by summing the translational velocity components $\dot{x}_R, \dot{y}_R,$ and the relative velocity $l\dot{\theta}$ due to the rotation shown in Figure 2. The wheel center A's velocity component along the contact roller's axis can be expressed as (Siegwart, Nourbakhsh, & Scaramuzza, 2011):

$$\begin{aligned}
&\dot{x}_R\cos\left[\frac{\pi}{2}-\left(\frac{\pi}{2}-(\alpha+\beta)\right)-\left(\frac{\pi}{2}-\gamma\right)\right]\\
&+\dot{y}_R\cos\left[\left(\frac{\pi}{2}-(\alpha+\beta)\right)+\left(\frac{\pi}{2}-\gamma\right)\right]\\
&+l\dot{\theta}\cos\left[\alpha+\left(\frac{\pi}{2}-(\alpha+\beta)\right)+\left(\frac{\pi}{2}-\gamma\right)\right]\\
&=\dot{x}_R\cos\left[(\alpha+\beta+\gamma)-\left(\frac{\pi}{2}\right)\right]\\
&\quad+\dot{y}_R\cos\left[\pi-(\alpha+\beta+\gamma)\right]+l\dot{\theta}\cos\left[\pi-(\beta+\gamma)\right]\\
&=\left[\sin(\alpha+\beta+\gamma)\ \ -\cos(\alpha+\beta+\gamma)\ \ -l\cos(\beta+\gamma)\right]\cdot\\
&\quad\left[\dot{x}_R\ \dot{y}_R\ \dot{\theta}\right]^T
\end{aligned} \tag{1}$$

Thus, the constraint equation for a Swedish wheel to have no slipping along the contact roller's axis as:

$$\begin{aligned}
&\left[\sin(\alpha+\beta+\gamma)\ \ -\cos(\alpha+\beta+\gamma)\ \ -\boldsymbol{l}\cos(\beta+\gamma)\right]\cdot\\
&\quad\left[\dot{\boldsymbol{x}}_{\boldsymbol{R}}\ \dot{\boldsymbol{y}}_{\boldsymbol{R}}\ \dot{\theta}\right]^{\boldsymbol{T}}=r\dot{\varphi}\cos\gamma
\end{aligned} \tag{2}$$

Since the rotation matrix representing the orientation of the inertia frame {I} with respect to the robot frame {R} can be expressed as

$$ {}^{R}\boldsymbol{R}_I(\boldsymbol{\theta}) = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}, $$

where θ is the angle between axes X_R and X_I, and the robot's velocity vector in terms of robot frame {R}, $\dot{\boldsymbol{\xi}}_R = \left[\dot{\boldsymbol{x}}_R \ \dot{\boldsymbol{y}}_R \ \dot{\theta}\right]^T$ can be computed as:

$$ \dot{\xi}_R = {}^{R}\boldsymbol{R}_I(\theta)\dot{\xi}_I, $$

where $\dot{\boldsymbol{\xi}}_I = \left[\dot{x}_I \ \dot{y}_I \ \dot{\theta}\right]^T$ is the velocity vector of the robot geometric center G (refer to Figure3) in terms of inertia frame {I}. And Eq. (2) can be transformed to:

$$ \begin{aligned} &\left[\sin(\alpha+\beta+\gamma) \ \ -\cos(\alpha+\beta+\gamma) \ \ -\boldsymbol{l}\cos(\beta+\gamma)\right]\cdot \\ &\ {}^{R}\boldsymbol{R}_I(\theta)\dot{\boldsymbol{\xi}}_I = r\dot{\varphi}\cos\gamma \end{aligned} $$

In the direction orthogonal to the contact roller's axis, the motion is not constrained because of the free rotation of the passive contact roller, thus we have the following velocity relation:

$$ \begin{aligned} &\dot{x}_R \sin\left[\frac{\pi}{2}-\left(\frac{\pi}{2}-(\alpha+\beta)\right)-\left(\frac{\pi}{2}-\gamma\right)\right] \\ &-\dot{y}_R \sin\left[\left(\frac{\pi}{2}-(\alpha+\beta)\right)+\left(\frac{\pi}{2}-\gamma\right)\right] \\ &-l\dot{\theta}\sin\left[\alpha+\left(\frac{\pi}{2}-(\alpha+\beta)\right)+\left(\frac{\pi}{2}-\gamma\right)\right] \\ &= r\dot{\varphi}\sin\gamma + r_{sw}\dot{\varphi}_{sw} \\ &\therefore \left[\cos(\alpha+\beta+\gamma) \ \ \sin(\alpha+\beta+\gamma) \ \ l\sin(\beta+\gamma)\right]\cdot \\ &\quad \left[\dot{x}_R \ \dot{y}_R \ \ \dot{\theta}\right]^T + r\dot{\varphi}\sin\gamma + r_{sw}\dot{\varphi}_{sw} = 0 \end{aligned} $$

Thus, the above rolling condition can be transformed to be:

$$ \begin{aligned} &\left[\cos(\alpha+\beta+\gamma) \ \ \sin(\alpha+\beta+\gamma) \ \ l\sin(\beta+\gamma)\right]\cdot \\ &\ {}^{R}R_I(\theta)\dot{\boldsymbol{\xi}}_I + r\dot{\varphi}\sin\gamma + r_{sw}\dot{\varphi}_{sw} = 0 \end{aligned} $$

In this paper researchersemploy the omni-directional robot with one Swedish wheel shown in Figure3. In fact, students know the angles $\alpha_i, \beta_i,$ and γ_i of the three Swedish wheels, $i = 1,2,3,$ are based on Eq. (3), we have the three constraint equations for the centers of the three Swedish wheels as follows:

$$ \begin{aligned} &\begin{bmatrix} \sin(\alpha_1+\beta_1+\gamma_1) & -\cos(\alpha_1+\beta_1+\gamma_1) & -\boldsymbol{l}_1\cos(\beta_1+\gamma_1) \\ \sin(\alpha_2+\beta_2+\gamma_2) & -\cos(\alpha_2+\beta_2+\gamma_2) & -\boldsymbol{l}_2\cos(\beta_2+\gamma_2) \\ \sin(\alpha_3+\beta_3+\gamma_3) & -\cos(\alpha_3+\beta_3+\gamma_3) & -\boldsymbol{l}_3\cos(\beta_3+\gamma_3) \end{bmatrix}\cdot \\ &{}^{R}\boldsymbol{R}_I(\theta)\dot{\boldsymbol{\xi}}_I = \begin{bmatrix} r_1\dot{\varphi}_1\cos\gamma_1 \\ r_2\dot{\varphi}_2\cos\gamma_2 \\ r_3\dot{\varphi}_3\cos\gamma_3 \end{bmatrix} \end{aligned} $$

However, the paper is focused on teaching and learning in DSMA, assume three same Swedish-90° wheels be used, and the mounting distances be also equal, thus $\gamma_i = 0^\circ$, and $r_i = r, l_i = l, i = 1,2,3.$ Students can be obtained the following inverse velocity kinematics equation from Eq.(5):

$$r\begin{bmatrix}\dot{\varphi}_1\\ \dot{\varphi}_2\\ \dot{\varphi}_3\end{bmatrix}=\begin{bmatrix}\cos(\frac{\pi}{6}-\theta) & -\sin(\frac{\pi}{6}-\theta) & -l\\ -\sin\theta & \cos\theta & -l\\ -\cos(\frac{\pi}{6}+\theta) & -\sin(\frac{\pi}{6}+\theta) & -l\end{bmatrix}\begin{bmatrix}\dot{x}_I\\ \dot{y}_I\\ \dot{\theta}\end{bmatrix} \qquad (6)$$

From Eq. (6) is a solution for kinematic modeling in this study.

Insert Figure 3 here

B. Dynamic modeling

In most of the dynamic modeling researches about the omni-directional mobile manipulators, teachers taught the redundantly actuated property of the platform. Consider the mobile robot shown in Figure.3, where G is the geometric center with position vector ${}^I\boldsymbol{r}_G = [x_I \quad y_I]^T$ in terms of inertia frame {I}, and G' is the mass center of the moving platform with relative position vector ${}^R\boldsymbol{r}_{G'/G} = [-d_1 \quad -d_2]^T$ in terms of robot frame {R}. The velocity of point G, ${}^R\boldsymbol{v}_G$, in terms of robot frame {R} can be expressed as

$$\begin{aligned}{}^R\boldsymbol{v}_G &= \begin{bmatrix}\cos\theta & \sin\theta\\ -\sin\theta & \cos\theta\end{bmatrix}\begin{bmatrix}\dot{x}_I\\ \dot{y}_I\end{bmatrix}\\ &= [\dot{x}_I\cos\theta + \dot{y}_I\sin\theta \quad -\dot{x}_I\sin\theta + \dot{y}_I\cos\theta]^T\end{aligned}$$

where $\dot{x}_I$ and $\dot{y}_I$ are the velocity components of G along the x_I and y_I axes, respectively, and θ is the orientation of the platform relative to reference frame {I}. Hence the velocity of the mass center G', ${}^R\boldsymbol{v}_{G'}$, in terms of robot frame {R} can be obtained as:

$$\begin{aligned}{}^R\boldsymbol{v}_{G'} &= {}^R\boldsymbol{v}_G + \dot{\theta}\boldsymbol{k}_R \times {}^R\boldsymbol{r}_{G'/G}\\ &= (\dot{x}_I\cos\theta + \dot{y}_I\sin\theta + \dot{\theta}d_2)\boldsymbol{i}_R\\ &+(-\dot{x}_I\sin\theta + \dot{y}_I\cos\theta - \dot{\theta}d_1)\boldsymbol{j}_R\end{aligned}$$

The total kinetic energy T of the mobile robot including the translational and rotational parts of the platform and the three Swedish wheels can be computed as below:

$$T = \frac{1}{2}[m_b\boldsymbol{v}_{G'}^T\boldsymbol{v}_{G'} + I_b\dot{\theta}^2 + \sum_{i=1}^{3} m_w(r\dot{\varphi}_i)^2 + \sum_{i=1}^{3} I\dot{\varphi}_i^2]$$

where m_b is the mass of the platform, and m_w is the mass of each wheel; I_b is the moment of inertia of the platform about Z_R' axis (parallel to Z_R) through point G', and I_i is the moment of inertia of ith wheel about its main axis; $\dot{\theta}$ is the rotational speed of the platform, and $\dot{\varphi}_i$ is the rotational speed of the ith wheel about its main axis; and r is the radius of each Swedish wheel. Since the mobile robot is assumed moving in a plane, the total potential energy is $V=0$. After substituting Eq. (3)into Eq. (9) and some computations, the Lagrange's equations $L=T-V=T$ can be obtained as follows:

$$
\begin{aligned}
L = \frac{1}{2}\{ & m_b \left[(\dot{x}_I \cos\theta + \dot{y}_I \sin\theta + \dot{\theta} d_2)^2 \right. \\
& \left. +(-\dot{x}_I \sin\theta + \dot{y}_I \cos\theta - \dot{\theta} d_1)^2 \right] \\
& + I_b \dot{\theta}^2 + m_w \left\{ [\dot{x}_I \cos(\frac{\pi}{6}-\theta) - \dot{y}_I \sin(\frac{\pi}{6}-\theta) - l\dot{\theta}]^2 + \right. \\
& + \left[-\dot{x}_I \sin\theta + \dot{y}_I \cos\theta - l\dot{\theta} \right]^2 \\
& \left. +[-\dot{x}_I \cos(\frac{\pi}{6}+\theta) - \dot{y}_I \sin(\frac{\pi}{6}+\theta) - l\dot{\theta}]^2 \right\} \\
& + \frac{1}{r^2} I_1 \left[\dot{x}_I \cos(\frac{\pi}{6}-\theta) - \dot{y}_I \sin(\frac{\pi}{6}-\theta) - l\dot{\theta} \right]^2 \\
& + \frac{1}{r^2} I_2 \left[-\dot{x}_I \sin\theta + \dot{y}_I \cos\theta - l\dot{\theta} \right]^2 \\
& + \frac{1}{r^2} I_3 \left[-\dot{x}_I \cos(\frac{\pi}{6}+\theta) - \dot{y}_I \sin(\frac{\pi}{6}+\theta) - l\dot{\theta} \right]^2 \}
\end{aligned}
$$

The dynamics model can then be derived using the Lagrange's equations:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) - \frac{\partial L}{\partial q_i} = F_i,\ i = 1,2,3$$

where q_i is the ith generalized coordinate, and F_i is the ith generalized force/torque. The generalized coordinate vector is defined as: $\boldsymbol{q} = [q_1\ q_2\ q_3]^T = [x_I \quad y_I \quad \theta]^T$. Refer to Fig. 3, where f_i is the contact friction force of the ith Swedish wheel with the floor, the generalized force/torque F_i , $i = 1,2,3$, can be derived as follows (Spong, Hutchinson, & Vidyasagar, 2006):

$$F_1 = \sum_{i=1}^{3} \left(\tau_i - r\,\mathrm{sgn}(\dot{\varphi}_i) f_i \right) \frac{\partial \varphi_i}{\partial x_I} = \sum_{i=1}^{3} \left(\tau_i - r\,\mathrm{sgn}(\dot{\varphi}_i) f_i \right) \frac{\partial \dot{\varphi}_i}{\partial \dot{x}_I}$$

By Eq. (6),

$$\frac{\partial \dot{\varphi}_1}{\partial \dot{x}_I} = \frac{1}{r}\cos(\frac{\pi}{6}-\theta),$$

$$\frac{\partial \dot{\varphi}_2}{\partial \dot{x}_I} = -\frac{1}{r}\sin\theta,$$

$$\frac{\partial \dot{\varphi}_3}{\partial \dot{x}_I} = -\frac{1}{r}\cos(\frac{\pi}{6}+\theta)$$

Thus,

$$
\begin{aligned}
F_1 = & [\tau_1 - r\,\mathrm{sgn}(\dot{\varphi}_1) f_1][\frac{1}{r}\cos(\frac{\pi}{6}-\theta)] \\
& + [\tau_2 - r\,\mathrm{sgn}(\dot{\varphi}_2) f_2][-\frac{1}{r}\sin\theta] \\
& + [\tau_3 - r\,\mathrm{sgn}(\dot{\varphi}_3) f_3][-\frac{1}{r}\cos(\frac{\pi}{6}+\theta)]
\end{aligned}
\tag{14}
$$

Similarly,

$$\begin{aligned} F_2 &= \sum_{i=1}^{3}\left(\tau_i - r\,\mathrm{sgn}(\dot{\varphi}_i)f_i\right)\frac{\partial\dot{\varphi}_i}{\partial\dot{y}_I} \\ &= [\tau_1 - r\,\mathrm{sgn}(\dot{\varphi}_1)f_1][-\frac{1}{r}\sin(\frac{\pi}{6}-\theta)] \\ &\quad +[\tau_2 - r\,\mathrm{sgn}(\dot{\varphi}_2)f_2][\frac{1}{r}\cos\theta] \\ &\quad +[\tau_3 - r\,\mathrm{sgn}(\dot{\varphi}_3)f_3][-\frac{1}{r}\sin(\frac{\pi}{6}+\theta)] \end{aligned} \qquad (15)$$

$$\begin{aligned} F_3 &= \sum_{i=1}^{3}\left(\tau_i - r\,\mathrm{sgn}(\dot{\varphi}_i)f_i\right)\frac{\partial\dot{\varphi}_i}{\partial\dot{\theta}} \\ &= (\tau_1+\tau_2+\tau_3)(-\frac{l}{r}) \\ &\quad +[\mathrm{sgn}(\dot{\varphi}_1)f_1 + \mathrm{sgn}(\dot{\varphi}_2)f_2 + \mathrm{sgn}(\dot{\varphi}_3)f_3]l \end{aligned} \qquad (16)$$

After some straightforward computations with equal wheel inertias $I_i = I, i = 1,2,3,$ the equations of motion of the mobile robot can be expressed in matrix/vector form as:

$$\boldsymbol{M}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{C}(\boldsymbol{q},\dot{\boldsymbol{q}})\dot{\boldsymbol{q}} + \boldsymbol{J}^T\boldsymbol{S}\boldsymbol{f} = \frac{1}{r}\boldsymbol{J}^T\boldsymbol{\tau}$$

where

$\boldsymbol{M} = \left[m_{ij}\right]_{3\times 3}$ is the inertia matrix,

$\boldsymbol{C} = \left[c_{ij}\right]_{3\times 3}$ is the Coriolis and centripetal matrix,

$\boldsymbol{\tau} = [\tau_1, \tau_2, \tau_3]^T$, $\boldsymbol{f} = [f_1, f_2, f_3]^T$,

$\boldsymbol{S} = \mathrm{diag}[\,\mathrm{sgn}(\dot{\varphi}_1) \quad \mathrm{sgn}(\dot{\varphi}_2) \quad \mathrm{sgn}(\dot{\varphi}_3)\,]$,

$$m_{11} = m_b + \frac{3}{2}(m_w + \frac{1}{r^2}I), m_{12} = m_{21} = 0,$$

$$m_{13} = m_{31} = m_b(d_1\sin\theta + d_2\cos\theta),$$

$$m_{22} = m_b + \frac{3}{2}(m_w + \frac{1}{r^2}I),$$

$$m_{23} = m_{32} = m_b(-d_1\cos\theta + d_2\sin\theta),$$

$$m_{33} = m_b(d_1^2 + d_2^2) + \left[I_b + 3l^2\left(m_w + \frac{1}{r^2}I\right)\right],$$

$$c_{13} = m_b\dot{\theta}(d_1\cos\theta - d_2\sin\theta),$$

$$c_{23} = m_b\dot{\theta}(d_1\sin\theta + d_2\cos\theta),$$

and other c_{ij}'s are all zero, and

$$\boldsymbol{J} = \begin{bmatrix} \cos(\frac{\pi}{6}-\theta) & -\sin(\frac{\pi}{6}-\theta) & -l \\ -\sin\theta & \cos\theta & -l \\ -\cos(\frac{\pi}{6}+\theta) & -\sin(\frac{\pi}{6}+\theta) & -l \end{bmatrix}.$$

Although using fixed largeboundedness can guarantee good performance, this controlscheme is conservative in essence and cannot be applied inpractical systems directly. For the integrated scaffolding problem-solving in TELES, researchers were applied by the five problem-solving approaches: problem identification and engagement, evidence exploration, explanation reconstruction, communication andjustification of explanation, and revision and reflection of explanation were employed (Kim & Hannafin, 2010) as shown in Figure 4.

Insert Figure 4 here

Problem identification and engagement. Starting this phase, learners find or generate problems with the kinematic model by recording ideas. The goal is to guide learners to observe phenomena, derive inferences as to possible causes, relate them to engage in problem solving activities, and establish shared goals between and among peers and teachers-activities crucial in making scientific discoveries in practice. In order to understand the whole mobile manipulator's kinematic model results, identify problems warranting further exploration, and generate Problem reconstruction. Students considers the trajectory tracking problem of the redundantly actuated mobile manipulator system discussedabove. Hence, TELEs reconstruct problems by comparing findings and hypotheses with initial assumptions, observations and inferences. The findings are supported by scientific data collected through experimentations and observations and models proposed to explain causations and/or correlations among relevant variables. Similarly during reconstruction, students generate and revise potential solutions and explanations as they encounter confirmatory or contradictory evidence. As problem reconstruction evolves based on comparisons with findings and interpretations, teachers and peers help students to identify, select, and frame resources relevant to answer their questions.

Presentation and communication. Typically, the presentation of scientific findings involves distributed rather than solely individual reasoning. potential causal models to explain the results, scientists employ a range of cognitive strategies such as inductions, deductions, and causal reasoning. Problem exploration. In most of the dynamic model researches about the omnidirectional mobile manipulator systems, the redundantly actuated property of the platform was not emphasized. Moreover, the integrated dynamic model of the omnidirectional mobile manipulator which was derived from the driving wheels was not explicitly addressed.

In classrooms, this involves visualizing or verbalizing solutions and explanations, sharing constructive feedback with peers and teachers, and contemplating potential revisions to proposed solutions. As students propose tentative solutions, they warrant their claims and justify their theories with evidence. Scaffolds help guide students to challenge their thinking, consider alternative evidence, and evaluate alternate solutions. Reflection and negotiation. Finally, results provide more than simple solutions to given problems; among scientists, findings provide the basis for further exploration. Students plan further investigations by increasing or reducing the number of variables, or test their to examine impact on other organisms, theories, domains, and fields of study. During reflection and negotiation learners in class examine the processes and strategies used and revise their solutions and explanations.

The proposed model for application of TELEs via CBR

A CBR approach retrieves cases corresponding to similar problems from its case-base. The adaptation step found differences between the new and retrieved problems, and refines the retrieved solution to solve these differences in the context of appropriate. Kolodner (1993) described three types of adaptation:

Substitution: replaces values in the retrieved solution with new values appropriate for the new problem;
Transformation: alters the retrieved solution by adding, deleting or replacing parts of the retrieved solution to suit the new problems; and
Special: methods apply specialized heuristic knowledge to repair the retrieved solution, or replay the method used to derive the retrieved solution for the new problem.

Insert Figure 5 here

For application, the proposed model is shown in Figure 5 should be applied by the new and retrieved problems are effectively derive to the retrieved solution. An adaptation knowledge can be conducted as a captures the update for the retrieved solution: kinematic constraints for the reused solution; solution of the kinematic modeling and dynamic modeling to be added, deleted or transformed to database; and more specifically knowledge to enhance the special. The proposed model discusses adaptation knowledge that students learn more sophisticated adaptations and incorporate different learning algorithms to solve more robust adaptive control for mobile manipulators. The existing knowledge is the most knowledge intensive adaptation and to capture well teaching and learning effectively DSMA while its highly learning achievement and applications.

Implication

CBR approach is illustrated in Figure 6; it is constructing of problem-solving in the knowledge domain. The implication is conducted by comparing the relevance of CBR approach and TELEs adaptation. The implications are shown in Figure 6.

Insert Figure 6 here

Conclusion

In this paper, CBR approach classifier enhanced students problem-solving skills had been ready applied to conduct a reliable teaching and learning effectively in dynamic DSMA. The proposed model used TELEs via CBR as a non-holonomic mechanical systems adaptive idea for mobile manipulators system. From the proposed model, the TELES via CBR not produced higher accuracy than the traditional learning classifiers (Sudsomboon & Anmanatrakul, 2010). The most important appeal of TELEs via CBR model is that alternative solutions can be recommended to the experts for final decision and implications.

This is a more theoretical suggestion and establishes reliable procedure for the mechanical engineering education. In addition, several issues about teaching and learning effectively in DSMA had been tackled (Sudsomboon & Maungmungkun, 2013). The first one is an adaptation knowledge can be conducted as a captures the update for the retrieved solution: kinematic constraints (NHC) for the reused solution; solution of the kinematic modeling and dynamic modeling to be added, deleted or transformed to database; and more specifically knowledge to enhance the special, which is improved by computer programmers. The second one is the feature extraction of students' achievement for comparison. The third one is using CBR approach fit an update control law in selecting the adaptive control scheme, respectively.

This paper is several frameworks have been established to promote research on students' learning innovation, but integrated interest research by scaffolding problem-solving in TELEs via CBR has not been evident in Thai engineering education. The future study was verified by laboratory studies (e.g., experimental and simulation). The effectiveness of the proposed model will illustrate on the real-world situation of the controller design. The learning has been introspective because students' is adapted by existing knowledge the basic knowledge (STEM) in the problem-solving with CBRapproach intensively. Educators know the learning environment of adaptation is an important issue to promote the knowledge acquisition of students' adaptation knowledge. The learning achievement of the study should be conducted for the future research.

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