Smart–IPM: an adaptive tool for the preventive maintenance of medical equipment

2 authors:

Burak Arslan
Galatasaray Üniversitesi
17 PUBLICATIONS   **52** CITATIONS

SEE PROFILE

Yekta Ulgen
Bogazici University
56 PUBLICATIONS   **173** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Laser Photobiomodulation View project

Brain Computer Interfaces View project

SMART-IPM: AN ADAPTIVE TOOL
FOR THE PREVENTIVE MAINTENANCE OF MEDICAL EQUIPMENT

R.Burak Arslan, Yekta Ulgen

Institute of Biomedical Engineering, Bogazici University, 80815, Bebek, Istanbul, Turkey

Abstract- **The breakdown of a medical equipment in service is of particular concern because of its possible use in critical conditions. This may be a direct life support situation as therapy or an indirect effect such as providing information on the patient's health status. The signs of equipment failure may not always be apparent to clinical staff. Therefore they should be inspected periodically. Scheduled inspections help ensure the safety and efficacy of the medical equipment. In this study, a software tool is developed to implement a risk oriented prioritization of devices for preventive maintenance inspections. The database contains the equipment inventory, and related data files. The reports based on the inspection results, help determining a better scheduling than the constant sweeping of all devices.**

Keywords- **Preventive maintenance, Risk criteria**

I. INTRODUCTION

Preventive maintenance (PM) is "to clean, lubricate, adjust, check for wear, and perhaps replace components that might cause total breakdown or serious functional impairment of the equipment before the next scheduled inspection"[1]. Once a medical device is added to the equipment inventory, an appropriate maintenance schedule has to be selected. The device can fail from time to time with causes of failure including wear, mechanical damage, user abuse, random component failure and aging [2]. PM helps eliminate hazards before they develop, but there are many problems that occur suddenly and therefore cannot be detected and prevented by a PM procedure. The PM procedure is primarily a performance test to ensure that the equipment is operating properly and is calibrated.

The period of the PM is important. Inspections too frequent may degrade device longevity and may not be cost effective. If they are not frequent enough, they may affect reliability, accuracy and safety. Therefore the aims of a scheduled inspection program should be to:

- reduce the risk of hazard,
- minimize equipment down time,
- avoid excessive repair costs by providing timely interventions,
- correct minor problems before they result in major system failures,
- comply with codes, standards and regulations.

These goals can be achieved by classifying equipment into risk categories to determine the frequency and details of the performance checks. These categories may be based on information derived from the previous inspections such as failure histories. The scheduled inspection program must be effective in detecting faults and should reduce the number of repairs while being feasible, considering the number of man-hours available for the task [3].

An inspection system consists of the equipment inventories, documentation sheets, inventory control and service orders. An appropriate and complete inventory control system is fundamental to any equipment control program [4]. Although manual inventory record keeping systems are still widely used, computerized systems provide easy data entry and access, thus facilitating the management and maintenance of the system. They:

a) Produce maintenance work schedules and track inspection and work order requests;
b) Produce reports to evaluate personnel productivity, identify departments with higher equipment repair costs, identify repeated repairs, and document potential user errors or equipment abuse;
c) Provide documentation for malpractice suits involving medical equipment;
d) Demonstrate to accreditation inspectors that equipment is properly maintained;
e) Support repair versus replacement decisions and forecast equipment replacement requirements with historical data;
f) Determine the location of the devices;
g) Determine charges to user departments and prepare operating budgets.

The purpose of this study is to design an adaptive preventive maintenance protocol based on the inspections database. The management of the medical equipment will be done using the developed software. This will constitute a first step in the implementation of a complete medical equipment control system to be used in hospitals.

II. IMPLEMENTATION

The main component of the system is the equipment inventory [5]. An equipment control record is required for each device, including at least: the equipment identification number, item name, model number, serial number, manufacturer ID, location, owner, acquisition date, cost, warranty expiration date, vendor, responsible staff, inspection schedule. Additional information should include calibration and inspection results.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25OCT2001	N/A	-

Title and Subtitle	Contract Number
Smart-IPM: An Adaptive Tool for the Preventive Maintenance of Medical Equipment	**Grant Number**
	Program Element Number

Author(s)	Project Number
	Task Number
	Work Unit Number

Performing Organization Name(s) and Address(es)	Performing Organization Report Number
Institute of Biomedical Engineering, Bogazici University, 80815, Bebek, Istanbul, Turkey	

Sponsoring/Monitoring Agency Name(s) and Address(es)	Sponsor/Monitor's Acronym(s)
US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Report Number(s)**

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 25-28 OCT 201, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification	Classification of this page
unclassified	unclassified

Classification of Abstract	Limitation of Abstract
unclassified	UU

Number of Pages
4

While designing the database, following report options are also considered:

- Summaries that specify what work has been accomplished by whom;
- Test and repair equipment histories;
- Labor and total cost required to perform scheduled and unscheduled tasks;
- Inventory control information that summarizes parts and materials used and includes current information about stock levels.

A. Structure of the Database

The database is designed using Microsoft Access. The five digit product code nomenclature of Emergency Care Research Institute (ECRI) sourcebook has been accepted to represent each product.

The software has three main parts: data entry, reports and tools (Fig.1). Data entry to tables in the database is done through the graphical user interface (GUI) with a minimization of entry faults. Several reports are available to schedule the risk-based management of the equipment. The tools can be used to preprocess inventory tables, compress and archive equipment files and restructure the user interface.

Several tables are used including the inventory table, device codes, risk codes, technical information, calibration and purchase details. The structure of the first two tables is illustrated in Figure 2. The inventory table contains information about each device in the hospital providing also its location and current status. Device code table lists the types of medical equipment with their specific ratings. These ratings can be modified using the Parameters option in the Data Entry menu.

The data entry is mainly done by selection from list boxes or combo boxes, thus minimizing typing errors and ensuring consistency in terminology (Fig.3).
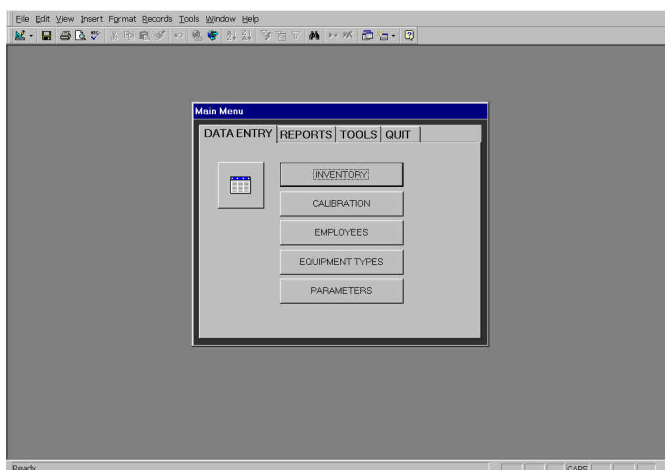
Table Inventory

Field Name	Data Type
DeviceID	Text
SpecialID	Text
DeviceCode	Number
ManufacturerCode	Number
Model	Text
SerialNo	Text
LocationCode	Text
Label1	Text
Label2	Text
StatusCode	Number

Table lkDeviceCodes

Field Name	Data Type
DeviceName	Text
Device Code	Text
RiskLevel	Number
InitialPMInterval	Number
FunctionCode	Number
ConsequenceCode	Number
MaintenanceCode	Number
ProtectionCode	Number
LethalityCode	Number
UseCode	Number

Figure 2. Field description of some elementary tables.

B. Preventive Maintenance Algorithm

An important part of any PM program is an effective inspection schedule. Joint Commission on Accreditation of Healthcare Organizations (JCAHO) states "all equipment is tested at intervals not to exceed six months, unless a different interval is approved". As can be inferred, a standard interval is not appropriate for all types of equipment. Analysis of repair histories provides some data on incidence of failure and reasons why equipment breaks down [6]. A risk based adjustment of the inspection interval is therefore targeted.

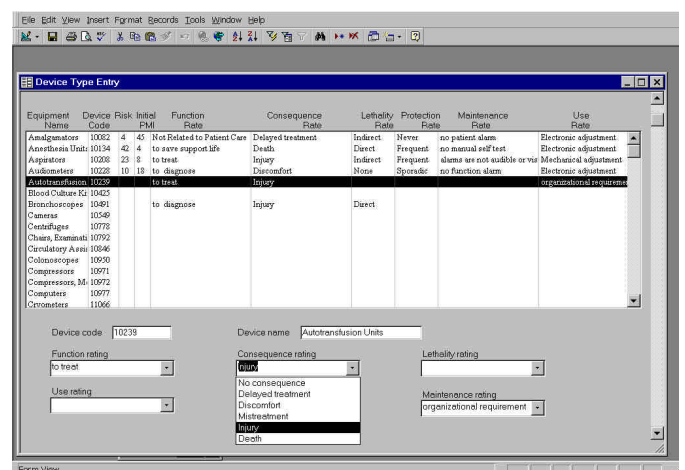Figure 1. Main menu of the SMART-IPM.

Figure 3. Device type entry screen.

The system uses the risk oriented prioritization approach instead of a constant inspection schedule [7,8]. This ensures that the devices that are most in need of inspection be inspected. The main functions of the system are as follows:

Equipment entry into the inventory table:

The device table includes the risk levels for each piece of equipment. The risk level for each type of equipment is determined according,

$$RL = FR + CR + MR + PR + LR + UR$$

where,

RL is the risk level;

FR is the function rating that characterizes the device's purpose (therapeutic, diagnostic, analytic etc.);

CR is the consequence rating that expresses the effects a malfunctioning device can cause (death, injury discomfort etc.);

MR is the maintenance rating that indicates regular manipulations needed for the equipment (electronic, mechanical adjustments, replacements etc.);

PR is the protection rating that defines the protection factors not provided on the device (no alarms, no start-up tests etc.);

LR is the lethality rating that indicates the presence of hazardous parts on the device;

UR is the usage rating that describes its frequency of use.

The rating values are taken from [7], although they can be modified later with respect to the actual analysis results.

Automatic assignment of the PM intervals:

An initial PM interval is automatically assigned to each device in the inventory according to their risk levels:

$$PM_{frequency} = \frac{RL}{N}$$

and

$$PM_{interval} = \frac{1}{\dfrac{PM_{frequency}}{12}}$$

N is a normalization factor with an adopted value of 15. This value also can be modified to better suit the requirements of the current application. The initial PM interval is given in months.

Interval adjustment based on calibration history:

$$RPM = \frac{\# PM_{with\ repair}}{\# PM}$$

RPM is the ratio of the number of inspections that resulted with repair to the total number of inspections for a specific device. If RPM is 0 for the last 3 inspections, then the interval is increased. If it is 1 for the last 3 inspections, then the PM interval is decreased by 3 months. Otherwise the interval is not changed.

PM index reports:

An index value for each device is calculated, to prioritize the inspection procedure, using a due factor for the device:

$$DF = \frac{T}{I}$$

where,

T: elapsed time since last PM,
and

I is the PM interval.

If this ratio is greater than 1 then the PM for that device is overdue. The PM index is then,

$$PMI = RL * DF$$

PM effectiveness reports

These reports are used to evaluate the effectiveness of the performed PMs. The effectiveness is computed as,

$$PM_{effectiveness} = \left(\frac{\sum RL}{\sum PMI} \right) * 100$$

where

ΣRL is the sum of device risk levels,

and

ΣPMI is the sum of PM indexes.

Classification of devices onto age groups

Age of an equipment is a good indicator of its potential of failure. The devices are divided into age groups of 5 years in order to focus on the effects of aging of the equipment. Thus the failures of the equipment and the frequency of PM can be predicted.

III. DISCUSSION

SMART IPM is a stand-alone database program. It is designed as a sub-unit of a complete medical equipment management system. It uses a risk-based approach using equipment history, in order to focus the inspection on devices that most need it. The difference from the originally proposed system lies in the fact that, it is based on its own database therefore is flexible for modifications and enhancements.

A successful equipment control program is needed to optimize the selection, procurement, use and maintenance of electromedical instrumentation in the hospital. As the PM program becomes effective, the reliability of the equipment increases, and the users gain confidence in the equipment. They have less difficulty operating it, and they are sure of the calibration. Technicians also, become familiar with the equipment and its operation as they perform PM procedures. Thus if the PM and repair of a given item of equipment is done by the same individual, in case of a malfunction, the downtime is frequently less.

The advantages expected from the system will be evaluated after its installation and use in a hospital. Further requirements of the end user will be considered while the complete medical technology management project evolves.

REFERENCES

[1] John Webster, "Biomedical equipment maintenance", in *Encyclopedia of Medical Devices and Instrumentation*, pp.1227-1236.
[2] Joseph Bronzino, "Technology management", in *Management of Medical Technology. A primer for clinical engineers*, Chapter 3, Butterworth-Heinemann pub., pp.67-110, 1992.
[3] J.N. Amoore, D.G.Stay, J.Mather, "Scheduled inspection of electromedical equipment. Planning and assessment", pp.211-218.
[4] John Webster, "Equipment control program", in *Encyclopedia of Medical Devices and Instrumentation*, pp.1219-1226.
[5] L.Fennigkoh, N.Smith, "Clinical equipment management", *Plant Technology and Safety Management Series* No:2, pp.5-14, 1989.
[6] J.Acosta, "Data driven PM intervals", *Biomedical Instrumentation and Technology*, pp.439-441, 2000
[7] M.Capuano, S.Koritko, "Risk-oriented maintenance: increase the effectiveness of your PM program", *Biomedical Instrumentation and Technology*, pp.25-37, 1996.
[8] Ethan Hertz, "Establishing the priority of equipment inspections", *Biomedical Instrumentation and Technology*, pp.410-416, 1990.