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切换系统（稳定性、ADT）

6.Switched systems such as Networked Control Systems (NCSs), power systems, automotive engine

control, robotic manufacture and so on (see, also, [1–3] and the references therein) have received

much attention mainly because they have strong engineering background. In [1], the fundamental

issues for switched linear systems are focused on controllability, observability, feedback stabi-

lization, optimization and periodic switching. The problems of NCSs’ stability and disturbance

attenuation are formulated as the corresponding problems of switched systems [3]. The existence

of a common Lyapunov function for all subsystems means that a switched system is asymptotically

stable under an arbitrary switching law [4]. However, in most cases, a common Lyapunov function

for all subsystems is unknown or do not exist. Multiple Lyapunov functions (MLF) is interesting

to analyze the stability for switched systems [5]. The issues of stability, L2-gain analysis and H1

control for switched systems are addressed by proposing general Lyapunov-like functions based on

MLF method [2]. Average dwell time (ADT) method as a special class of MLF method is used

to achieve the exponential stability for switched systems [6]. Also, ADT method is employed to

study the stability of switched systems with stable and unstable subsystems [7]. Switched Lyapunov

function (SLF) as another kind of MLF is proposed for stability analysis and control synthesis of

discrete-time switched systems [8]. It is well known that time delays are the inherent features of

many physical processes because of the limited speed of signals travelling among the components

and the main sources of instability and poor performance. Therefore, switched systems with time delays have much wider engineering background and have been extensively studied recently. For

some representative work on this general topic, to name a few, we refer readers to [9–16] and the

references therein. In [10], uniform asymptotic stability of a class of linear switching systems with

time delay is achieved. A switched digital control is constructed for continuous time switched sys-

tems, which is robust to the model uncertainties produced by unknown varying feedback delay [11].

An adaptive sliding mode controller for a continuous-time switched system with time-varying delay

is designed by using the ADT approach and the piecewise Lyapunov function technique[14]. Suf-

ficient condition for the existence of robust fault detection filter of switched systems with constant

delay is presented [16].

7. On the other hand, during the recent decades, the switched systems as an important class

of hybrid systems have attracted much research attention in control theory and practice.

A switched system comprises a family of subsystems described by continuous or discrete-

time dynamics, and a switching law that specifies the active subsystem at each instant of

time. Many physical processes possess switched and hybrid nature [7–9], and switched

systems arise in many engineering applications, for example, in motor engine control [10],

constrained robotics [11], networked control systems [12], etc. Furthermore, more and

more engineering applications resort to switching strategy to improve control performance

[13–16]. There are many results about Lyapunov stability and stabilization of switched

systems. Many Lyapunov function techniques are effective tools dealing with switched

systems [17–20]. Dwell time and average dwell time approaches were employed to study the

stability and stabilization of time-dependent switched systems [21–24]. A recent survey on

the basic problems in stability and design for switched systems is proposed in [25].

8.近年来，切换系统的事件触发设计问题越来越受到研究学者的重视，也获得了许

多新的研究成果。在文献[69]中，提出了一种基于事件触发的采样机制，并为线性切换

系统的各个子系统设计了状态估计器，只有在估计状态和采样状态之间的误差超过阈

值时才触发采样。文献[70]研究了连续时间切换线性系统的事件触发H∞滤波问题，得

到了滤波误差系统指数渐近稳定且满足加权H∞性能的充分条件。文献[71]研究了切换

线性系统的事件触发采样、动态输入量化和约束切换的协同设计问题，提出了一种混

合量化控制策略保证了量化输入下切换系统的指数稳定性。

9. In recent years, the so-called switched systems have been widely studied and many interesting

results have been reported in the literature, see for instance, [1–4] and the references therein. As

a crucial factor, switching signals determine the dynamic behavior of a switched system in most cases. The switching in systems or control can be classified into autonomous and controlled ones,

which result from the system itself and the designers’ intervention, respectively [5, 6]. Autonomous

switched systems, arising from nonlinear systems, large-scale uncertain systems, parameter-varying

systems, etc., have been investigated by probing the internal switching features in systems [3, 7, 8].

In particular, some analysis and synthesis results have been presented assuming the switching

signals are arbitrary, in virtue of general linear or nonlinear system theories [2, 9–11]. However, as

for the controlled switched systems, the switching signal constitutes system design such that the

corresponding problem is more complicated in finding a suitable switching signal for improving

system performance [3, 12, 13]. Some special switching signals are studied in this context, such as

dwell (average dwell) time switching, hysteresis switching and so on [5], and average dwell time

switching has been recognized to be more flexible and efficient in system stability analysis [3, 14].

Often, the switched systems with dwell (or average dwell) time are also viewed as slowly switched

system in the literature, and many results on stability analysis and control synthesis for the systems

have been reported within the continuous-time context including both linear and nonlinear cases,

see for example [6, 12, 14].

10.A switched system is composed of an indexed family of subsystems described by continuous or

discrete-time dynamics and a rule orchestrating the switching among them. Many real-world pro-

cesses and systems can be modeled as switched systems, including power electronics, embedded

systems, chemical processes, and computer-controlled systems. Because of the importance in theory

and practice, much research effort has been devoted to studying switched systems for such problems

as stability, stabilization, and reachability [1,2]. A number of efficient methodologies have been

proposed in the literature to deal with the aforementioned problems for switched systems [3–6].

For instance, multiple Lyapunov functions were employed to establish certain general Lyapunov-

like results for both linear time-invariant switched systems and nonlinear switched systems [7,8].

The average dwell time technique was proposed in [9] to cope with the stability problem of slow

switching systems[10,11]. It should be pointed out that most of the existing literature related to sta-

bilityandstabilizationofswitchedsystemsfocusuponLyapunovasymptoticstabilityorexponential

stability, which is defined over an infinite-time interval.

11. 切换系统是一类比较特殊的混杂系统

[1-6]

，混杂系统中的离散特性的动力学行为可以

用切换规则来描述。典型的切换系统由一系列子系统和切换信号构成，系统的状态不仅

与各个子系统的动态特性相关，同时还与相应的切换规则有关。切换控制系统可以描述

更多复杂的实际系统，所以受到了研究者的关注，并且在控制理论及工程实践中得到了

广泛的应用。如智能能源系统

[7]

，飞行器控制系统

[8,9]

，微电网切换

[10]

，网络控制系统

[11]

，

传感器调度

[12]

，电动汽车能源监控

[13]

，开关电源转换器

[14]

和其他领域

[15,16]

。在许多工程

实践的系统中，受到各种外部因素的影响，单一的控制器经常无法满足系统对控制性能

的要求，系统只能给定多个控制器，根据不同的环境在多个控制器之间进行切换。因此

就需要设计一个合理的切换律，通过在有限个控制器里切换来达到性能的要求。因此，

对于切换系统的研究有着重要的应用价值。

随着控制对象越来越复杂，对控制性能指标要求也越来越高，同时系统运行机制受

到多方面因素的制约，许多实际的控制问题须通过切换系统的理论才能得到更好的解决，

切换系统分析与综合研究成为了学术界和工程研究领域的热点问题。切换系统的动力学

行为不仅取决于各个切换子系统，还与切换规则密切相关。

ADT

切换规则是切换系统的

稳定性分析和控制器设计的一种有效工具。尽管经过数十年的研究，切换系统的理论与

应用研究已取得了丰硕的成果，然而，切换系统控制系统设计还有许多需要进一步探讨

的问题。首先，在基于多

Lyapunov

函数的切换系统控制器设计中，约束两个相邻

Lyapunov

函数跳变的边界条件的数值计算复杂，往往只能得到一个充分条件的保守解；

其次，关于切换系统的加权

2

L 增益性能切换控制器参数化的研究情况还不是尽人意；最

后，切换系统的降阶控制器设计也是一个关键的科学问题。针对上述三个方面问题，本

文着重研究了基于平均驻留时间切换规则的切换控制器设计。

传感器网络

PIO

1. Since the seminal work for the proportional–integral

observer (PIO) in [45], the past four decades have wit-

nessed the successful applications of PIOs in various practical

systems, such as manufacturing processes, network com-

munication systems, power circuit systems, and economic

systems [2], [3], [50]. Roughly speaking, the PIO refers

to a kind of observer that introduces an additional integral

term of the output estimation error into the structure of the

Luenberger observer in order to achieve unbiased estima-

tion. Compared with the conventional Luenberger observer,

the PIO is equipped with an extra integral term that offers

more design freedom for improving the robustness against

parameter variations and enhancing the insensitivity to exoge-

nous noises. Up to date, the PIO design problem has become

an increasingly attractive research topic, leading to fruitful

research results [15], [16], [39]. For instance, in [31], the PIO

has been utilized to cope with the loop transfer recovery

problem for continuous-time systems and, in [32], similar

results have been obtained for discrete-time systems. In [4],

the PIO has been applied to handle the estimation problem for

system states and unknown disturbance inputs for multiple-

input–multiple-output linear systems. However, to the best of

our knowledge, the PIO design problem for RNNs has not been

investigated yet primarily due to the complexities in mathe-

matical/numerical analysis caused by the integral term in PIO, and this situation constitutes the main motivation of our current

investigation.

4. During the past few decades, the so-called proportional–

integral observer (PIO) has received an ever-increasing interest

from a variety of research communities, such as manufactur-

ing process, network communication systems, power supply

systems, and economic systems [4], [6], [41]. To be more

specific, the structure of a typical PIO consists of two terms,

namely, the proportional term (proportional to the output

estimation error) and the integral term (integral to the output

estimation error), by which both the current and the historical

information can be ideally exploited. In comparison with the

conventional Luenberger observer, the PIO possesses certain

distinguishing merits, such as better steady-state accuracy,

stronger robustness, more insensitive to exogenous noises, and

more freedom to observer’s design. Due to the extra integral

term in its structure, the PIO has long been an attractive

research topic leading to fruitful results in the literature [5],

[17], [36]. Nevertheless, to the best of our knowledge, very

few results have been available on the PIO design problem

for RNNs, not to mention the case where the H∞ performance

index is a major concern as well, and this leaves a gap that

will be narrowed through our endeavors in this article.

An implicit assumption with almost all available PIO design

schemes is that the designed PIO can be precisely implemented

in practice. Such an assumption, however, is not always

reasonable in reality because the imprecision in implementing

the PIO parameters is a frequently occurred phenomenon

for various reasons: 1) the finite precision of measuring

equipment; 2) the round-off error in numerical calculation;

3) the random failures/repairs of system components; and 4)

the requirement of safe-tuning margin reserved for practic-

ing engineers [22], [44]. In other words, the gains of the

designed PIOs might encounter undesired fluctuations during

the execution process, which could jeopardize the estimation

performance to a great extent. In this sense, a natural idea

is to design a PIO that is insensitive/invulnerable to the gain

variations, and this gives rise to the so-called nonfragile PIO

design problem. On the other hand, the gain variations might

take place on a random basis owing mainly to the network-

induced complexities (e.g., quantizations, saturations, disor-

ders, or channel fadings) and changes of network conditions

(e.g., network load, network congestion, and network trans-

mission rate) whose occurrences are typically random [15],

[24], [29]. Consequently, it is of both theoretical importance

and practical significance to design a nonfragile PIO in case of

the randomly occurring gain variations (ROGVs) in order to

maintain a satisfactory estimation performance, and this leads

to another motivation for the current investigation.

传感器网络中的事件触发、网络攻击

1. In recent years, event-triggered control/estimation issues

have attracted ever-increasing research interest, and a large

number of results have been acquired in the literature for net-

worked control systems, complex networks, sensor networks,

and RNNs [20], [28], [30], [33], [38], [42], [47]. Different

from the traditional time-triggered schemes, the distinguish-

ing feature of the event-triggered control/estimation schemes

is that the controller/estimator is modulated only when a

particular “event” occurs, and therefore the event-triggered

protocol (ETP) is more capable of mitigating the compu-

tational burden and reducing energy consumption than its

time-triggered counterpart. In particular, in the context of

RNNs, since the state of each neuron needs to be estimated

separately, the inherent characteristics of RNNs (e.g., huge

dimension and complex structure) contribute much to the

excessive consumption of resources (e.g., cost for processing,

storage, and communication) in the state estimation process.

Naturally, from a resource conservation perspective, it is of

both theoretical importance and practical significance to intro-

duce the ETP into the state estimation problem for RNNs.

By now, some initial research results have been obtained

on the event-triggered state estimation problems for RNNs

(see [22], [23] and the references therein).

It is noteworthy that the ETPs adopted in most existing lit-

erature belong to the category of static ETPs (SETPs), whose

threshold parameters are fixed a priori. From a technical stand-

point, however, the dynamic ETP (DETP) is more attractive

than the SETP because the threshold parameters of the DETP

are adaptive to the dynamical changes of the environment. To

be more specific, for DETP, an offset variable generated by an

auxiliary system model is introduced into the threshold so that

the triggering condition is dynamically adjusted according to

practical requirements. In other words, the dynamic threshold

adopted by DETP is of the time-varying nature that reflects

the necessity/urgency for event triggers and system updates.

With DETPs, a smaller triggering threshold contributes to

a higher data transmission rate, which usually caters to the

case of larger estimation/control errors. Recently, there has

been an increasing research interest on the control/estimation

problems under DETP, and some preliminary research results

have appeared (see [12], [18], [29]). Unfortunately, so far, the

PIO design problem for RNNs under DETP has not yet been

investigated, let alone the case of sensor saturation.

2. On another research forefront, owing to the quick evolu-

tion of the network communication technologies, considerable

research attention has been paid to the networked systems

[33]–[35]. Compared with the traditional control systems, the

utilization of common communication networks offers several

benefits such as low cost, large flexibility, high reliability and

simple installation/maintenance [36], and also leads to certain

unfavorable network-induced phenomena such as channel fad-

ings [11], [37], packet dropouts [3], [38], quantization effects

[39]–[41], sensor saturations [42] and so on. To mitigate

the network congestion and avoid the network-induced phe-

nomena, an effective way is to introduce the communication

protocol so as to schedule the information exchange on a

shared channel.

Recently, the protocol-based networked systems have begun

to stir some initial research interest [37], [41], [43]–[45]. For

example, in [41], the ultimate boundedness control problem

has been investigated for quantized networked control systems

(NCSs) subject to Try-Once-Discard protocol. The quantized

control problem has been studied in [39] for networked

systems with the Round Robin (RR) protocol. Based on a time-

varying system approach, the stabilization problem of NCSs

under two types of stochastic protocols has been investigated

in [46]. Nevertheless, to the best of the authors’ knowledge,

the H∞ fuzzy PID control problem has not been studied yet

for fuzzy systems with infinite-DTDs and RR protocol, which

is probably due to the resultant system complexity, and we are

therefore inspired to shorten such a gap in this paper.

3. With the quiet revolution of network technologies, the

past

decade

has

seen

increasing

popularity

and

usage

on

the

networked

control

systems

(NCSs)

in

prac-

tice [21], [34], [37], [39], [42]. However, in comparison with

the traditional point-to-point control systems, NCSs are more

susceptible to network-induced phenomena, including com-

munication delay [7], [26], [27], [32], [43], [47], packet

dropout [22], [28], [33], signal quantization [12], and fading

channel [41]. Furthermore, owing to the inherent opening-up

characteristic of network links, the information transmission in

NCSs is vulnerable to cyber threats which are likely to result

in performance degradation or even instability [25], [29], [30].

In this case, the security protection becomes a vitally important

issue and the so-called security control problem has received

some initial research attention, see [3], [11], [31] and the

references therein. Generally speaking, the main idea of the

security control is to design a control law such that a desired

security level is achieved for the closed-loop system under

cyber-attacks that include, but are not limited to, denial-of-

service (DoS) attacks [4], replay attacks [45], and deception

attacks [13].

In the context of cyber defense, the attacks initiated by

opponents might be unsuccessful in NCSs due to the installed

devices or software for security protection. As such, from

the defenders’ perspective, the cyber-attacks are likely to

take place in a random manner and the occurrence mech-

anism of the attacks can be mathematically modeled by

the Bernoulli/Markov processes with certain statistical prop-

erty, see [13], [24] and the references therein. For cyber-

physical systems, in addition to the basic security, one

would expect that certain system performance can be main-

tained for necessary system operation. In this case, the

quadratic cost behaves as an adequate performance index

and a realistic criterion would be to ensure an upper bound

on the quadratic cost function for the closed-loop system in

spite of the randomly occurring cyber-attacks, which leads

to the so-called cost-guaranteed security control [13], [31].

It should be pointed out that, the observer-based PID

security control problem for NCSs has not been inves-

tigated yet, not to mention the case that the quadratic

performance index is also a major concern for system design-

ers. Therefore, the main purpose of this article is to narrow

such a gap.

5. 传感器网络是由大量的具有传感、计算、无线传输能力的微型传感器节点构成的

网络。这些传感器节点按照一定的拓扑结构，以网络的形式在空间上分布，各个传感器

节点相互协同工作。在基于传感器网络的估计中，每个传感器节点不仅要利用自身的

测量信息，还要利用相邻节点的测量值实现对目标的估计。因此，在传感器网络的框架

下，如何建立一个能够根据给定的网络拓扑结构，正确地描述每个传感器节点的估计

器结构变得至关重要。

近年来，网络技术迅速发展，传感器网络技术成功应用到控制理论研究的同时，随

之产生的网络化现象也给理论与应用研究带来了困难。由于受到网络带宽的限制，容

易产生一系列网络诱导现象，例如测量数据的丢失或衰减、延时、网络拥塞等，从而导

致分析和设计系统的复杂性和难度明显增加。网络通信协议的出现，能够很大程度上

解决网络拥塞等问题。目前，常见的通信协议有：Round-Robin 协议、随机通信协议以

及最大误差优先- 试一次丢弃(MEF-TOD) 协议等。然而需要注意的是，引入某种通信协

议后，需要结合该类协议的特点建立对应的数学模型，并且给出合适的性能指标，设计

出符合要求的估计器或滤波器。

综上所述，基于传感器网络的分布式估计问题已经有了相当丰富的研究成果，但

仍有许多问题尚未解决。

12. 随着现代通信技术飞速发展, 数据和信息传输需

求越来越大, 但系统的计算资源是有限的. 针对这一

问题, Jensen.M等人 [7]首次提出事件触发的思想, 在

基于事件触发的控制策略中, 仅当特定事件发生时才

更新控制率, 否则传输的信号将保持最新值, 与传统

的时间触发策略相比事件触发在一定程度节约了网

络化系统的计算资源. 近年来关于事件触发策略的研

究十分丰富 [8–10], Tabuada等人提出了一种基于状态

的事件触发条件, 通过持续监视状态判断是否传输.

Heemels等人讨论了基于观测器的周期事件触发策略,

并指出事件触发系统的性能可以任意逼近周期时间

触发. Postoyan等人提出了一种基于自由选择的有限

传感信息和内部变量对线性定常系统触发机制进行

重新设计, 提出一种具有最小执行时间的稳定性条件.

在事件触发的研究中, 由状态或输出构成的静态规则

判断触发条件为静态事件触发. 类似Postoyan等人研

究的静态事件触发, 需要保证存在非负的最小事件触

发间隔时间避免芝诺行为. 为了解决这一问题, Yue等

人 [11]提出了基于采样数据的事件触发策略. 为了进

一步节约计算资源, Girard [12] 提出了一种新的事件触

发机制, 通过在传统事件触发中引入一个额外的内部

动态变量, 从而启发了动态事件触发名称. Liu等

人 [13]提出了一种新的动态周期事件触发策略, 协同

设 计 了 触 发 条 件 的 加 权 矩 阵 与 控 制 增 益.

Tarbouriech等人 [14]针对基于观测器的反馈控制线性

系统, 设计了一种基于局部信息的动态触发机制. 以

上研究结果表明, 动态事件触发策略能达到与静态策

略相同的控制性能, 同时有效地减少传输次数且避免

讨论芝诺行为.

在考虑网络资源有限的同时, 也应该考虑网络化

系统面临的安全问题 [15], 特别是在近几年工业开放

网络受到攻击的事件频发. Foroush等人 [16]研究表明

网络化系统常见的安全问题为DoS攻击, 这种攻击试

图传输大量无效数据, 故意干扰网络通信资源, 通常

会导致系统无法进行通信. Persis等人 [17]证明了在保

证系统渐近稳定的前提下, DoS攻击活跃时间平均不

能超过一定的百分比, 即系统所能容忍的DoS攻击存

在能量和持续时间的限制, 从攻击者的角度来看, DoS攻击也存在能量限制. 近年来, 关于事件触发的网

络化系统安全性问题的研究已有一些进展 [18–21].

Hu等人研究了周期DoS攻击的网络系统弹性事件触

发控制, 将DoS攻击建模为开关信号, 给出了保证闭

环系统稳定时所需的控制器参数, 但其研究在DoS攻

击活跃期间没有控制信号, 所应用的网络化系统存在

一定局限. Jiang等人研究了网络化系统在DoS攻击下

的稳定性问题, 提出一种具有应答信号的改进事件触

发机制, 并建立了闭环系统的干扰周期、收敛速度和

发散速度之间的关系, 但其事件触发策略仅限于静态

事件触发. Sun 等人研究了输出反馈弹性事件触发网

络化系统拒绝服务攻击, 通过在静态触发条件中加入

一个正项表示DoS攻击对系统的影响, 指出了系统在

容忍DoS攻击的同时存在一定的性能损失. Tamba等

人研究了基于动态事件触发实现拒绝服务下的弹性

控制, 但其结果不具有LMI形式, 不易直接设计控制

器参数. 尽管Hu等人在研究静态事件触发基础上提出

了动态事件触发的DoS攻击协同设计 [22], 但其研究侧

重在DoS攻击活跃时采用零输入策略. 因此关于动态

事件触发中考虑DoS 攻击还没有得到充分的研究, 仍

具有挑战性.

13. 随着通信工程、控制科学和计算机技术的发展和融合, 网络控制系统(Networked control systems, NCSs)通过共

享的通信网络进行信息交换, 但是信道带宽是有限的.传统的控制以周期的方式执行, 即所谓的时间触发控制, 基于采

样数据系统理论[1], 具有可预测性, 易于实现.但是, 从资源利用的角度看, 时间触发控制周期地执行控制任务会浪费计

算和电池设备能源资源.此外, 如果采样周期比较小, 则大量冗余采样信号将被释放到带宽有限的共享通信网络中, 这

必然会造成网络拥塞.因此, 事件触发控制引起了越来越多学者的关注[2-3].所谓事件触发控制, 是指控制任务是否执行

由事先给定的事件触发条件决定, 而不是根据时间情况[2].如果触发条件在某一时刻违背, 则意味着事件触发, 立即执

行控制任务.与时间触发控制机制相比, 事件触发控制方案可以减少计算资源、电池装置能源和通信资源使用.事实上,

已经通过实验表明[4-5], 事件触发控制方法可以有效地减少控制任务执行数量, 从而在保证闭环系统性能的基础上, 显

著地节约通信资源.

20世纪90年代, 基于事件的思想被率先应用到发动机控制中[6].文献[4-5]的出现显示出基于事件控制的优点, 而后

自触发控制出现[7].需要指出, 早期的事件触发控制是所谓的连续事件触发, 需要特殊的硬件对当前状态进行连续监测.

为克服这一问题[8], 文献[9]提出了周期事件触发.但无论是事件触发还是自触发, 都需要注意一个重要的问题, 那就是

需要保证任意两个事件执行时刻的最小时间间隔, 即最小事件间隔时间严格大于零.为了解决这一问题, 文献[10]提出

了基于采样数据的事件触发.周期事件触发和基于采样数据的事件触发都属于离散事件触发, 关于离散事件触发的稳定

性分析和控制器设计方法已有一些文献进行了研究[11-12].随着网络化的日益加深, 控制系统日趋大规模集成化, 为了

减轻系统间的通信压力, 对于大规模系统的分散式事件触发控制[13-14]和分布式事件触发控制[15-16]引起了越来越多

学者的关注.文献[17-18]提出了动态事件触发机制, 与静态事件触发相比, 它可以增大最小事件间隔时间, 甚至可以接

近可允许最大传输间隔.

事件触发控制(ETC)已成为当前流行的研究主题[19], 这点也可从2010年到2015年顶级会议IEEE CDC每年都设

置有关ETC的专题分会窥见一斑, 并且自2015年独立发起了基于事件的控制、通信与信号处理国际会议(EBCCSP),

今年将在葡萄牙举办第3届EBCCSP'2017.值得一提的是, 现代工业过程的日益复杂化所引起的有线和无线网络系统的

流行, 不可避免地出现能源、通信和计算资源的限制.将事件触发思想应用于嵌入式系统, 可以有效地解决这些问题.从

潜在的设计方法角度讲, 基于事件控制的嵌入式系统中导出的许多结果可以看作是网络控制系统的一种特殊情况[2].

本文全面综述基于事件的控制系统的研究现状与最新成果.主要介绍事件驱动通信机制的各种类型和事件触发控

制的主要研究内容, 包括不同的建模方法以及控制器与事件产生器的联合设计方案, 重点对时延系统建模方法进行分

析, 将事件触发闭环控制系统建模成连续时滞模型.此外, 关于网络诱导因素对事件触发机制的影响以及网络化事件触

发控制的一些应用也进行说明.最后, 提出目前研究工作所存在的不足, 以及下一步需要解决的开放难题

14.