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# How Turing and Wolf Influenced my Decision Support Systems

Bernard RICHARDS[1]
*School of Computer Science, University of Manchester, Manchester M13 9PL, UK*

**Abstract.** Decision Support Systems (DSS) have a vital role to play in today's scenario for Patient Care. They can embody a vast knowledge not normally found in one individual where diagnosis and treatment are involved. This paper highlights the training in minute details and precise mathematics needed in a successful DSS and indicates how such attention-to-detail was instilled into the writer as a result of working with Alan Turing and Emil Wolf who have both since achieved world-wide recognition in their own fields as a result of international publicity by the current writer. The article discusses four Decision Support Systems written by the present writer all of which have been shown to improve patient treatment and care, and which are of such complexity that, without their use, patient care would fall short of optimum. The Systems considered are those for Intensive Care Units, Cardiovascular Surgery, a Programmed Investigation Unit, and Diagnosis of Congenital Abnormalities. All these Systems have performed better than the human alternatives and have shown their value in the improvement of patient care.

**Keywords.** Decision Support Systems, Intensive Care Units, cardiovascular surgery

## Introduction

When I completed my University Honours Degree in Mathematics at Manchester University and was thinking of starting a research degree, it was suggested that I might approach Alan Turing to see if he had any suitable Projects for me. He was the Director of the new Computing Machine Laboratory at the University of Manchester. He welcomed me and indicated the Project. In 1952, Turing had published his, now famous, Paper on the Chemical Basis of Morphogenesis [1] in which he postulated an Equation to explain the growth of biological species. He solved his equation in two dimensions and then he asked me to solve it in three dimensions, which I did [2]. The computer which I was using was the Ferranti Mark I Computer, the world's first computer to be on sale. In those days there were no Operating Systems, no Windows Software, and no High-level Programming Languages. The programmer was responsible for every binary digit in the computer. That training, and the attention to every minute detail, served me well in my subsequent production of Expert Systems.

[1] Corresponding Author. Bernard Richards, PhD, Prof.; School of Computer Science, University of Manchester, Kilburn Building, Manchester M13 9PL, UK; Email: bernard.richards@manchester.ac.uk; Phone: + 44 161 306 3325

Alas Alan Turing died before my researches were completed, but I did demonstrate to the world that his Equation would predict growth in three dimensions. So then I sought for someone to supervise my PhD. I teamed-up with a physicist of Czech origin, one Emil Wolf. My Project was to accurately solve Maxwell’s Wave-equation for the diffraction of light passing through a convex lens. Others had made approximations, but I sought the complete mathematical solution with no approximations. The result was the publication of a Paper by Richards and Wolf [3] which was recently described by the President of the Optical Society of America at its Annual Conference as ‘the most important contribution to Optics in the last sixty years’. What the experience taught me was the need to stick rigorously to the equation, as I did later when using the Hendersen-Hasslebach Equation in my Cardiovascular Expert System.

## 1. Decision Support Systems

Decision Support Systems – often called ‘Expert Systems’ – are there to aid clinicians in making appropriate decisions when treating patients. Such systems must have taken account of evidenced-based Medicine and will generally embrace the collective decisions of the best available experts on each and every question put to the System. Four Systems are described below. In no case was the capacity or speed of the computer a limiting factor in its use.

## 2. The Intensive Care Unit

In 1969 Howard Bleich [4] produced a program to analyse the Blood Gas Laboratory results in the Intensive Care Unit. It would do the simple calculations and indicate anomalies, such as raised Acid-Base levels. Subsequently, that topic was progressed further by my Team in Manchester. Firstly, the analysis of blood Results was extended to all blood constituents, and, in a later version, was extended in Expert System Mode to indicate how a patient should be treated. This new Decision Support System [5] analysed the patient’s Blood Pressure, Heart Rate, and Central Venous Pressure, and indicated how abnormal values should be corrected, e.g. either by changing the setting on the ventilator or by drug-therapy. This Program was so successful that it was brought into use in the Hospital in Prague, and also in Wroclaw in Poland.

So how does the Program work? To cover the spectrum of patient conditions, the Central Venous Pressure is divided into three Ranges, viz CVP<5, 5<CVP,12, and CVP>12; the Heart-rate (HR)is divided into three ranges, viz HR,60, 60<HR<120, and HR>120, and the Mean Arterial Blod pressure (BP) is divided into five ranges, BP<55, 55<BP<70, 70<BP<100, 100<BP,130, and BP>130. The result is a 45-position cube within three-dimensional CVP/HR/BP space. The Program allows for, and often recommends, the insertion of a Pulmonary Artery Catheter. This latter would produce data on the Cardiac Index, the Pulmonary Artery Occlusion Pressure, and the Systemic Vascular Resistance., each of these latter four variables being divided into three ranges. A typical patient had the following parameter values:- HR=80, BP=75, CVP=22, The DSS gave the following advice:- (i) Give GTN at the rate of 3ml/hr, (ii) Observe the patient,(iii) Measure the parameters again in 15 minutes. In another patient, the parameter values were: HR=80, BP=60, and CVP=8. The advice was: “Give 250ml of Gelofusin over the next 20 minutes”.

This system used on all patients in the Unit: there were no medical conditions outside its scope. The System was in regular use from 1980 until 2006 when the Director of the Unit retired. It was welcomed by both junior and senior clinicians since, at night, the junior staff no longer had to telephone the Consultant for advice, but could seek the answer from the computer. Because of the wide variety of conditions found in the patients coming into the Intensive Care Unit, it was thought not to be possible, or appropriate, to devise and carry-out controlled trials. It was agreed that the value of the System had been demonstrated by its use.

## 3. Cardiovascular Surgery

A new DSS has been produced for this situation [6]. Cardiovascular Surgery covers operations on the external cardiac arteries and internally on the cardiac valves. These latter operations are often referred to as 'Open Heart Surgery'. In both cases, the patient's heart has to be stopped. The function of the heart – pumping oxygenated blood around the body – has to be replaced by an external 'Heart-Lung Machine' whose role is to oxygenate the blood and then pump it through the body. Computer-wise the operation has two Phases. Firstly the Heart-Lung Machine – the By-pass Pump – must be primed, and then, during the Operation itself the DSS must advise on the drugs to be given to the patient and on the settings on the Ventilator once the heart has been re-started. A typical Pump-priming message was the following:-

Current Serum Values;- PCV=36, PH=7.2, BE=-1, K = 3.6
Add the following to the Pump: 3ml of MGSO4,
42 ml of NAHCO3
29ml of 5% Dextrose
45ml of 15% KCL

Subsequently, the following message appeared after the heart was re-started:-
"Set the following flow rates on the Ventilator:-
Oxygen at 3L/min, N2O at 4L/min, CO2 at 42cc/min."
The patient went home very happy.

This Expert System was in use from 1977 until the Consultant Anaesthetist retired in 2006. It was also use, by was 9of a demonstration, on real patients in a neighbouring Hospital. It the former, its value was demonstrated many times by its accuracy and guidance. It a Trial, 50 cases, done previously, were matched by 50 cases done under computer-control. A statistically better result was obtained in the cases done under computer supervision.

## 4. Congenital Malformations

From time to time new babies are born with anomalies. At a post-partum check-up and again after several weeks of normal life, a parent might notice that the baby 'doesn't look quite right'. A Hospital Paediatrician well- versed in such things might be able to explain any underlying problems, but the Family Doctor who rarely sees such things might be stretched to make the correct diagnosis. So to help, a Decision Support System has been provided.

This DSS requests the doctor to input into the computer a decision as to normal/abnormal on 103 visible characteristics of the child, e.g. low-set ears, wide-set eyes, etc. No invasive procedures are needed, e.g. taking blood for Chromosome-testing. Then, based on the answers to those questions being stored in a matrix, the computer will produce a 'List of Likely Diagnoses', ranking them in decreasing order of probability. And so the Family doctor can reassure the anxious parent. This Program is a valuable tool in the hands of a non-expert clinician. For further information see [7].

The authors of this System, whilst noting that it had performed well on the many cases tested, recognised that it could be expanded and were keen to do that. The System was welcomed by Family Practitioners who saw few cases in any given years and hence saw it as a valuable diagnostic too, and by Junior Paediatricians who also saw it value as a Training Tool, but it was frowned upon by the Consultant who saw it as a threat to his authority and status. For that reason it was not released into wide-spread use.

## 5. A Programmed Investigation Unit

A situation exists whereby patients are brought into hospital for Investigation. A series of Tests and Investigations will need to be carried out. But many of the Tests will have side-effects which will interact with other Tests within a short period, eg 12 or 24 hours. This means, for example, that Test B cannot be done after Test A, but it can be done before Test A. With a range of over 180 different Tests the sequencing of the Tests had become a very demanding task for the PIU Sister. Because the Sister was the only person who could do that Sequencing Job, it was felt that the situation was vulnerable to breakdown. So an Expert System was provided. A Matrix was constructed and stored in the computer. It showed how soon one Test could be done after another Test. For example, a Lumber Puncture can be done immediately after a Red-Cell Survival Test, but staff must wait for 12 hours after a Lumber Puncture before doing a Red Cell Survival Test. Some Tests cannot be carried out on the same admission, for example an Intravenous Cholangiogram and a Cholecystogram. The full matrix, with its 180 Tests, contains 32,400 interactions, and this proved to be beyond human capabilities. As well as the clinical need for having the sequencing done correctly, a second advantage of the DSS was that patient-stay was minimised. This was an important factor when there was a constant demand for beds in the PIU. This DS is described in [8].

The value of this System was recognised when the number of Tests was increased to 180, as it was then beyond the capabilities of the Ward Sister. Also its values was recognised on those occasions when Sister was absent, as no other staff member had been able to use the Manual System, namely doing it in ones head. The System remained in use for many years and until a great change in the Structure and Organisation within the Hospital.

## 6. Conclusion,

All these systems have shown proven benefits in improving Patient Care

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