### Overview and screenshots

© RWD Nickalls,
Department of Anaesthesia,
Nottingham University Hospitals,
City Hospital Campus,
Nottingham, UK.

dick@nickalls.org
www.nickalls.org

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Chapter 1

Overview and screenshots

1.1 Introduction

Since 1994 I have run an on-going research-project to develop an open-source anaesthesia workstation for free use by the NHS in the operating theatre. What started as a small project to automate the production of the anaesthetic record, has since developed into a clinically-useful support tool for anaesthetists.

During the period 1996–2001 I developed a working theatre-based prototype MS-DOS program\(^1\), which was used in the thoracic operating theatre (City Hospital). A paper anaesthesia record (for the patient notes) was output using the open-source programs GNUplot (for graphic trends) and \(\LaTeX\) (for typesetting). Much of the initial work relating to interfacing medical devices via the serial port was published as a book by Cambridge University Press (Nickalls and Ramasubramanian, 1995).

During 2002-2004 the program was ported to Linux (see Section 1.3) and expanded to include alarms, some basic decision-support, as well as the calculation of various useful so-called \emph{value-added} real-time parameters, for example, age-dependent MAC\(^2\) (Nickalls and Mapleson 2003).

1.2 Difficulty with funding and R&D

During the past eight years or so I have tried to collaborate with various university departments with a view to R&D. Discussions with the Nottingham University Departments of Computing and Department of Electrical and Electronic Engineering in 2005 did not lead anywhere owing to lack of funding. Unfortunately funding has not been forthcoming (an EPSRC grant application in conjunction with Dept Med Physics, Liverpool Univ Hosp was rejected—see details below), and therefore serious development has stalled. These ventures are summarised below.

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\(^1\)My original MS-DOS version was in QuickBasic 4.5, and subsequently ported to PowerBasic 3.5. During 2002–2004 it was reimplemented for Linux.

\(^2\)Minimum Alveolar Concentration (MAC) of an anaesthetic agent is an index of anaesthetic potency. A typical anaesthetic is associated with approximately 1–1.2 MAC.
Collaboration with Leicester University—2001

During the academic year 2001–2002 I formed a collaboration with the Department of Electronic & Software Engineering, University of Leicester, UK, with a view to porting the existing program to the Linux operating system and making several enhancements, including a module for accessing existing patient data via the City Hospital Information System (HIS) (in conjunction with Andy Smith, Department of Information and Computing Technology, City Hospital). During this period four engineering students worked on parts of the program for their final year practical modules. Unfortunately however, the relatively short time allowed the students for their project was insufficient for a prototype to be developed, and the project terminated after one year.

Collaboration with Liverpool University — 2002

Significant interest in this project was shown by the Department of Clinical Engineering at the Royal Liverpool University Hospital. Unfortunately, however, a joint grant application (2004) to the EPSRC (Engineering and Physical Sciences Research Council) in conjunction with the Department of Clinical Engineering (RLUH) to fund research and development was not successful.

Collaboration with Nottingham Trent University — 2005

In December 2005 we explored a collaboration with Department of Computing and Informatics, Nottingham Trent University with a view to rewriting the software and implementing a more robust and scalable architecture. However, funding was unsuccessful.

Collaboration with Nottingham University Hospitals — 2008

In December 2008 we embarked (in conjunction with Professor Mahajan, Department of Anaesthesia) on a collaboration with the Department of Medical Physics at the Nottingham University Hospitals, City Hospital Campus, with a view to developing a stand-alone real-time MAC-monitor for use by anaesthetists. This project failed to progress owing to insufficient resources.

1.3 The Linux project

Towards the end of 2002 I formed an ‘open-source’ collaboration with Simon Dales (Software engineer, Oxford, UK). During 2003–2004 the original program was rewritten from scratch for the Linux operating system—the data acquisition and display module in C/C++ by SD, and the printing & processing modules in Perl, GNUplot and \LaTeX by RWDN.

The resulting working ‘stand-alone’ Linux prototype has been ‘up-and-running’ in the ‘thoracic’ operating theatre at the City Hospital, Nottingham since 2004, used by both consultant and trainee anaesthetists, and has been very successful (see illustrations at the end). The program gives a continuous trend display of a variety of measured and derived parameters, as well as ‘help’ and other general information, allows inputting of drug and other information, and automatically prints out the Anaesthesia Record at the end of the operation in a form suitable to be placed directly into the patient’s notes as a final record. In time we would like to incorporate a suitable database, develop
smart-alarm and decision-support software, extend the on-line help facility, and to explore connectivity with the hospital information system (HISS).

Support is ‘in-house’ by the Group members (see below). Electrical safety issues relating to the hardware are overseen by Ged Dean (Medical Physics, City Hospital); Linux support is by Adrian Nice (Department of Information and Computing Technology, City Hospital).

This project has been the subject of many lecture presentations over the last few years, and these are listed in the References.

**Group members**

The project team consists of the following members.

- **Richard WD Nickalls**, Consultant in Anaesthesia & Intensive Care, Department of Anaesthesia, Nottingham University Hospitals, City Hospital Campus, Nottingham, UK.
- **Simon Dales**, Software Engineer, PurrSoft, Oxford, UK.
- **Adrian K Nice**, Senior Systems Developer, Department of Information and Computing Technology, Nottingham University Hospitals, City Hospital Campus, Nottingham, UK.
- **Ged Dean**, Clinical Engineer, Department of Medical Physics, Nottingham University Hospitals, City Hospital Campus, Nottingham, UK.

1.4 Modules

The Anaesthesia Workstation project currently consists of four software components as follows (see screenshots at the end).

1.4.1 Printing/archiving module

This is written in the Perl language (Perl5) and coordinates data manipulation, graph plotting (using GNUplot), and typesetting (using \LaTeX 2e). An electronic form of the *Anaesthesia Record* and associated data and programs is made available for easy viewing via a HTML front-end.

A paper version of the *Anaesthesia Record* in a format suitable for placing directly into the patient notes generated and is printed in the operating theatre at the end of anaesthesia. This consists of (a) the graphic trends (a series of 1-hour graphic records of measured parameters), and (b) the data log and keyboard entries (events, procedures, drugs given, blood lost etc.).

1.4.2 Data acquisition and display module

This is written in C/C++ and uses the Qt library (standard with Linux systems). The program accesses serial data from the Datex AS/3 anaesthesia monitor and displays the data in trend and tabular formats on the screen. The operating theatre PC runs Mandriva-Linux on a Dell Pentium PC.
1.4.3 MAC display widget

A key invention/development by our group is the real-time MAC display widget (Figure 1.1), which is positioned in the lower right part of the main display screen (Figure 1.2). This widget displays the current MAC value, and implements an alerting colour change (to red) to warn the anaesthetists of an out of range value, and hence greatly facilitates the avoidance of inadvertent awareness of the patient under anaesthesia.

Figure 1.1: Example of the real-time age-corrected MAC-widget displayed by the anaesthesia workstation software (© Nickalls RWD and Dales S (1996–2009)) interfaced to the Datex S/5 monitor. If the corrected MAC is too low or too high (as shown in this case—total MAC 1.87) then, in addition to sounding an audible alarm, the dial of the MAC-widget turns red.

The development of this displayed real-time MAC data follows from our earlier work on developing charts facilitating the determination of age-corrected MAC for anaesthetists (Nickalls and Mapleson 2003). These charts are also included in a widely used anaesthesia handbook (Nickalls 2006).

Figure 1.2: Screenshot showing the MAC widget in a red-alert state. Note that the main display screen (pushed to the LHS) is designed so that all the important minute-to-minute data and alarm data is positioned on the RHS of the main display screen, and so allows the main display screen to be moved towards the left in order to view other data, files, or images as required. In this example a file is opened on the RHS of the PC screen.
1.4.4 Decision-support module

This is an HTML information system offering decision-support, information on relevant drugs, medical conditions, etc. for anaesthetists in the operating theatre. The emphasis is on an intuitive well structured menuing system to enable items to be found easily and quickly. We hope to include suitable commercially available HTML texts as they come available.

1.4.5 A diabetes alert module

This is a program (in Perl) which makes use of the Linux KAlarm utility. Tk widgets are used to present a menu which allows the user to quickly set special alerts to prompt regular monitoring of blood glucose. A ‘help’ system allows the user to access protocols for the insulin management of diabetic patients during major surgery.

1.4.6 A drug-menu module

This is a pull-down drug menu from which the anaesthetists can select a drugname for addition to the drug record. This database is the standard DM+D EU drug-list database (downloaded from the NHS DM+D website) which is updated weekly. The list currently consists of about 2500 drugs.

1.5 References


• Nickalls RWD (2008). *Linux goes to hospital*. Invited presentation to the Nottingham Linux Users Group, Nottingham, UK; September 18, 2008.


• Nickalls RWD (2005a). *Interfacing the PC to medical equipment*. Invited talk to the Nottingham & East Midlands Society of Anaesthesia (NEMSA) (Queen’s Medical Centre; April 8, 2005). [mini-symposium on Information Technology]

• Nickalls RWD (2005b). *Linux in the operating theatre*. Invited presentation to the Nottingham Linux Users Group, Nottingham, UK; March 16, 2005.
  Invited presentation to the Institute of Physics and Engineering in Medicine one-day conference on “The software medical device” (London; November 12, 2004).

• Nickalls RWD (2004b) Age corrected MAC.
  Invited talk to the Nottingham & East Midlands Society of Anaesthesia (NEMSA) (Queen’s Medical Centre; October 8, 2004). [mini-symposium on MAC, elderly patients and confusion]

• Nickalls RWD (2004c). An open-source anaesthesia workstation for the NHS.
  [Presentation to the Patient Safety Network meeting; IBIS Hotel, Birmingham, UK; April 27, 2004]

• Nickalls RWD and Dales S (2003). Camomile—an open-source anaesthesia record keeper and information system. [Presentation to the Society for Computing and Technology in Anaesthesia (SCATA). Manchester, UK; November 12-14, 2003]

  http://bja.oupjournals.org/cgi/reprint/91/2/170.pdf


• Nickalls RWD (1998b). \TeX{} in the operating theatre: an Anaesthesia application. [Invited presentation to the Annual UK \TeX{} Users Group meeting, Cambridge, UK. (September 21–22, 1998)]

• Nickalls RWD (1998c). \TeX{} in the operating theatre: an Anaesthesia application. TUGboat; 19, Proceedings of the 19th International \TeX{} Users Group Meeting; p 7–9. (Toruń, Poland, August 17–20, 1998)


3 A meeting concerned with the IEEE-1073 Standard regarding computer interfacing to Medical Devices.
1.6 Screen-shots

Figure 1.3: Program running in Theatre 1
Figure 1.4: Screen showing full width option for the lower half of the screen. Top half shows saturation (red), blood pressure (dark blue), ecg heart rate (green); oximeter heart rate (black), inspired oxygen (red), central venous pressure (pale blue)—current values are shown in top right window. Bottom half of the screen shows expired CO$_2$ (blue), inspired CO$_2$ (red), tidal volume TV (blue), respiratory rate (green), expired anes agent (sevoflurane, red) and age corrected MAC (blue).

Figure 1.5: Anaesthetic record — HTML front-end
Figure 1.6: Anaesthetic record — graphic record

Figure 1.7: Anaesthetic record — drug record
Figure 1.8: Screen showing the initial graphic front-end (right) which allows the user to either start the program, or access other utilities. For example, clicking on the `<epidural>` button runs the Epidural and Double-lumen tube database program (shown on the left of the screen) which predicts epidural depth and tube length for a given height and weight.

Figure 1.9: Screen showing the log, alarm, MAC and trend windows. The blood pressure (BP) is highlighted in yellow in the alarms window, indicating a minor departure from the ‘normal’ range.
Figure 1.10: Screen showing use of the Patient Data widget

Figure 1.11: Screen showing the Datex controller (bottom left of screen)
Figure 1.12: Screen showing a ‘help’ file viewed using the KDE web browser

Figure 1.13: Screen showing real-time data plus preview of printout
Figure 1.14: Screen showing help desk home page.

Figure 1.15: Help desk showing the drug info for Calcium.
Figure 1.16: Screen showing preview of the Anaesthetic Record about to be printed