A Statistical Approach to Efficiency and Reliability Analysis of Embedded GSM Remote Billboard Design

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ABSTRACT

Embedded System designs (ESD) comprises of portable devices such as digital watches, modems, MP3 players, including large stationary installations like traffic lights, factory controllers, complex hybrid vehicles, avionics, etc. Various contributions have been made in developing embedded systems both on low and complex systems with little consideration on reliability analysis of these systems. In this regard, the factors that contribute to the overall reliability of these systems have been scarcely investigated on. This research then addresses these issues by developing a Prototype GSM Billboard Display System (PGBDS) for limitless geographical reach, based on embedded AT89C51 Microcontroller chip with its associated peripherals mounted inside a large chassis or enclosure. We used an independent statistical approach to test a null hypothesis based on the responses of expert implementers in a sample population. Electronics Development Institute, Awka-Nigeria, was used as the testbed for the sample population. Independent-Variable Data Validation Scheme (IVDVS) is applied to analyse the data collected while accepting the null hypothesis, showing adequate agreement between computed results and actual prototype system reliability at 0.05 significance levels.

Keywords: Embedded, Prototype, Microcontroller, Reliability, Hypothesis, Significance level, Validation.

1. INTRODUCTION

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints [1], [2]. In most cases, it is embedded as part of a complete device often including hardware and mechanical parts with software driving the system. A general-purpose computer, such as a personal computer (PC), is completely different from an embedded system because it is designed to be flexible while meeting a wide range of end-user needs. A large percentage of the devices commonly used today [3] are built from embedded systems integrations. Embedded systems contain processing cores that are either microcontrollers, or digital signal processors (DSP) [4]. A central processor is an important unit in the embedded system hardware and is the heart of the embedded system [5]. The key characteristic in adopting embedded controllers is found in its ability to handle dedicated tasks. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance.

Again, since most embedded systems can be mass-produced, leverage can be achieved from its economies of scale. Embedded systems are commonly found in consumer, cooking, industrial, automotive, medical [6], commercial and military applications. Telecommunications systems employ numerous embedded systems from telephone switches for the network to mobile phones at the end-user. Computer networking uses dedicated routers and network bridges with embedded controllers at its core to route data. Examples of Consumer electronics with embedded controllers includes: personal digital assistants (PDAs), mp3 players, mobile phones, videogame consoles, digital cameras, DVD players, GPS receivers, and printers. Household appliances, such as microwave ovens, washing machines and dishwashers, include embedded systems to provide flexibility, efficiency and features, etc.
However, this paper observes that most embedded system designers lack the culture of making careful analysis on the performance efficiency, and reliability of their finished products leading to abysmal failures in unexpected moments. The reliability-as an-independent-variable Data validation scheme is the solution proposed by expressing quantitatively the reliability trade space as ranges of a number of real life responses from embedded system scientists and engineers.

**RESEARCH QUESTION AND HYPOTHESIS:**

Q1: What are the factors that affect efficiency and reliability test of embedded GSM based remote display billboard?

H0: There is no significant difference between the responses of Expert implementers below 5years working experience in embedded systems and those with above 5years experience in embedded systems designs.

2. RELATED WORKS

A representative sample of works on embedded display systems in literature was studied in [7], [8], [9], [10], [11] and [12]. The work in [13] aimed at designing a textual display system, based on a light emitting diode (LED) dot matrix array powered by solar energy. The work involves taking the device from an initial concept, through a design phase, to constructing a prototype of the product. The system consists of the display unit, which is powered from a photovoltaic (PV) module and a solar sealed lead acid battery in its prototype construction. Most of the works in literature follows the same design ideology but concludes their contribution at the implementation level only.

This work will completely formulate and develop an embedded GSM display system which will help in information dissemination particularly in the context of e-governance citizen awareness campaigns.

3. METHODOLOGY

The methodology employed in this research comprises of two schemes viz: Scenario Formulation and Implementation and Hypothesis validation using Independent-Variable Data Validation Scheme (IVDVS) which will be discussed in section VIII of this work.

- **Scenario Formulation:** In this research, a wide consultations including online survey of literature, and field investigations on display technologies was carried out in order to develop an intelligent display system. At first, this work reviewed various display design methodologies as well as sensing technologies that can be used for the design of digital notice board. A scenario that will leverage GSM network operators was considered while integrating the SMS cloud with SIM 300 in the presence of the expert agent as shown in figure 4. It expected that each time an SMS is sent via the cloud, as long as the security conditions, AT Commands, and service requirements are met, the controller will display the received messages accordingly.

The responses are usually based on a set of parameters considered necessary to develop and qualify the actually system functionality and a stated reliability/efficiency observation. This work will only focus on exhaustive embedded display system developments while using a statistical independent test to validate a formulated hypothesis in this research.

In our initial approach, figure 5 gives the end user perspective on the control flow. The operational flow chart and system flow chart at the receiver module is as shown in figure 5. During normal operations, the LCD reads a message from a fixed memory location in the microcontroller and displays it continuously, until a new message arrives for validation.

On windows 2000 / Windows XP, we configured the HyperTerminal taking cognizance of the COM port where the mobile phone or GSM modem is connected to. For the SIM 300 GSM Modem, we used MS HyperTerminal to send AT commands to the GSM modem by following the outlined procedure, viz:

- First, we obtain a SIM card by subscribing to the GSM service of a wireless network operator. By fixing a valid SIM card into the GSM modem, we start up MS HyperTerminal by selecting Start -> Programs -> Accessories -> Communications -> HyperTerminal.

- In the Connection Description dialog box as shown in figure 1, we entered GSMConsole as name and chose an icon we preferred for the connection before clicking the OK button.

![Fig. 1: Screenshot of MS HyperTerminal's connection Description.](image)
In the Connect to dialog box as shown in figure 2, we choose the COM port that the mobile phone or GSM modem is connecting to in the Connect using combo box.

We tested the console window by typing “AT” in the main window as shown in figure 3. A response "OK" is now returned from the mobile phone and or GSM modem. By typing “AT+CPIN?” in the main window, this is used to query whether the mobile phone or GSM modem is waiting for a PIN (personal identification number, i.e. password). If the response is "+CPIN: READY", it means the SIM card does not require a PIN and it is ready for use. If the SIM card needs a PIN, the expert agent will set the PIN with the AT command "AT+CPIN=<PIN>".
Figure 4: System Model for Embedded GSM Display System
Figure 5: Operational/System Flowchart
The AT89C51 operates based on an external crystal which serves as an electrical device which when energy is applied, emits pulses at a fixed frequency. We used the common crystal frequency of 11.0592 megahertz because of baud rate generation. The AT89C51 operates using its machine cycles. A single machine cycle is the minimum amount of time in which a single AT89C51 instruction can be executed although many instructions take multiple cycles. A cycle is, in reality, 12 pulses of the crystal. That is to say, if an instruction takes one machine cycle to execute, it will take 12 pulses of the crystal to execute thus:

\[ \frac{F_{osc}}{12} = 1 \text{ machine cycle} \]  \hspace{1cm} \text{(1)}

Since we know the crystal is pulsing 11,059,200 times per second and that one machine cycle is 12 pulses, we can calculate how many instruction cycles the AT89C52 can execute per second:

\[ F_{osc} = 11.0592 \text{ MHZ} = 11059200 \text{ Hz} \]

Thus, \( \frac{11,059,000}{12} = 921,583 \)

Now, the \( F_{\text{effective}} = 921.6 \text{ khz} \).

AT89C51 UART or serial communication block further divide this frequency \( 921.6 \text{ KHz} \) by 32 to generate its baud rate.

Therefore, Effective frequency available to generate Baud rates is \( 921.6 \text{ KHz}/32 = 28800 \text{Hz} \).

The controller can be configured to operate at any of the following baud rates: 1200, 2400, 4800, 9600, 19200 and 38400 bps. The process of the configuration is detailed in [14].

### Implementation Framework

This section discussed the actual implementation of this work, all the steps involved will be outlined both for software and the hardware subsystem. The steps involved for hardware subsystem implementation are as follows;

- Assembling of components
- Fixing of components on board
- Soldering of components
- Hardware testing
- Packaging

### B. Basic System Assumptions

The list of assumptions for this work includes:

a. The user SMS cloud and control units will establish communication via GSM air interface
b. The cell phone/mobile device and service provider chosen will support text messaging service.

c. The user is familiar with the text messaging program on their cell phone/mobile device.
d. All service charges (standard messaging rates) from the service provider apply based on service level agreement.

### C. Functional Requirements

The following is a list of functional requirements of the ASIC control unit/modules as explained previously.

a. The control unit from the GSM Modem will have the ability to connect to the cellular network automatically.
b. The GSM control unit will be able to receive text messages and instructions to be sent to the AT89C52 controller.
c. The framework algorithms within the control unit of the ASIC processor will issue its command to the microcontroller to display the SMS characters.
d. The AFF and proxemics peddler cognitive responses are to be in cooperated into the controller for the required intelligence.

The list of components that make up our receiving section includes:

1) SIM 300 GSM modem
2) Four 10uf capacitors
3) Two 30pf capacitors
4) Max 232 Embedded API Interface Chip
5) 11.0592MHZ crystal oscillator
6) Microcontroller (AT89C52) or RHC.

We will now present a unified display implementation implemented in this work.
D. Unified Intelligent Display

We used Protus Virtual Simulation Module (PVSM) to develop a Unified schematic capture of the system depicted in figure 4. As shown in figure 6, the pins are connected accordingly to the respective interfaces. The crystal oscillator is used for stability and to determine the baud rate of the transmission between the modem and the microcontroller. A +5v DC regulated power supply is used to supply power to all the modules requiring power. The buzzer with frequency of 1 to 18 kHz is connected pin 2.6 to produce an audible sound when the pin goes high. Pins db0 to db7 of the LCD are connected to pins 1.0 to 1.7 of the controller chip (see figure 6) for sending data to the LCD. As shown in figure 4, RS232-TTL level converter (Max 232) was connected to the microcontroller to enable serial communication with the GSM modem, capacitors C4, C5, C6 and C7 are used for capacitive voltage generator as specified in max 232 manual, the resistor R2 is used as pull-down resistor for reset button.

Figure 6: Unified System schematics with Protus VSM

7. SYSTEM TESTING

The test approach used for this system is bottom up approach; this test implies testing for different modules that make up the subsystem to ascertain their workability before incorporating them in the design, after that the subsystems that make up the system are tested to make sure that there is accurate interfacing between them, then the whole system is tested together as a whole, to make sure that it meets its requirement. The control program is also tested before integrating it with the hardware. All the modules were tested including the power supply unit, receiver unit and the display units and the expected voltage and current values were ascertained precisely. More precisely, type of components, programming approach, environmental conditions, network availability, and type of PSU, power availability, system timing metrics, and nature of deployments were used to validate the efficiency our design. Having concluded the implementation phase, this work will now discuss on the use of IVDVS. This real life results must be correlated with a statistical hypothesis.
8. INDEPENDENT-VARIABLE DATA VALIDATION SCHEME (IVDVS)

This work defines IVDVS as an approach that deals with Hypothesis Analysis using any statistical package.

In this research, using IVDVS, our primary data were collected and used through aid of questionnaires. The Questionnaire was answered by expert implementers in the Electronics Development institute, Awka, Anambra State after several observations of the prototype system deployment. Two major categories of respondents were used for validating our hypothesis. Experts below 5 years working experience ($E_1$) and those above 5 years working experience ($E_2$).

The questionnaire was administered in order to ensure the accuracy of data and was collected immediately from respondents after answering the questions. In all cases, 24 questionnaires were returned out of the 30 questionnaires distributed. Frequency count was used in analyzing section A of the instrument eliciting data on the working experience characteristics of the respondents, while mean was used to answer the five research questions. In analyzing the hypotheses, t-Test was used.

Research Question - $Q_1$: What are the factors that affect efficiency and reliability test of GSM based remote display billboard.

In this research, SPSS statistical package was used to analyze the complete data as shown in fig. 7. Table 1 shows the frequency and percentage distribution of respondents on working experience $E_1$ and $E_2$, respectively.

Table 1: Frequency and Percentage Distribution of Respondents on working experience

<table>
<thead>
<tr>
<th>S/N</th>
<th>RanIVVS Item</th>
<th>Experts Working Experience Categories</th>
<th>$E_1$: Below 5 yrs</th>
<th>$E_2$: Above 5 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Frequency</td>
<td></td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>2.</td>
<td>Percentage (%)</td>
<td></td>
<td>46</td>
<td>54</td>
</tr>
</tbody>
</table>

Table 2: Mean and Standard Deviation of Respondents on the factors that affect efficiency and reliability test of GSM based remote display billboard.

<table>
<thead>
<tr>
<th>Item statement</th>
<th>Mean</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type of components</td>
<td>4.54</td>
<td>Agree</td>
</tr>
<tr>
<td>2. Packaging design</td>
<td>3.08</td>
<td>Disagree</td>
</tr>
<tr>
<td>3. Programming approach</td>
<td>4.63</td>
<td>Agree</td>
</tr>
<tr>
<td>4. Environmental condition</td>
<td>4.00</td>
<td>Agree</td>
</tr>
<tr>
<td>5. Network availability</td>
<td>4.63</td>
<td>Agree</td>
</tr>
<tr>
<td>6. Type of PSU</td>
<td>4.04</td>
<td>Agree</td>
</tr>
<tr>
<td>7. Power availability</td>
<td>4.63</td>
<td>Agree</td>
</tr>
<tr>
<td>8. System timing metric</td>
<td>4.54</td>
<td>Agree</td>
</tr>
<tr>
<td>9. Nature of deployment</td>
<td>3.75</td>
<td>Agree</td>
</tr>
<tr>
<td>10. Operator tariff</td>
<td>3.04</td>
<td>Disagree</td>
</tr>
<tr>
<td>11. Human factors</td>
<td>3.13</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

In this research, Table 2 shows the mean and standard deviation of respondents on the factors that affect efficiency and reliability test of GSM based remote display billboard. As shown in the table, $E_1$ and $E_2$ respondents agreed that all other factors pertaining to efficiency and reliability test of GSM based remote display billboard affect efficiency and reliability test of GSM based remote display billboard, except items 2, 10 and 11. Hence, type of components, programming approach, environmental conditions, network availability, the type of PSU, power availability, system timing metrics, and nature of deployments, all contribute to the lifespan of such systems.

Hypothesis - $H_0$: There is no statistical significant difference in the mean responses of experts with above 5 years of working experience and those with below 5 years.
Figure 7: Snapshots of SPSS version 20 Environment for IVVDS with Result Output Window
Table 3 shows the t-Test analysis of the mean and standard deviation of responses of expert implementers ($E_1$ and $E_2$ respondents).

From the table, $N_1 = 13$, $N_2 = 11$, $DF = 22$ 
Where, $S = \text{Significant level at 0.05 (reject hypothesis)}$

Now, $X_1 = \text{mean score for expert implementers with above 5yrs of working experience}$, $X_2 = \text{mean score for expert implementers with below 5yrs of working experience}$.

$S.D_1 = \text{standard deviation for expert implementers with above 5yrs of working experience}$, $S.D_2 = \text{standard deviation for expert implementers with below 5yrs of working experience}$.

In the analysis, “sig (2-tailed)” are the figures showing the probability/significance level in which the calculated t-value will be significant.

**TEST:** The $H_0$ is rejected if the significance level is less or equal to 0.05.

From Table 3, the significance levels of all the items is greater than the stated 0.05 level of significance, therefore the null hypothesis for all the items is accepted.

<table>
<thead>
<tr>
<th>S/N of Items</th>
<th>Expert Implementers with Above 5yrs of working experience</th>
<th>Expert Implementers with Below 5yrs of working experience</th>
<th>t-cal</th>
<th>Sig(2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$X_1$</td>
<td>$S.D_1$</td>
<td>$X_2$</td>
<td>$S.D_2$</td>
</tr>
<tr>
<td>1</td>
<td>4.62</td>
<td>1.121</td>
<td>4.73</td>
<td>0.467</td>
</tr>
<tr>
<td>2</td>
<td>3.46</td>
<td>0.877</td>
<td>3.27</td>
<td>1.272</td>
</tr>
<tr>
<td>3</td>
<td>4.69</td>
<td>0.480</td>
<td>4.45</td>
<td>0.688</td>
</tr>
<tr>
<td>4</td>
<td>4.15</td>
<td>0.899</td>
<td>4.09</td>
<td>0.701</td>
</tr>
<tr>
<td>5</td>
<td>4.85</td>
<td>0.376</td>
<td>4.36</td>
<td>1.027</td>
</tr>
<tr>
<td>6</td>
<td>4.46</td>
<td>0.776</td>
<td>3.82</td>
<td>0.874</td>
</tr>
<tr>
<td>7</td>
<td>4.77</td>
<td>0.439</td>
<td>4.55</td>
<td>0.522</td>
</tr>
<tr>
<td>8</td>
<td>3.46</td>
<td>1.050</td>
<td>3.09</td>
<td>1.300</td>
</tr>
<tr>
<td>9</td>
<td>3.54</td>
<td>0.877</td>
<td>3.82</td>
<td>0.874</td>
</tr>
<tr>
<td>10</td>
<td>3.00</td>
<td>1.354</td>
<td>3.27</td>
<td>0.786</td>
</tr>
<tr>
<td>11</td>
<td>3.31</td>
<td>1.109</td>
<td>3.00</td>
<td>0.447</td>
</tr>
</tbody>
</table>

### 9. DISCUSSION AND ANALYSIS

For embedded system developers, the use of right metrics while developing such systems will go a long way in maintaining the long life span of such systems. The factors that affect the efficiency and reliability of embedded system display systems includes programming type of components, programming approach, environmental conditions, network availability, type of PSU, power availability, system timing metrics, and nature of deployments, all contribute to the lifespan of such systems.

Since t-Test linearly correlates with the real life test documentation, this paper then argues that our developed embedded system display system satisfies the conditions that are prerequisite to optimal system performance, reliability, stability and durability.

### 10. CONCLUSION

This work has developed a prototype GSM embedded display system using AT8951 as the core processor using the system model of fig 4 for its implementation design. We outlined a scenario formulation methodology and Independent variable Data Schemed for validating a null hypothesis. In this regard, SPSS statistical package was used for all the computations using 0.05 significant level. Essentially, this work shows that there is no statistical significant difference in the mean responses of experts with above 5 years of working experience and those with below 5 years and answer the research question -Q1 in this work.
REFERENCES


Author’s Brief

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