# Software Performance Evaluation of a Polar Satellite Antenna Control Embedded System

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## ABSTRACT

*Performance evaluation of embedded system software unlike conventional software needs special attention and care. This must be achieved during the design phase of software. Antenna control systems generally, belong to soft real-time system well particular, polar satellite antenna control systems are used mainly in earth observatory systems. The thrust behind the performance evaluation of such systems is limited in the present available literature. This paper lists out various performances evaluation unexplored design methodologies for improved through put. Simulation results are also presented accordingly.*
**Keywords:** Performance, polar satellite, antenna

## 1. INTRODUCTION

Over the last two decades, research has addressed the importance of integrating quantitative justification in the software development process, in order to meet nonfunctional requirements. Traditional software development methods focus on software correctness, introducing performance issues later in the development process. Software performance modeling techniques such as mathematical analysis [1, 2, 3, 4, 5], simulation [1] and performance oriented prototypes [6], performance solutions [7] can be used to predict and improve the performance of the software system being modeled. Embedded systems being the real-time systems, performance evaluation and improvement is still needs more exploration in such systems. Performance evaluation of household embedded systems like microwave oven, washing machines etc have less impact than compared to avionics, satellite systems, space shuttles etc. This paper focuses in software performance evaluation while designing the polar satellite antenna control embedded systems.

## 2. POLAR SATELLITE ANTENNA CONTROL SYSTEM

A Polar Satellite Antenna Control System (Refer figure 1) is normally leveraged in the setup of satellite real-time data transmission and/or communications. Normally, antenna system is driven by motors through a rotating belt. The rotating belt is equipped with a sensor (normally called home sensor, (Refer figure 2), that detects the co-ordinates of the antenna. Some key parameters are taken into consideration during the design and evaluation.

- Length/Diameter of the antenna
- Velocity of the antenna
- Current Azimuth angle
- Current Elevation Angle
- Current cross-level angle

## 3. PROCESS FOR A SINGLE SATELLITE PASS COVERAGE

Satellite coverage can be either ascending or descending according to its orbit design and life cycle. Figure 3 shows the transition model of an instance G, One rotating belt V and the associated control processes C with three drive motors fixed to the arms of the antenna. Processes $V_{end}$ and $C_{end}$ are associated to design a closed system. Both synchronization channels and shared variables are depicted in the figure 3. pc0 , pc1, pc2, p0, p1, p2 are the synchronization channels and s0 , s1 , v0 , v1 are shared variables.

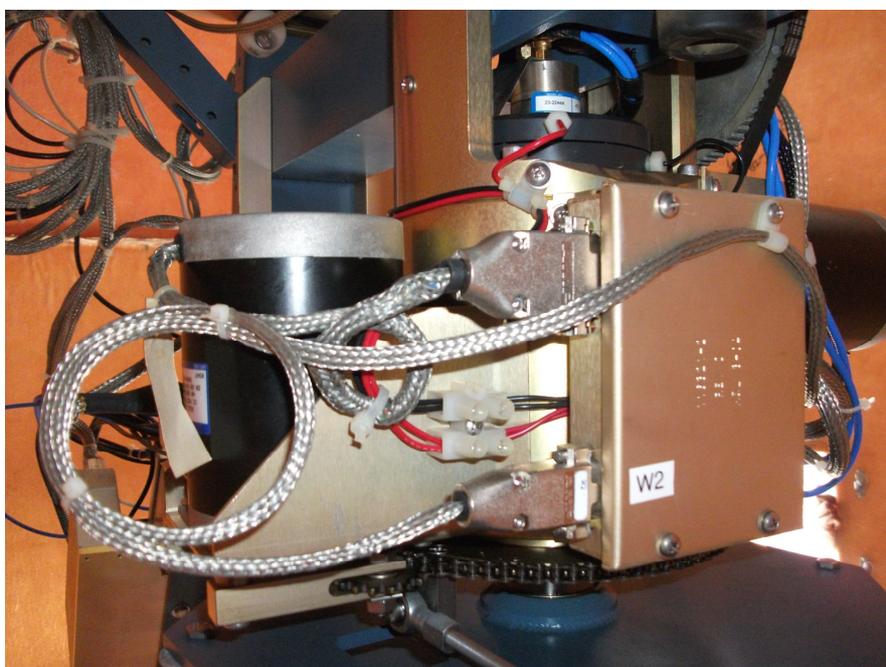**Figure 1:** X-Band Polar Satellite Antenna


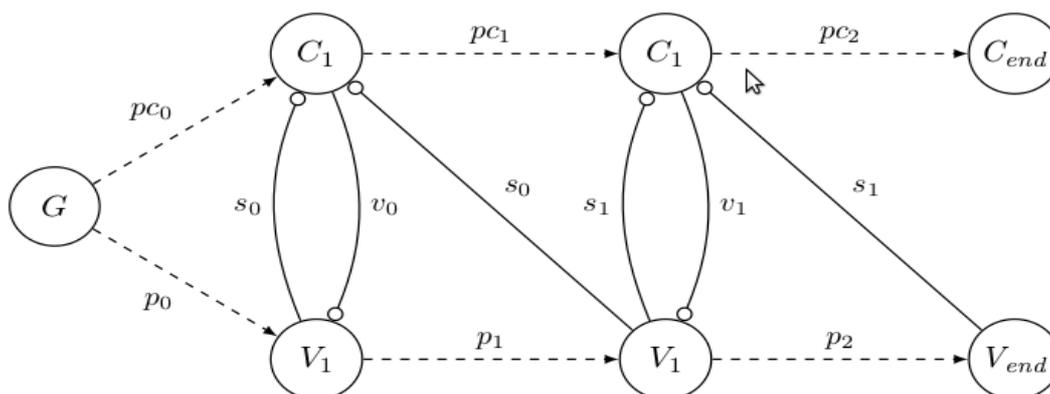
**Figure 2:** X/L band Polar Satellite Antenna Home Sensor



**Figure 3** The transitional model of the satellite tracking antenna system process per belt.

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- **Universal variable definitions**

The performance evaluation generally represented as Chi specification of the transitional model from Figure 3 is as follows:

```
model C1V1(val x1ini,x2ini: real) =
|[ cont x1: real = x1ini, x2: real = x2ini
, var v1: nat = 0, v2: nat = 0
, s0: bool = false, s1: bool = false, s2: bool = false
, chan pc0,pc1,pc2: void
, p0,p1,p2: void
:: G(pc0,p0)
|| C1(v1,s1,pc0,pc1) || V1(x1,v1,s0,s1,p0,p1)
|| C1(v2,s2,pc1,pc2) || V1(x2,v2,s1,s2,p1,p2)
|| Cend(pc2)
|| Vend(s2,p2)
]|
```

Channels p0, p1, p2 are used to synchronize the antenna position transition from the current to the next belt. Channels pc0, pc1 , pc2 are directed synchronization channels. Variables s0, s1, v0, v1 are shared variables, where s0 and s1 represent the sensors that indicate the presence of a home sensor, and v0 and v1 are actuators that determine the velocity of the respective motors. The process definitions are:

```
proc G(chan pc!: void, p!: void) =
|[ *( pc!; delay 1.0; p!! ) ]|



proc Cend(chan pc?: void) =
|[ * pc? ]|



proc V1( cont x: real, var v: nat, var sprev: bool, s: bool, chan pin?,pout!: void) =
|[ eqn dot x = ( x < -0.5 -> 0.0 | x >= -0.5 -> v*1.0 )
|| |[ mode waitforTray =    ( pin?
        ; x := 0.0
        ; x >= 3 -> sprev := false; waitforSensor
        )


  , waitforSensor =  ( x >= 5 -> s := true
        ; x >= 6 and v > 0 -> pout!
        ; x := -1.0; waitforTray
        )

:: ( x = -1        -> skip; waitforTray
| x >= 0 and x < 3 ->     !! "Error, incorrect initial value for x"
        ; deadlock

| x >= 3       -> skip; waitforSensor
        )
        ]|
```

*]|*

```
proc Vend(var sprev: bool, chan pin?: void) =
|[ cont x: real = -1.0
:: eqn dot x = ( x < -0.5 -> 0.0 | x >= -0.5 -> 1.0 )
||    *( pin?
  ; x := 0.0
  ; x >= 3 -> sprev, x := false, -1.0
  )
]|
```

- **Control and timing preservative paradigm**

The work can commenced with a conservative control strategy, where a triplet of azimuth, elevation and cross-level angles is allowed through home sensor thus indicating the electromechanical signals initiated to the rotating belt, after the previous spatial coordinates has reached the sensor completely.

```
proc C1(var v: nat, var s: bool, chan pcin?,pcout!: void) =
|[ mode emptyon = (    ( pcin?
       | delay 5.0; v := 0; pcin?; v := 1
       )
       ; entering
         )
, mode entering = ( s -> skip; atsensor)
, mode atsensor = ( pcout!; leaving
       | delay 0.2; v := 0; pcout!; v := 1; leaving
       )
, mode leaving =   ( not s -> skip; emptyon
       )
:: v := 1
; ( s -> skip; atsensor
   | delay 3.0; empty on
   )
]|
```

Figure 4 show simulation result for antenna system that is initially rest and system where the initial positions of the antenna are $180^o$ and $300^o$ azimuth angles with respect to $90^o$ elevation angle.
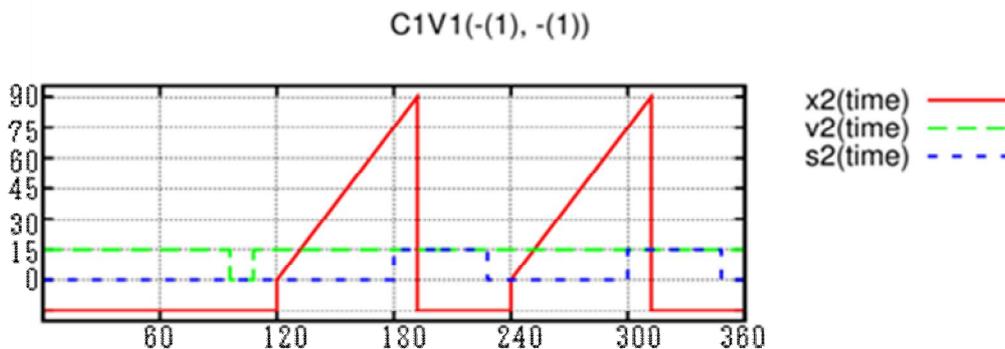


**Figure 3** Antenna System initially at selected idle state

- **Improved throughput paradigm**

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The throughput of the system can be improved by accurate positioning of antenna for maximum possible values of azimuth and elevation values. To achieve this goal, a new mode is added to the controller, providing the next position value as soon as the expected position is reached. This can b represented as:

*proc C2(var v: nat, var s: bool, chan pcin?,pcout!: void) =*
*|[ mode emptyon = ( ( pcin?*
*| delay 5.0; v := 0; pcin?; v := 1*
*)*
*; entering*
*)*
*, mode entering = ( s -> skip; atsensor)*
*, mode atsensor = ( pcout!; leaving*
*| delay 0.2; v := 0; pcout!; v := 1; leaving*
*)*
*, mode leaving = ( not s -> skip; emptyon*
*| pcin?; leaving_entering*
*)*
*, mode leaving_entering = ( not s -> skip; entering )*
*:: v := 1*
*; ( s -> skip; atsensor*
*| delay 3.0; emptyon*
*)*
*]|*

The other processes remain the same, leading to model C2V1.

*model C2V1(val x1ini,x2ini: real) =*
*|[ cont x1: real = x1ini, x2: real = x2ini*
*, var v1: nat = 0, v2: nat = 0*
*, s0: bool = false, s1: bool = false, s2: bool = false*
*, chan pc0,pc1,pc2: void*
*, p0,p1,p2: void*
*:: G(pc0,p0)*
*|| C2(v1,s1,pc0,pc1) || V1(x1,v1,s0,s1,p0,p1)*
*|| C2(v2,s2,pc1,pc2) || V1(x2,v2,s1,s2,p1,p2)*
*|| Cend(pc2) || Vend(s2,p2)*
*]|*

However, the system sometimes shows undesired behavior. Huge amount of data gaps can be found. This can be resulting of many reasons: Lack of recent orbital elements, GPS time sensor might not be synchronized, control system is busy with other priority tasks, and the poor synchronization of the drive motor to the given embedded signals. In the mode *waitforSensor*, the synchronization pout! is set delayed, allowing the antenna to move desired position.

- **Enhanced drive belt model (One feasible early solution)**

To eliminate the  poor response the first and best solution is the improved drive belt design. The tooth of the belt is restructured to increase or decrease the tooth. This can be represented as:

*proc G2(chan pc!: void, p!: real) =*
*|[ *( pc!; delay 1.0; p!!0.0 ) ]|*

*proc V2( cont x: real, var v: nat, var sprev: bool, s: bool, chan pin?,pout!: real) =*
*|[ eqn dot x = ( x < -0.5 -> 0.0 | x >= -0.5 -> v*1.0 )*
*|| |[ mode waitforTray = ( pin?x*
*; x >= 3 -> sprev := false; waitforSensor*
*)*
*, waitforSensor = ( x >= 5 -> s := true*
*; x >= 6 and v > 0 -> pout! x - 6*
*; x := -1.0; waitforTray*

```
)
:: ( x = -1 -> skip; waitforTray
| x >= 0 and x < 3 -> !! "Error, incorrect initial value for x"
; deadlock
| x >= 3 -> skip; waitforSensor
)
]|
]|

model C2V2(val x1ini,x2ini: real) =
|[ cont x1: real = x1ini, x2: real = x2ini
, var v1: nat = 0, v2: nat = 0
, s0: bool = false, s1: bool = false, s2: bool = false
, chan pc0,pc1,pc2: void
, p0,p1,p2: real
:: G2(pc0,p0)
|| C2(v1,s1,pc0,pc1) || V2(x1,v1,s0,s1,p0,p1)
|| C2(v2,s2,pc1,pc2) || V2(x2,v2,s1,s2,p1,p2)
|| Cend(pc2) || Vend2(s2,p2)
```

The solution is can be simulated to various possible initial boundary conditions combined with other proposed solutions. As the structure of the drive belt is enhanced or modified, the model works positively with the accurate values of orbital positions.

- **Local spatial position variable declarations (Second feasible solution)**

Traversing various solutions can yield the optimal solution model. Modeling the system using local variables for the positions of the antenna might give a fruitful behavior, thus leading to the following model:

```
model CVlocal() =
|[ var v1: nat = 0, v2: nat = 0
, s0: bool = false, s1: bool = false, s2: bool = false
, chan pc0,pc1,pc2: void
, p0,p1,p2: void
:: G(pc0,p0)
|| C1(v1,s1,pc0,pc1) || Vlocal(v1,s0,s1,p0,p1)
|| C1(v2,s2,pc1,pc2) || Vlocal(v2,s1,s2,p1,p2)
|| Cend(pc2) || Vlocalend(s2,p2)
]|
```

Here changes include the velocity of each conscan drive motor associated to each arm of the antenna and can be represented as:

```
proc Vlocal(var v: nat, var sprev: bool, s: bool, chan pin?,pout!: void) =
|[ *( pin?
; |[ cont x: real = 0.0
:: ( eqn dot x = v*1.0 | x >= 3 -> sprev := false )
; ( eqn dot x = v*1.0 | x >= 5 -> s := true )
; ( eqn dot x = v*1.0 | x >= 6 -> pout!! )
]|
)
]|

proc Vlocalend(var sprev: bool, chan pin?: void) =
|[ *( pin?
; |[ cont x: real = 0.0
```

```
:: ( eqn dot x = 1 | x >= 3 -> sprev := false )
]|
)
]|
```

The algebraic notation of the variables of the sensors can be represented as:

```
model CBalg(val xini,yini,zini: real) =
|[ cont x: real = xini, y: real = yini, z: real = zini
, var v1: nat = 0, v2: nat = 0
, alg s1,s2: bool
, chan pc0,pc1,pc2: void
, p0,p1,p2: real
:: eqn s1 = ((x >= 0 and x <=360) or (y >= 0 and y <= 90) or (z >=5 and z <= 85))
|| Galg(pc0,p0,p1,p2)
|| C(v1,s1,pc0,pc1)
|| C(v2,s2,pc1,pc2)
|| Cend(pc2)
|| PosAlg(x,v1,v2,p0)
|| PosAlg(y,v1,v2,p1)
|| PosAlg(z,v1,v2,p2)
]|

proc Galg(chan pc!: void, p0,p1,p2!: real) =
|[ *( pc!; delay 1.0
; (p0!!0.0 | p1!!0.0 | p2!!0.0)
)
]|
proc PosAlg(cont x: real, var v1,v2: nat, chan pin?: real) =
|[ mode empty =
( (eqn dot x = 0 | pin?x); tray )
, mode tray =
)
:: ( x = -1 -> skip; empty // assume initially x = -1 or x >= 0
| x >= 0 -> skip; tray
)
]|
```

### 4. CONCLUSION

The paper has presented some unexplored design paradigms of software evaluation while designing the embedded systems well particular like polar satellite antenna control systems. Adequate simulations can be done using the models specified in this paper. These models can further be enhanced with other feasible solutions which has direct impact in target embedded system.

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