Modeling of control system for LAMOST Based on Petri net Workflow

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ABSTRACT

The Chinese ever-ambitious project LAMOST (Large sky Area Multi-Object fibre Spectroscopic Telescope) has now come to its final completion of R&D stage. Major functions of the telescope have successfully passed a serial of pilot observation recently, and various kinds of applications integrated into the automation of the telescope chamber are being under vigorous site tests too. The TCS (Telescope Control System) is built on multi-layer distributed network platform with many sub-systems at different levels. How to efficiently process the enormous amount of message with particular implications running in and out the TCS is one of the major issues of the TCS software package. The paper focuses on the modelling of control system for LAMOST based on Petri net workflow. The model is also analyzed and verified with the matrix equation.

Keywords: LAMOST, Petri net，workflow，TCS， modeling

1. INTRODUCTION

The Large sky Area Multi-Object fiber Spectroscopic Telescope (LAMOST)，had passed the acceptance of project in 2009. The telescope can observe 4000 celestial objects simultaneously, thus become the world’s most powerful ground astronomical optical survey instrument with 6m aperture[2]. The price of such a unique design philosophy is an extraordinary technical challenge. Of course, the realization of such a task would put unprecedented challenge to our control design team.

Figure 1 shows the TCS（Telescope Control System） with its major function modules below and OCS (Observatory Control System) on its top. The OCS is at the top in the hierarchy responsible for supporting the on-site observer and system operator in their tasks and coordinates the activities of the other three principal systems immediately at one level below the OCS in the hierarchy, namely Telescope Control System (TCS), Instrument Control System (ICS) and Data Handling System (DHS)[1].

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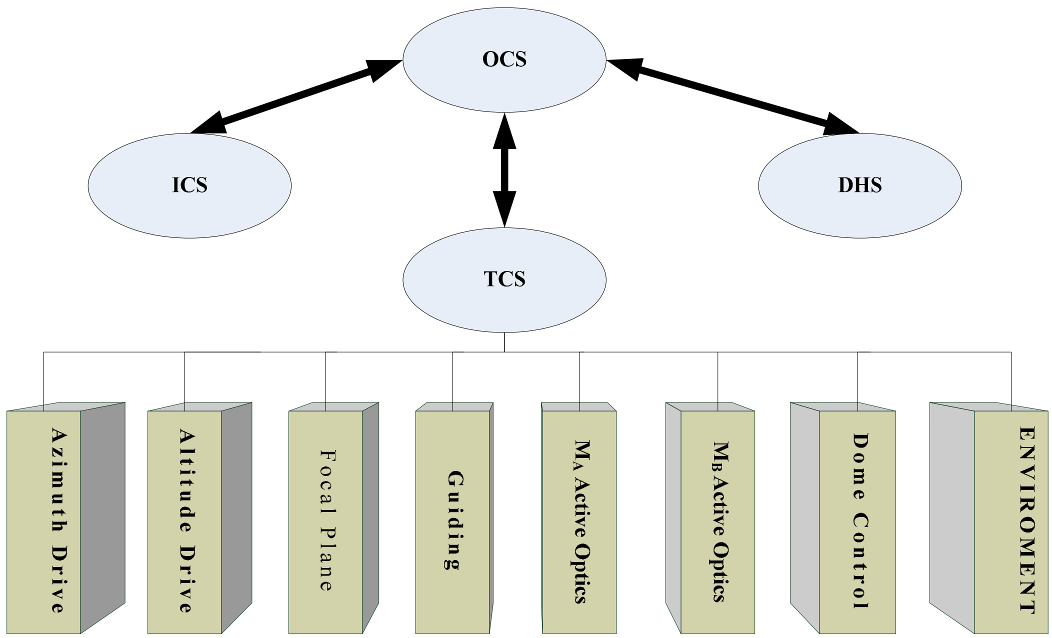

Figure 1: LAMOST high-level control and interfaces

The term workflow management refers to the domain which focuses on the logistics of business processes. There are also people that use the term office logistics. The ultimate goal of workflow management is to make sure that the proper activities are executed by the right person at the right time. Workflows are case-based, i.e., every piece of work is executed for a specific case. A workflow process is designed to handle similar cases. Cases are handled by executing tasks in a specific order. The workflow process definition specifies which tasks need to be executed.

In this paper we use a framework based on Petri nets to establish a model for TCS process. Petri nets are a well-founded process modeling technique. The classical Petri net was invented by Carl Adam Petri in the sixties. Since then Petri nets have been used to model and analyze all kinds of processes with applications ranging from protocols, hardware, and embedded systems to flexible manufacturing systems, user interaction, and business processes[3]. We set up a matrix equation from the model for TCS process based on Petri nets. Through this matrix equation, we can validate the process of TCS effectively.

2. The Process of TCS

List1 shows the process of TCS .

Event	define	condition	define
T0	OCS sends self check command to TCS	P0	begin
T1	TCS sends self check command to subsystem	P1	TCS receives self check command
T2	TCS begins refrigerate	P2	OCS checks if it needs to refrigerate
T3	OCS sends open dome command to TCS	P3	It doesn't need to refrigerate
T4	OCS sends open focal plane door command	P4	Refrigeration is ready
T5	OCS sends back home command to TCS	P5	The dome is open
T6	OCS sends active optics command to TCS	P6	The focal plane door is open
T7	Mirror B begins co-focusing	P7	The Mount is at home
T8	Mirror A begins auto collimation	P8	TCS receives the co-focusing command
T9	TCS sends track command	P9	Mirror B co-focusing is over
T10	TCS sends star guide command	P10	Mirror B co-focusing is not over
T11	TCS sends co-focusing command to MA	P11	Mirror A co-focusing is over
T12	Mirror A begins closed loop control	P12	The star is in the field of view
T13	Mirror A begins open loop control	P13	The star is not in the field of view
T14	TCS sends stop track command	P14	Star guide is running
T15	OCS sends close focal plane door command to TCS	P15	There is bright star in the field of view
T16	OCS sends close dome command to TCS	P16	There is no bright star in the field of view
		P17	Still need to observe and the optics system is good
		P18	Still need to observe and the optics system is not good
		P19	Stop observing
		P20	Stop tracking
		P21	Close focal plane door
		P22	Close dome

List1. Definition of Event & Condition

3. Modeling of TCS process based on Petri net

We can get the modeling of TCS from List1.

We can get the relation list between Event and condition from figure2.

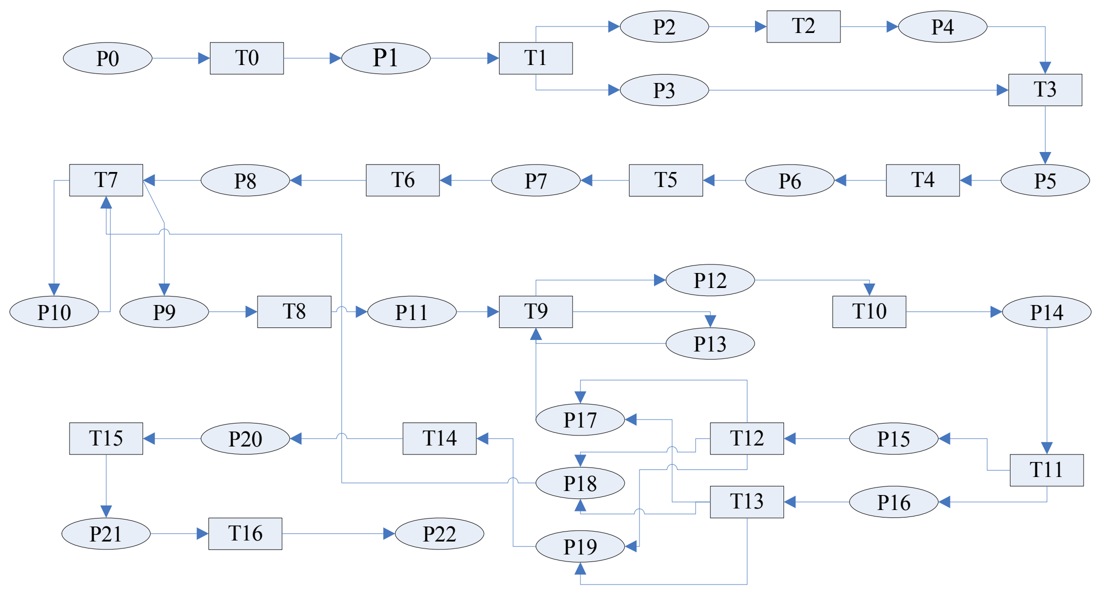

Figure2.The model for TCS Workflow based on Petri Net

precondition	case	postcondition
P0	T0	P1
P2	T2	P4
P5	T4	P6
P7	T6	P8
P9	T8	P11
P12	T10	P14
P15	T12	P17 , P18 , P19
P19	T14	P20
P21	T16	P22
P1	T1	P2 , P3
P3 , P4	T3	P5
P6	T5	P7
P8 , P10 , P18	T7	P9 , P10
P11 , P13 , P17	T9	P12 , P13
P14	T11	P15 , P16

P16	T13	P17，P18，P19
P20	T15	P21

List2. Relation of Event & Condition

4. Modeling analysis

We can build two matrix equations L1 and L2. L1 means the relationship between event and precondition.L2 means the relationship between event and postcondition[4].

$$\boldsymbol{L1}[j,i]=\boldsymbol{W}(pi,tj) = \left\{\begin{matrix}
1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,1,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,1,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0
\end{matrix}\right\}$$

$$\boldsymbol{L2}[j,i]=\boldsymbol{W}(tj,pi)= \left\{\begin{matrix}
0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1
\end{matrix}\right\}$$

$\boldsymbol{L1}[j,i]=\boldsymbol{W}(pi,tj)$, $0 =< i <= 22$, $0 <= j <= 16$

$\boldsymbol{L2}[j,i]=\boldsymbol{W}(tj,pi)$, $0 =< i <= 22$, $0 <= j <= 16$

Be noted above ***L*** is identified as the relational matrix corresponding to the Petri net, particularly here are ***L2-L1.*** The reachable qualification: if ***M*** is reachable from the state ***M1,*** then there exists a firing sequence $\boldsymbol{\delta}$ making the transition from ***M1*** to ***M*** possible。 In other words, there exists a solution ***F[δ]*** for the following equation.

$$M1 = M + X.*L$$

In order to let the Petri nets workflow dynamically run ***M*** must have the power to trigger the enabled transition and to redistribute the token thus reach a new state ***M1***. If the power to trigger the transition does not exist, the running process ceases[5].

$$L = L2 - L1 = \left\{\begin{matrix}
-1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,-1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,-1,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,-1,-1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,-1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,-1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,-1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,-1,1,0,0,0,0,0,0,0,0,-1,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,-1,0,1,0,0,0,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,-1,1,0,0,0,0,-1,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,-1,0,1,0,0,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,1,1,0,0,0,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,0,1,1,1,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,1,1,1,0,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,1,0,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,1,0 \\
0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,-1,1
\end{matrix}\right\}$$

TCS workflow start state ***M***={1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0} denotes the observation workflow starts.

$$T0 : {}'T0 = \{p0\},\ M(p0) = W(p0, t0) = 1$$

$$T0' = \{p1\},\ M(p1) + W(t0, p1) = 0 + 1 = 1$$

Therefore ***T0*** has the power to trigger. Likewise it is possible to validate other sequences. For example, in order to validate state {0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0} is reachable from state {1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0} the following equation is given:

$$\{0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0\} + X*L = \{1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0\}$$

Suppose ***X*** is the solution for the equation, and if every item value of ***X*** is equale to 0 or lager than 0 then it is reachable, otherwise it is unreachable. In order to validate if it is possible to reach a state at discretion it is only needed to search the solution for the matrix ***X*** of equation $M1 = M + X. * L$ and to see if the ***X*** satisfies the request. From above analyses and validation the given workflow for TCS in the Petri nets is reachable. The Petri nets method provides a analyses tool to theoretically validate the reachability for random sequences, so to assure every observation process is able to be run in order, which is theoretical correctness for observation process of astronomical telescopes.

5. Conclusion

China's ambitious LAMOST is being developed and the telescope features largest ever field of view of 5^0 among all existent meter-class level ground astronomical optical telescopes in the world. The large field of view offers the telescope capability of observing 4000 stars simultaneously. All these inevitably call for a sophisticate control system to meet all tough requirements for the process control. It is vital to assure correctness of the telescope observation process, and here comes in the Petri nets analyses tool. The modelling of control system for Lamost is only a study work, which could also be mapped to other control system design for future astronomical telescopes.

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