OVERSEA CORPORATIVE EDUCATION REPORT

Fuzzy Stability and Synchronization of Hyperchaos System

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Oversea Corporative Education Title : Fuzzy stability and synchronization of hyperchaos systems
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ABSTRACT

This research studies about stability and synchronization of hyperchaos systems via a fuzzy-model-based control design methodology. Firstly, we utilize a Takagi–Sugeno fuzzy model to represent a hyperchaos system. Second, we design fuzzy-model-based controllers for stability and synchronization of the system, based on so-called ‘‘parallel distributed compensation (PDC)’’. Third, we reduce a question of stabilizing and synchronizing hyperchaos systems to linear matrix inequalities (LMI) so that convex programming techniques can solve these LMIs efficiently. Finally, the generalized Lorenz hyperchaos system is employed to illustrate the effectiveness of our designing controller.

Keyword

Fuzzy control, Fuzzy logic, Takagi–Sugeno fuzzy model, T-S fuzzy model

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Panuwat Boonchareonsombut

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Chapter 1

Introduction

1.1 Description of the research

Since Ott, Grebogi and Yorke proposed the famous OGY method for chaos control, various control methods have been proposed, including adaptive method, back-stepping design, time-delay feedback control, active control, etc. In recent years, chaos control and synchronization have become one of the most focusing research topics considering their potential applications in laser physics, chemical reactor, secure communication, biomedical science, and so on. There has been some significant progress in the studies of identification, control and utilization of chaos by artificial intelligence technologies such as fuzzy logic and neural networks. Artificial intelligence systems are envisioned to be adaptive, robust, and fault tolerant. Expert systems, fuzzy systems, and neural networks are among the most important artificial intelligence technologies that have emerged. Among these intelligent control technologies, fuzzy control has enjoyed remarkable success in many applications. Moreover, recent advances in the study of fuzzy control have laid foundation for intelligent control of various nonlinear processes (including chaotic cases)

Regarding fuzzy control, there have existed some works. In Ref. [12], so-called Takagi–Sugeno (T–S) fuzzy models on the Chua's circuit with two types of nonlinear resistors are given, respectively. Tanaka et al. proposed a fuzzy model that can be applied to various chaotic systems and designed a fuzzy controller by using the idea of ''parallel distributed compensation (PDC)'', to control chaotic systems. In Refs. [15–18], the authors proposed a few adaptive fuzzy schemes for control of chaotic systems with unknown parameters.

1.2 Purpose of the research

The main purpose of this study is to represent that the controller for stability and synchronization of hyperchaos system based on Takagi–Sugeno (T-S) fuzzy model and parallel distributed compensation (PDC) control design can be applied to any kind of hyperchaos systems.

1.3 Scope of the work completed during the exchange program

Create the generalized Lorenz hyperchaos system (GLHS) with MATLAB and Simulink programs to demonstrate the dynamical behavior of the system. Generate Takagi–Sugeno(T–S) fuzzy model into the MATLAB and Simulink programs at first and design fuzzy controller by using the idea of parallel distributed compensation (PDC) are explored the result.

Chapter 2

Theory and Related Research

Almost all the physical dynamical systems in real life cannot be represented by linear differential equations and have a nonlinear nature. At the same time, linear control methods rely on the key assumption of small range of operation for the linear model, acquired from linearizing the nonlinear system, to be valid. When the required operation range is large, a linear controller is prone to be unstable, because the nonlinearities in the plant cannot be properly dealt with. Another assumption of linear control is that the system model is indeed linearizable and the linear model is accurate enough for building up the controller. However, the highly nonlinear and discontinuous nature of many, for instance, mechanical and electrical systems does not allow linear approximation. It is also necessary, in the design process of controllers, that the system model is well achievable through a mathematical model and the parameters of the system model are reasonably well-known. Nevertheless, for many nonlinear plans i.e. chemical processes, building a mathematical model is very difficult and only the input-output data yielded from running the process is accessible for an estimation. Many control problems involve uncertainties in the model parameters. A controller based on inaccurate or obsolete values of the model parameters may show significant performance degradation or even instability. There are some complicated approaches like auto-regressive model based on the input-output data to compensate model uncertainties, which usually use to design a process control. However due to the high nonlinearity of the process, the order of the model often becomes very high so that past effects are considered, even if that is physically unrealistic.

One way to cope with such difficulty is to develop a nonlinear model composing of several sub-models which are simple, understandable, and responsible for respective sub-domains. The idea of multi-model approach is not new, but the idea of fuzzy modeling using the concept of the fuzzy set theory offers a new technique to build multi-models of the process based on the input-output data or the original mathematical model of the system. Facing complex and nonlinear systems, we must recognize that modeling is an art and it is important to realize system modeling is generally an act to understand things directly rather than by computer. At most a linear combination like a fuzzy model is clearly understandable.

2.1 Takagi–Sugeno Fuzzy Model

A fuzzy controller or model uses fuzzy rules, which are linguistic if-then statements involving fuzzy sets, fuzzy logic, and fuzzy inference. Fuzzy rules play a key role in representing expert control/modeling knowledge and experience and in linking the input variables of fuzzy controllers/models to output variable (or variables). Two major types of fuzzy rules exist, namely, Mamdani fuzzy rules and Takagi-Sugeno fuzzy rules.

Takagi–Sugeno fuzzy model can be used to design an oriented fuzzy controller, and The main feature of the Takagi–Sugeno fuzzy model is that it can describe the local dynamics of each fuzzy rule by a linear system model, and that the overall fuzzy model is achieved by fuzzy blending of all the linear system models. Generally, the Takagi–Sugeno fuzzy model is of the following form:

Rule i: IF $x_1(t)$ is M_{i1} . . . and $x_n(t)$ is M_{in}

THEN

$$x(t) = A_i x(t) + B_i u(t), \tag{2.1}$$

where

$$x(t) = x_1(t),\ x_2(t), \dots,\ x_n(t)$$

$$u(t) = u_1(t), u_2(t), \dots, u_m(t)$$

$i = 1,2, \dots, r$ (r is the number of IF-THEN rules), M_{ij} are fuzzy sets, and $x(t) = A_i x(t) + B_i u(t)$ is the output from the ith IF-THEN rule. Given a pair of $\big(x(t), u(t)\big)$, the final output of the fuzzy system is inferred as follows:

$$\dot{x} = \frac{\sum_{i=1}^{r} \omega_i\big(x(t)\big)\{A_i x(t) + B_i u(t)\}}{\sum_{i=1}^{r} \omega_i\big(x(t)\big)}, \tag{2.2}$$

where

$$\omega_i\big(x(t)\big) = \prod_{j=1}^{n} M_{ij}\big(x(t)\big), \tag{2.3}$$

for all t, and $M_{ij}x(t)$ is the grade of membership of $x_j(t)$ in M_{ij}.

The open-loop system of (2) is

$$\dot{x} = \frac{\sum_{i=1}^{r} \omega_i\big(x(t)\big) A_i x(t)}{\sum_{i=1}^{r} \omega_i\big(x(t)\big)} \tag{2.4}$$

where it is assumed that

$$\sum_{i=1}^{r} \omega_i\big(x(t)\big) > 0,$$

$$\omega_i\big(x(t)\big) \geq 0, i = 1,2, \dots, r$$

By introducing $h_i\big(x(t)\big) = \frac{\omega_i(x(t))}{\sum_{i=1}^{r} \omega_i(x(t))}$ instead of $\omega_i(x(t)$, (2) and (4) can be rewritten as

$$\dot{x} = \sum_{i=1}^{r} h_i\big(x(t)\big)\{A_i x(t) + B_i u(t)\}, \tag{2.5}$$

$$\dot{x} = \sum_{i=1}^{r} h_i\big(x(t)\big) A_i x(t). \tag{2.6}$$

Note that

$$\sum_{i=1}^{r} h_i\big(x(t)\big) = 1,$$

$$h_i\big(x(t)\big) \geq 0, i = 1,2, \dots, r$$

for all t. $h_i\big(x(t)\big)$ can be regarded as the normalized weight of the IF-THEN rules.

For convenience, we only consider the case of $B_i = B = E$ *(unite matrix)*, $i = 1,2, . . ., r$ for the fuzzy system in the following sections.

Chapter 3

Research Methodology

3.1 Fuzzy Modeling of GLHS

In this subsection, we will express the GLHS with the T–S fuzzy model. The GLHS is derived by adding one more stable variable into the original generalized Lorenz system. The dynamical behavior of GLHS is governed by

$$\begin{cases} \dot{x} &= a_{11}x + a_{12}y, \\ \dot{y} &= a_{21}x + a_{22}y + w - xz, \\ \dot{z} &= a_{33}z + xy, \\ \dot{w} &= -kx \end{cases} \tag{3.1}$$

Note that equation. (7) covers a large class of hyperchaos systems, e.g., the Lorenz, Chen and Lu¨ hyperchaotic systems. Taking $a_{11} = -10$, $a_{12} = 10$, $a_{21} = 28$, $a_{22} = -1$, $a_{33} = -\frac{8}{3}$, $k = 10$, we obtain the hyperchaotic Lorenz attractor.

Assume that $x(t)\epsilon[-d,d]$ and $d > 0$. Then, we have the following fuzzy model which exactly represents the nonlinear equation (7), i.e., GLHS, under $x(t)\epsilon[-d,d]$:

$$\begin{aligned} &\text{Rule 1: If } x(t) \text{ is } M_1, \text{then } \dot{X} = A_1X(t), \\ &\text{Rule 2: If } x(t) \text{ is } M_2, \text{then } \dot{X} = A_2X(t), \end{aligned} \tag{3.2}$$

where

$$X(t) = [x(t), y(t), z(t), w(t)]^T$$

$$A_1 = \begin{pmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & -d & 1 \\ 0 & d & a_{33} & 0 \\ -k & 0 & 0 & 0 \end{pmatrix}$$

and

$$A_2 = \begin{pmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & d & 1 \\ 0 & d & a_{33} & 0 \\ -k & 0 & 0 & 0 \end{pmatrix}$$

$$M_1(x(t)) = \frac{1}{2}\left(1 + \frac{x(t)}{d}\right)$$

$$M_2(x(t)) = \frac{1}{2}\left(1 - \frac{x(t)}{d}\right)$$

In this research, $a_{11} = -10$, $a_{12} = 10$, $a_{21} = 28$, $a_{22} = -1$, $a_{33} = -\frac{8}{3}$, $k = 10$, and $k = 30$. So, the final output of the fuzzy model of GLHS is given by

$$\dot{X} = \sum_{i=1}^{2} M_iA_iX(t). \tag{3.3}$$

For any region of interest, GLHS can be modelled exactly by the fuzzy system via of appropriate choice of d. Moreover, the corresponding fuzzy control system has the following form:

$$\dot{X} = \sum_{i=1}^{2} M_i A_i X(t) + Bu(t). \tag{3.4}$$

3.2 Design of Fuzzy Controller and Its Stability Analysis

We employ the idea of PDC to design the fuzzy control law for stabilization of the GLHS. Each rule is constructed from the corresponding rule of the T–S fuzzy model of GLHS. The designed fuzzy controller shares the same fuzzy sets as in the fuzzy model of the GLHS in the previous subsection. The PDC provides the following structure of the fuzzy control rule for the T–S fuzzy model of the GLHS:

Rule 1: IF $x(t)$ is M_1,

THEN

$$u(t) = -F_1 X(t), \tag{3.5}$$

Rule 2: IF $x(t)$ is M_2,

THEN

$$u(t) = -F_2 X(t). \tag{3.6}$$

Thus, the overall fuzzy controller can be represented by

$$u(t) = -\sum_{i=1}^{2} M_i F_i X(t). \tag{3.7}$$

By substituting designed fuzzy controller (13) into the controlled GLHS (10), we obtain

$$\dot{X} = \sum_{i=1}^{2} M_i (A_i - BF_i) X(t). \tag{3.8}$$

Using Lyapunov stability theorem, we get the following theorem for the stabilization of the GLHS.

Theorem 1. The equilibrium of the fuzzy control system (14) of GLHS is asymptotically stable in the large if there exist a common positive definite matrix P such that

$$(A_i - BF_i)^T P + P(A_i - BF_i) < 0, i = 1,2. \tag{3.9}$$

Proof. Define the Lyapunov function as

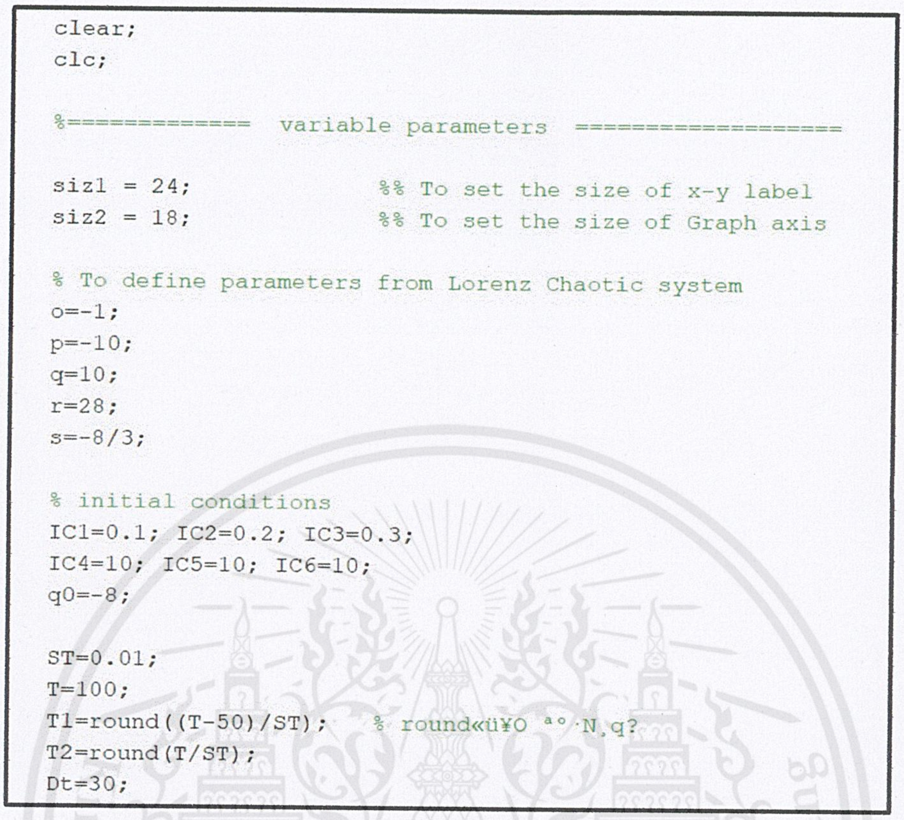
$$V(X) = X(t)^T P X(t).$$

Then, the derivative of V along trajectories (13) is given by

$$\dot{V}(X) = \dot{X}^T(t) P X(t) + X(t)^T P \dot{X}(t)$$

$$\dot{V}(X) = \sum_{i=1}^{2} M_i X^T(t)[(A_i - F_i)^T P + P(A_i - F_i)]X(t)$$

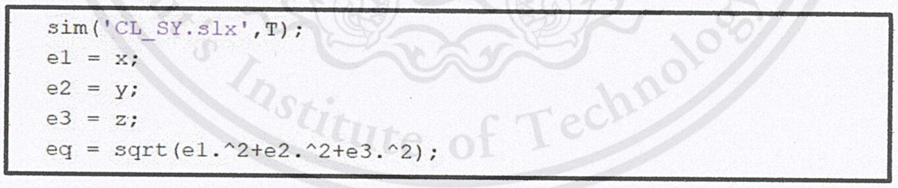
Under the conditions (15), we have $\dot{V}(X) < 0$. Therefore, by Lyapunov asymptotic stability theorem, we get the asymptotic stability of the equilibrium of the fuzzy control system (14).



```
clear;
clc;

%==============  variable parameters  ===================

siz1 = 24;              %% To set the size of x-y label
siz2 = 18;              %% To set the size of Graph axis

% To define parameters from Lorenz Chaotic system
o=-1;
p=-10;
q=10;
r=28;
s=-8/3;

% initial conditions
IC1=0.1; IC2=0.2; IC3=0.3;
IC4=10; IC5=10; IC6=10;
q0=-8;

ST=0.01;
T=100;
T1=round((T-50)/ST);    % round«ü¥O ªº ·N¸q?
T2=round(T/ST);
Dt=30;
```

Figure 4.2: Setup GLHS parameter in MATLAB

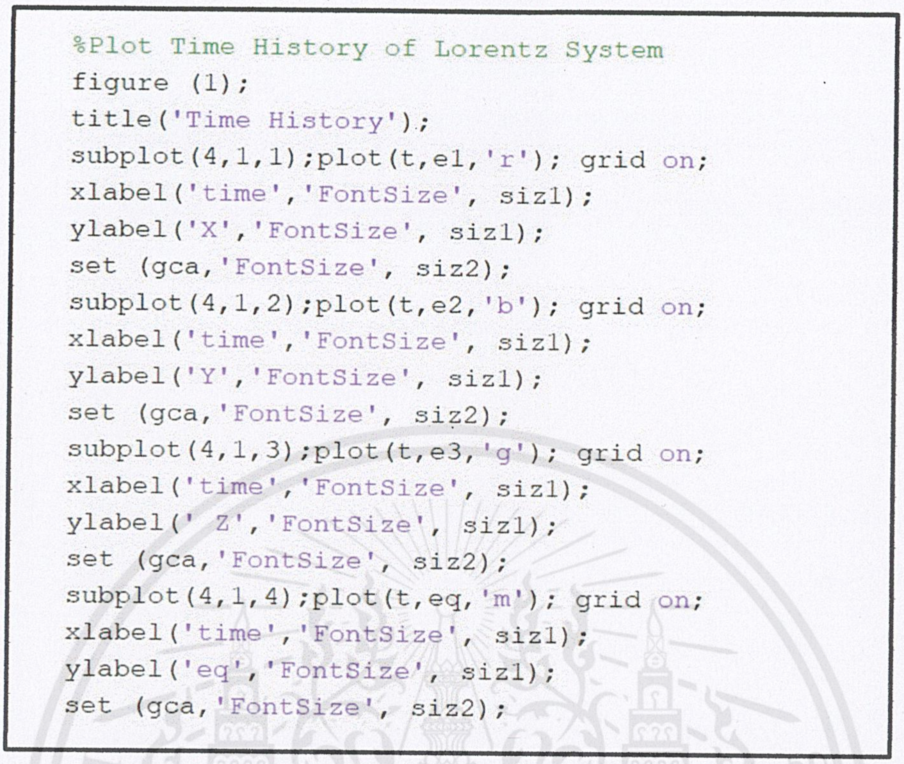
Setting the parameter in MATLAB for using Simulink program



```
sim('CL_SY.slx',T);
e1 = x;
e2 = y;
e3 = z;
eq = sqrt(e1.^2+e2.^2+e3.^2);
```

Figure 4.3: MATLAB and Simulink link the data to each other

Combine the data between MATLAB and Simulink



```
%Plot Time History of Lorentz System
figure (1);
title('Time History');
subplot(4,1,1);plot(t,e1,'r'); grid on;
xlabel('time','FontSize', siz1);
ylabel('X','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(4,1,2);plot(t,e2,'b'); grid on;
xlabel('time','FontSize', siz1);
ylabel('Y','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(4,1,3);plot(t,e3,'g'); grid on;
xlabel('time','FontSize', siz1);
ylabel(' Z','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(4,1,4);plot(t,eq,'m'); grid on;
xlabel('time','FontSize', siz1);
ylabel('eq','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.4: Plot Time History of Lorentz System code

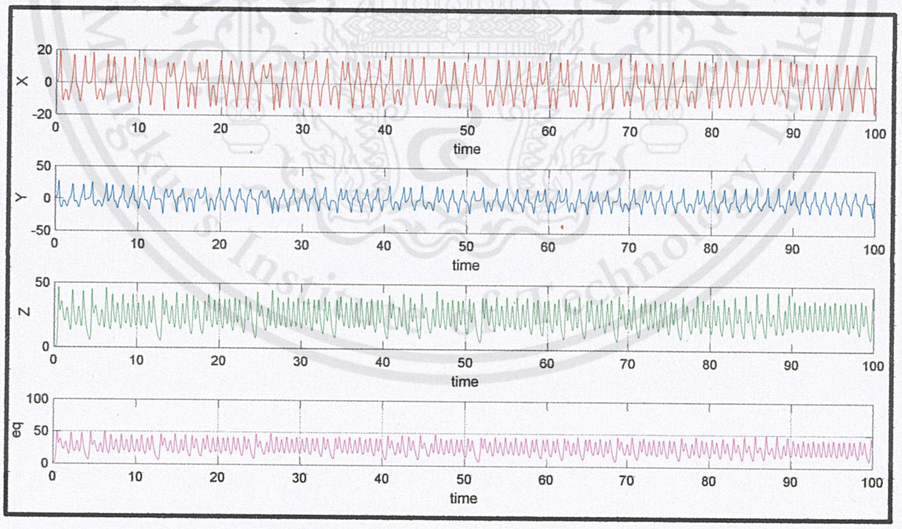
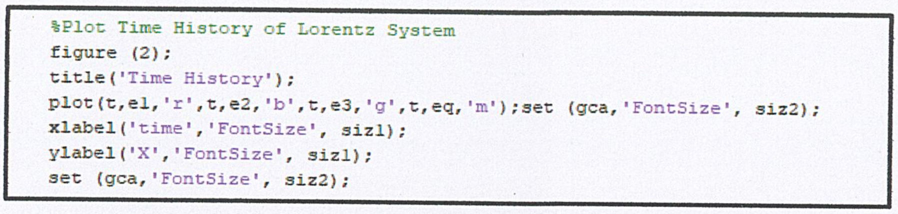


Figure 4.5: Time History of Lorentz System in all axis

From Figure 4.4 the code in MATLAB to show the result of time history of Lorentz System in x, y, z axis



```
%Plot Time History of Lorentz System
figure (2);
title('Time History');
plot(t,e1,'r',t,e2,'b',t,e3,'g',t,eq,'m');set (gca,'FontSize', siz2);
xlabel('time','FontSize', siz1);
ylabel('X','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.6: Plot Time History of Lorentz System code

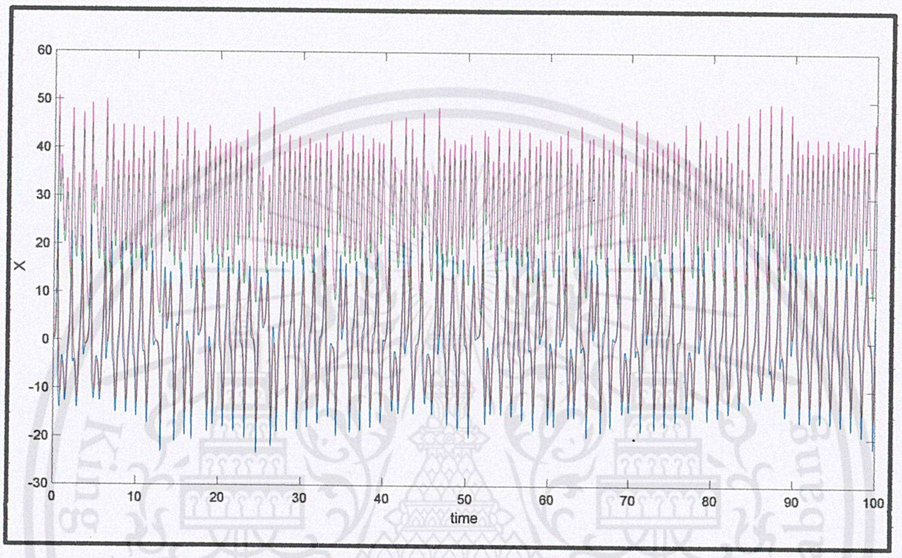
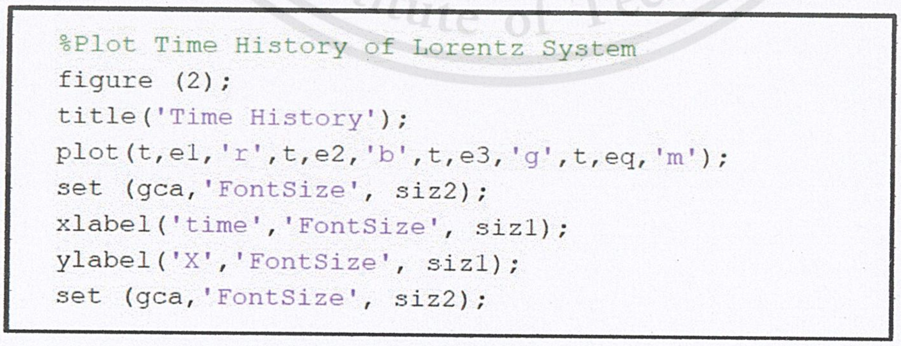


Figure 4.7: Time History of Lorentz System graph

Form Figure 4.6 the code in MATLAB the code in MATLAB to show the result of time history of Lorentz System in x, y, z axis in one graph



```
%Plot Time History of Lorentz System
figure (2);
title('Time History');
plot(t,e1,'r',t,e2,'b',t,e3,'g',t,eq,'m');
set (gca,'FontSize', siz2);
xlabel('time','FontSize', siz1);
ylabel('X','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.8: The GLHS on 2-Axis

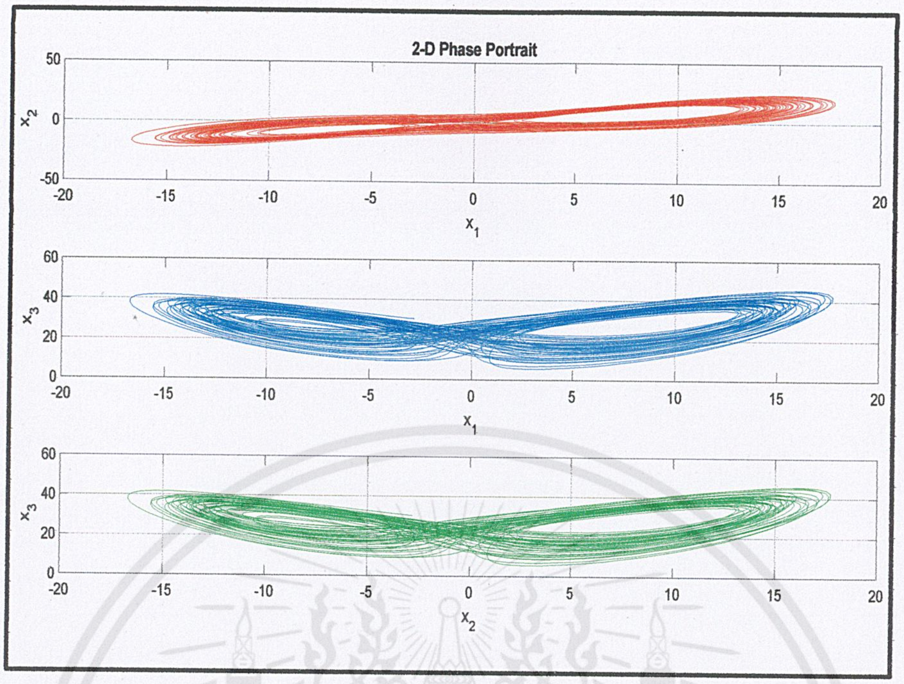


Figure 4.9: Projection of the Lorenz hyperchaotic attractor in the GLHS on 2-Axis

Form Figure 4.8 is the coding in MATLAB to show the graph of GLHS in 2-axis in x-y axis, x-z axis, and y-z axis

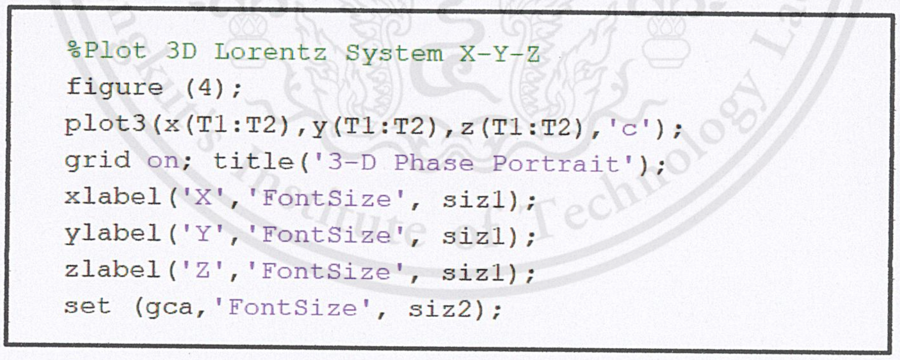

```
%Plot 3D Lorentz System X-Y-Z
figure (4);
plot3(x(T1:T2),y(T1:T2),z(T1:T2),'c');
grid on; title('3-D Phase Portrait');
xlabel('X','FontSize', siz1);
ylabel('Y','FontSize', siz1);
zlabel('Z','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.10: The GLHS on 3-Axis on X - Y - Z

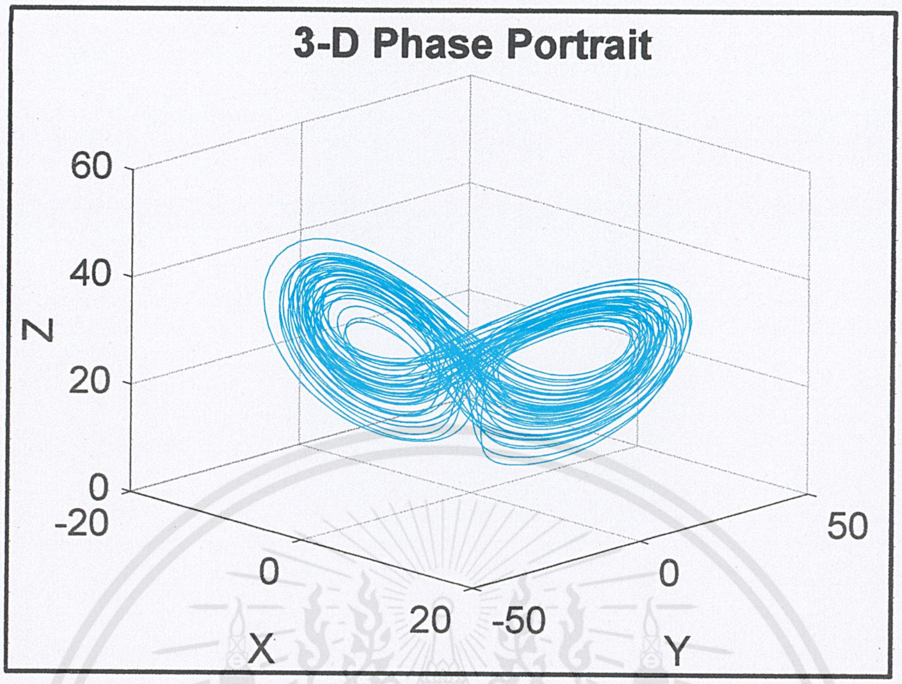
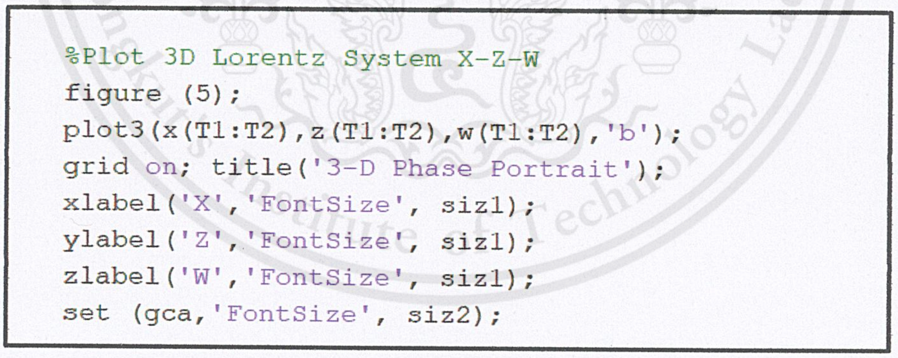


Figure 4.11: Projection of the Lorenz hyperchaotic attractor in the GLHS on X - Y – Z

Form Figure 4.10 is the coding in MATLAB to get the result Figure 4.11, Projection of the Lorenz hyperchaotic attractor in the GLHS on X - Y – Z



```
%Plot 3D Lorentz System X-Z-W
figure (5);
plot3(x(T1:T2),z(T1:T2),w(T1:T2),'b');
grid on; title('3-D Phase Portrait');
xlabel('X','FontSize', siz1);
ylabel('Z','FontSize', siz1);
zlabel('W','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.12: The GLHS on 3-Axis on X - Z - W

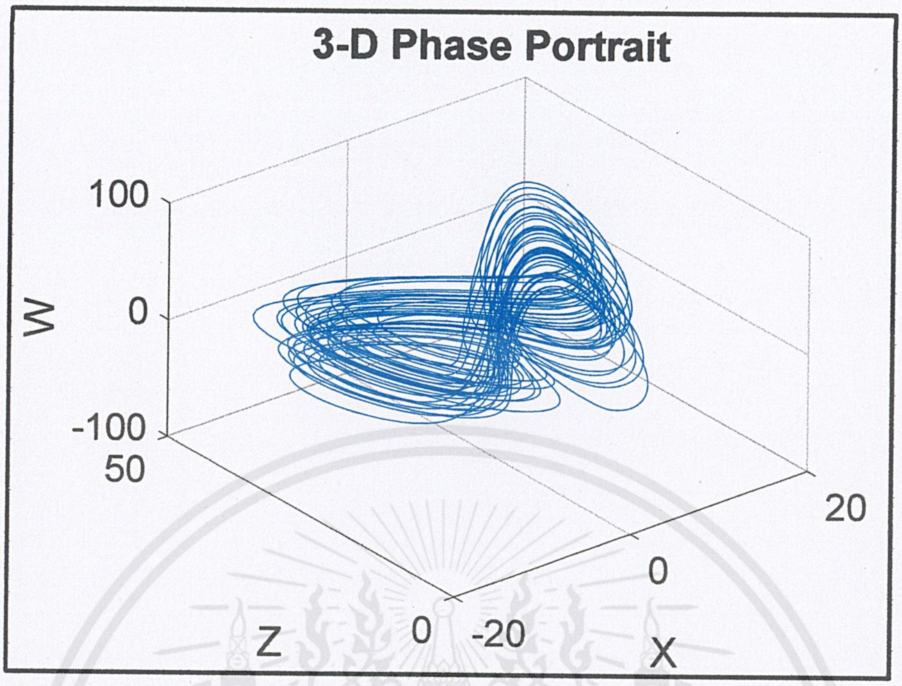
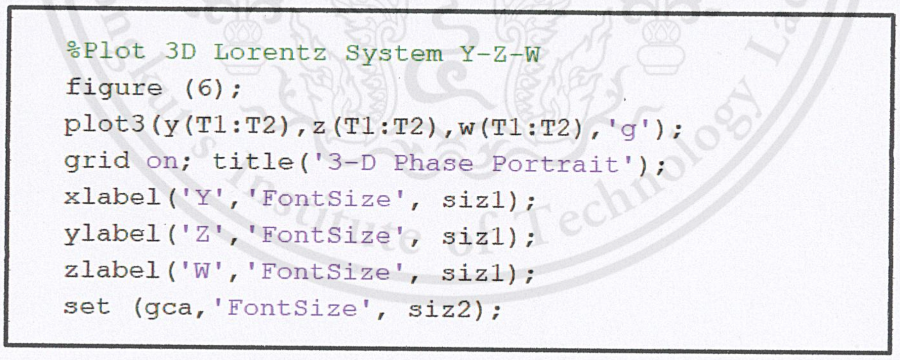


Figure 4.13: Projection of the Lorenz hyperchaotic attractor in the GLHS on X - Z - W

Form Figure 4.12 is the coding in MATLAB to get the result Figure 4.13, Projection of the Lorenz hyperchaotic attractor in the GLHS on X - Z – W



```
%Plot 3D Lorentz System Y-Z-W
figure (6);
plot3(y(T1:T2),z(T1:T2),w(T1:T2),'g');
grid on; title('3-D Phase Portrait');
xlabel('Y','FontSize', siz1);
ylabel('Z','FontSize', siz1);
zlabel('W','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Figure 4.14: The GLHS on 3-Axis on Y - Z – W

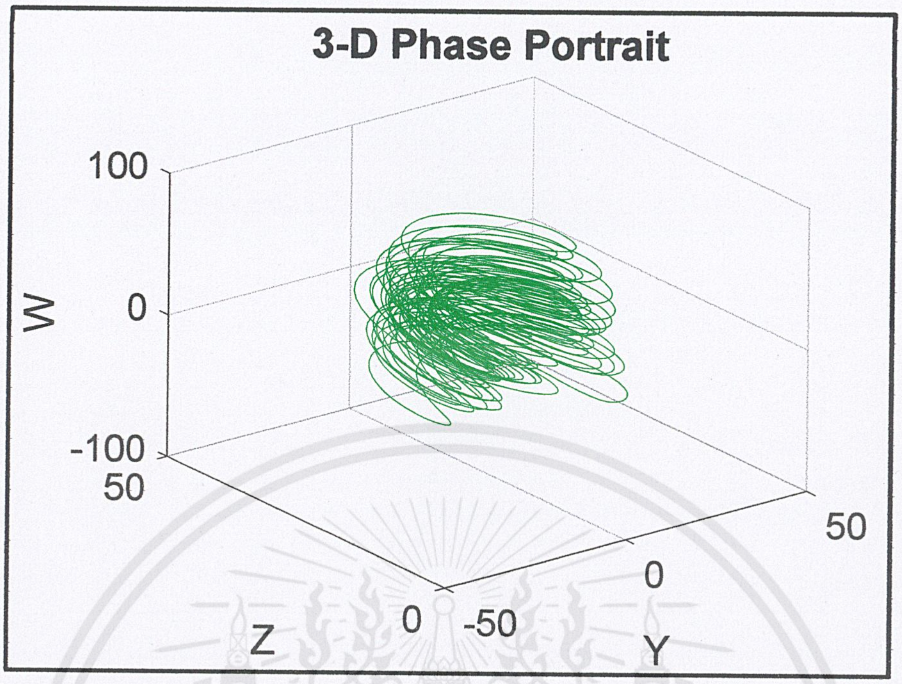


Figure 4.15: Projection of the Lorenz hyperchaotic attractor in the GLHS on Y - Z – W

Form Figure 4.14 is the coding in MATLAB to get the result Figure 4.15, Projection of the Lorenz hyperchaotic attractor in the GLHS on Y - Z – W

From Equation (9), The final output of the fuzzy model of GLHS

$$\dot{X} = \sum_{i=1}^{2} M_i A_i X(t) \tag{4.1}$$

So, we generate equation form in to Flow chart in Simulink

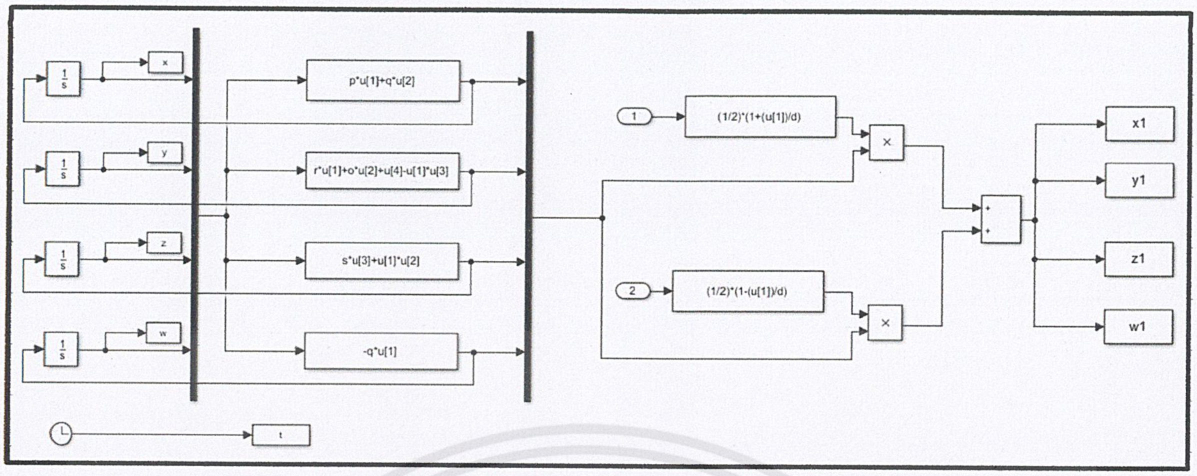


Figure 4.16: The GLHS with T-S fussy system in Simulink

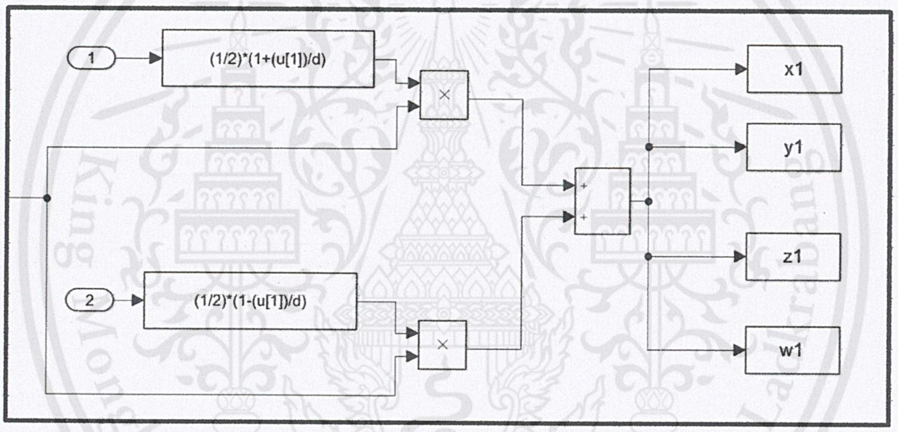


Figure 4.17: The T-S fussy system in Simulink

Chapter 5

Conclusions, and suggestions

5.1 Conclusions

In this research, we have represented the hyperchaos system with a Takagi–Sugeno fuzzy model. The controller for stability and synchronization of hyperchaos system based on T–S fuzzy model and PDC control design is given. Of course, the design procedure is conceptually simple and nature. Moreover, the enough conditions for hyperchaos stability and synchronization are reduced to linear matrix inequalities (LMI's) and so are solved very efficiently in practice by convex programming techniques for LMI's. Numerical simulations on GLHS are given to illustrate the effectiveness of the fuzzy model-based controller for hyperchaos stability and synchronization. To the best of our knowledge, this is the first report on fuzzy stability and synchronization of hyperchaos system. Finally, we note that this fuzzy model-based controller design for stability and synchronization can be applied to other hyperchaos systems.

5.2 Suggestions

The exchange program is great. I have learned a lot during the course of exchange program, such as Taiwan culture, Mandarin Chinese, Taiwanese and new knowledge in Engineering. However, the period of exchange program is short period for studying. If I have more times, I will have more time to prepare for the work on the T-S fuzzy system. It would be great if our universities keep continue the exchange program for students so students will get another knowledge from another university.

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Appendix

Appendix

MATLAB coding

```
clear;
clc;

%============  variable parameters  ===================
siz1 = 24;          %% To set the size of x-y label
siz2 = 18;          %% To set the size of Graph axis

% To define parameters from Lorenz Chaotic system
o= -1;
p= -10;
q=  10;
r=  28;
s=-8/3;

% initial conditions
IC1=0.1; IC2=0.2; IC3=0.3;
IC4=10; IC5=10; IC6=10;
q0=-8;

ST=0.01;
T=100;
T1=round((T-50)/ST);   % round«ü¥O ªº·N¸q?
T2=round(T/ST);
Dt=30;

sim('CL_SY.slx',T);
e1 = x;
e2 = y;
e3 = z;
eq = sqrt (e1. ^2+e2. ^2+e3. ^2);

%Plot Time History of Lorentz System
figure (1);
title ('Time History');
subplot (4,1,1); plot(t,e1,'r'); grid on;
xlabel('time','FontSize', siz1);
ylabel('X','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(4,1,2);plot(t,e2,'b'); grid on;
xlabel('time','FontSize', siz1);
ylabel('Y','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot (4,1,3); plot (t, e3,'g'); grid on;
xlabel('time','FontSize', siz1);
ylabel(' Z','FontSize', siz1);
```

```
set (gca,'FontSize', siz2);
subplot (4,1,4); plot(t,eq,'m'); grid on;
xlabel('time','FontSize', siz1);
ylabel('eq','FontSize', siz1);
set (gca,'FontSize', siz2);

%Plot Time History of Lorentz System
figure (2);
title ('Time History');
plot (t, e1,'r',t,e2,'b',t,e3,'g',t,eq,'m');set (gca,'FontSize', siz2);
xlabel('time','FontSize', siz1);
ylabel('X','FontSize', siz1);
set (gca,'FontSize', siz2);

%Plot 2D Lorentz System
figure (3);
subplot(3,1,1);plot(x(T1:T2),y(T1:T2),'r');
grid on;title('2-D Phase Portrait');
xlabel('x_1','FontSize', siz1);ylabel('x_2','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(3,1,2);plot(x(T1:T2),z(T1:T2),'b'); grid on;
xlabel('x_1','FontSize', siz1);ylabel('x_3','FontSize', siz1);
set (gca,'FontSize', siz2);
subplot(3,1,3);plot(x(T1:T2),z(T1:T2),'g'); grid on;
xlabel('x_2','FontSize', siz1);ylabel('x_3','FontSize', siz1);
set (gca,'FontSize', siz2);

%Plot 3D Lorentz System X-Y-Z
figure (4);
plot3(x(T1:T2),y(T1:T2),z(T1:T2),'c');
grid on; title('3-D Phase Portrait');
xlabel('X','FontSize', siz1);
ylabel('Y','FontSize', siz1);
zlabel('Z','FontSize', siz1);
set (gca,'FontSize', siz2);

%Plot 3D Lorentz System X-Z-W
figure (5);
plot3(x (T1:T2), z(T1:T2),w(T1:T2),'b');
grid on; title ('3-D Phase Portrait');
xlabel('X','FontSize', siz1);
ylabel('Z','FontSize', siz1);
zlabel('W','FontSize', siz1);
set (gca,'FontSize', siz2);
%Plot 3D Lorentz System Y-Z-W
figure (6);
plot3(y (T1:T2), z (T1:T2), w(T1:T2),'g');
grid on; title ('3-D Phase Portrait');
xlabel('Y','FontSize', siz1);
ylabel('Z','FontSize', siz1);
```

```
zlabel('W','FontSize', siz1);
set (gca,'FontSize', siz2);
```

Curriculum vitae

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PERSONAL DETAILS

Sex : Male
Date of Birth : March 26th, 1997
Nationality : Thai
Religion : Buddhism

EDUCATION

B.Eng. in Mechatronics Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand **08/2014 - Now**

- **Focuses:** Mechanical, Electrical, and Computer Programming

High School, Sarasas Witaed Suvarnabhumi School (SWSB), Thailand **05/2008 - 03/2014**

Pipattana School (PPN), Thailand **05/2006 - 03/2008**

Sarasas Witaed Romklao School (SWR), Thailand **05/2002 - 03/2006**

EXPERIENCE

Robot Club KMITL, Thailand. **08/2015 - Now**

Member of Robot Club KMITL

Photo Club KMITL, Thailand. **08/2015 - Now**

Member of Photo Club KMITL

Delta Trainee, Delta Electronics (Thailand) PLC, Thailand. **10/2015**

Training Delta software and programming for Delta's products

Create project in topic of smart manufacturing

IBOT 8th Camp, Robot Club KMITL, Thailand. **12/2015**

Teaching C Programming

TPA Robot Contest Thailand Championship 2016, Thailand. **02/2016**

Make a robot in topic of Clean Energy Recharging the World

Delta Trainee, Delta Electronics (Thailand) PLC, Thailand. **10/2016**

Member of Urgent team, became 1 of 5 teams from among 60 Thai teams for next competition

Freshy Robot Competition, Robot Club KMITL, Thailand. **12/2016**

Teach Freshman in C Programming and electrical knowledge

TPA Robot Contest Thailand Championship 2017, Thailand. **02/2017**

Make a robot in topic of Robo's Basketball 2017

Tech startup, Software Industry Promotion Agency (SIPA), Thailand **02/2017**

Member of Urgent team, passed 3rd round with 1 of 300 teams

Make project "MDM" of Digital Startup Pitching topic

First prize, Hackathon, Digital Economy Promotion Agency (DEPA), Thailand. **03/2017**

Leader of MANO team

Developed android application called "Healthy HUB"

Second price, 3rd Delta cup 2017, Delta Electronics (Wujiang) Inc., China. **08/2017**

Member of Urgent team, won 2nd prize from among 78 teams from 4 countries

University of Electronic Science and Technology of China (UESTC)., China. **06/2018**

University internship & Culture exchange

National Chung Cheng University (CCU)., Taiwan (ROC). **07/2018**

Summer school 2018

National Taipei University of Technology (NTUT)., Taiwan (ROC) **02/2019**

Oversea Training

SKILLS

ELECTRONICS : Have knowledge of circuit board, chip and electronics equipment
TECHNICIAN : Familiar of using tools and Maintenance
COMPUTER : **Programming, CAD, CAM, CAE, MS Office**
LANGUAGE : **Thai** (Native), **English** (excellent command), **Mandarin Chinese** (Daily conversation level)

INTERESTS

Playing Piano, Reading, Voluntary, Cooking, Taking Photographs, Tennis, Backpacking