

# ► Design and implementation of an automatic message-routing system for low-cost telemedicine

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## Summary

Email has been used for some years as a low-cost telemedicine medium to provide support for developing countries. However, all operations have been relatively small scale and fairly labour intensive to administer. A scalable, automatic message-routing system was constructed which automates many of the tasks. During a four-month study period in 2002, 485 messages were processed automatically. There were 31 referrals from eight hospitals in three countries. These referrals were handled by 25 volunteer specialists from a panel of 42. Two system operators, located 10 time zones apart, managed the system. The median time from receipt of a new referral to its allocation to a specialist was 1.0 days (interquartile range 0.7–2.4). The median interval between allocation and first reply was 0.7 days (interquartile range 0.3–2.3). Automatic message handling solves many of the problems of manual email telemedicine systems and represents a potentially scalable way of doing low-cost telemedicine in the developing world.

## Introduction

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Email has been used for some years as a medium for telemedicine. For example, the UK military used email and digital camera pictures to obtain telemedicine advice from the UK about patients in Bosnia<sup>1</sup>. A number of non-military organizations have also operated email-based telemedicine systems, usually to provide support for health-care staff in developing countries. These include the Swinfen Charitable Trust (SCT) and Partners Telemedicine (PT) (Table 1). In the context of such work, email has the advantage of being cheap. This is important in developing countries where more sophisticated Internet services, for example those requiring Web access, are not yet affordable for health-care staff.

The telemedicine systems listed in Table 1 fulfil a similar purpose (providing expert medical advice to a requestor) yet they all differ in their approach. The original SCT system was conceptually the simplest, but suffered a number of disadvantages, which are discussed below. The PT system is a similar, manually administered system, but each email request is sent to two large hospitals and results in replies from multiple specialists. The TeleMedMail system produces a structured email message, but requires special software on the referring doctor's PC to do so. These approaches all have their advantages and disadvantages and it will be interesting to see how they perform in the years to come.

Despite their differences, all these systems have in common the use of email to obtain specialist advice. Running such a system is essentially a resource management problem: requests arrive from the client population and must be allocated to one or more experts for reply. The system administrator(s) must track the progress of the requests to ensure a satisfactory resolution. Individual experts must not be overloaded with requests—something that is especially important if they are volunteers. The basic jobs in running such a network are therefore:

- (1) *allocation* of new referrals to appropriate specialists for reply;
- (2) message *routing*, that is, making sure that a specialist's reply is sent to the correct referring doctor (note that there may be subsequent dialogue between the two, which must also be routed appropriately);
- (3) system *administration* or problem tracking, that is, taking appropriate follow-up action if a specialist does not reply to a referral within a reasonable length of time.

## SCT experience

The SCT operated its telemedicine network entirely manually for the first three years<sup>3</sup>. During that period, the number of hospitals serviced grew from one to 12<sup>4</sup>. However, this method of operation, while it served the aims of the SCT very well, is relatively labour intensive and, perhaps more important, is not scalable. Given the success of the SCT telemedicine work, it became clear that some degree of automation was required.

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**Table 1** Organizations using email to support developing countries

Organization	Date started telemedicine	Referring countries	Method of operation	Reference
Swinfen Charitable Trust	1999	Bangladesh, Nepal, Solomon Islands, Tristan da Cunha, Sierra Leone	Email message sent by referring doctor to system administrator; message forwarded to a single chosen specialist for reply; subsequent messages copied by the sender to the administrator to enable coordination	3-6
Canadian charity	c. 2000	Kosovo	Email correspondence	S Edworthy, personal communication
Boston (TeleMedMail)	c. 2001	Peru	Structured email message sent by referring doctor to Web server; answered by one or more specialists	H Fraser, personal communication
Partners Telemedicine, Boston, MA	2001	Cambodia	Email message sent to two hospitals, one in Cambodia and one in the US; replies from multiple specialists	2 and J Kvedar, personal communication

## Methods

An automated message-handling system was constructed. There are three main components:

- (1) *A mail store.* This contains copies of all messages received and all messages sent by the AutoRouter.
- (2) *The AutoRouter program itself.* This is responsible for decision making.
- (3) *A database.* This stores information about referring doctors, specialists and the current case-load.

The relationship between these components is shown in Fig 1.

## System users

There are three principal classes of system users (i.e. people from whom messages may be received):

- (1) referring doctors or hospitals (note that referrals may be generated by an individual, or by the institution in which the individual is working);
- (2) specialists (these are individuals who deal with queries from the referring doctors);
- (3) system operators.

In addition, the system may receive messages from people who are unknown to it.

## System operation

The system provides a single point of contact for all users. New referrals are received by the AutoRouter and allocated to specialists for reply, in an analogous way to the previous method of working used by the SCT. However, when specialists reply, they do so to the AutoRouter, which is responsible for routing the messages to the appropriate referring doctor (Fig 2). System operator(s) manage the system by email.

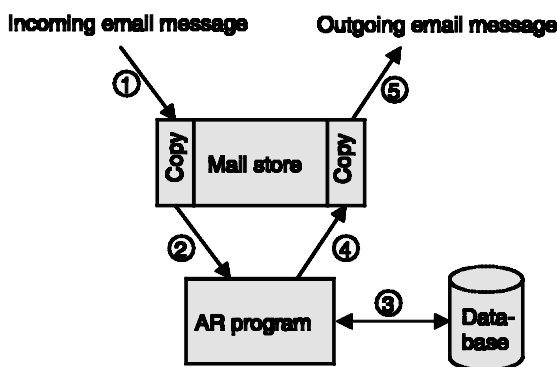
## Cases and queries

Each new patient referral received by the system represents a new *case*. Cases can exist in one of three states:

- (1) unallocated, that is, waiting for a decision about which specialist to send it to;
- (2) in progress;
- (3) closed, for example when the referring doctor has stated that the case has been dealt with to his/her satisfaction.

The decision to assign a new case to a particular specialist may be made either manually (by the systems operator) or automatically. Once that decision has been made, a new *query* is generated. Queries also exist in one of three states:

- (1) unanswered, that is, waiting for a first reply from the chosen specialist;



**Fig 1** AutoRouter system architecture. An incoming email message (1) is copied in the mail store before being passed to the AutoRouter (AR) (2). A decision is then made about how to handle the message using information in the database (3). The resulting message(s) are then copied in the mail store (4) before being transmitted (5).

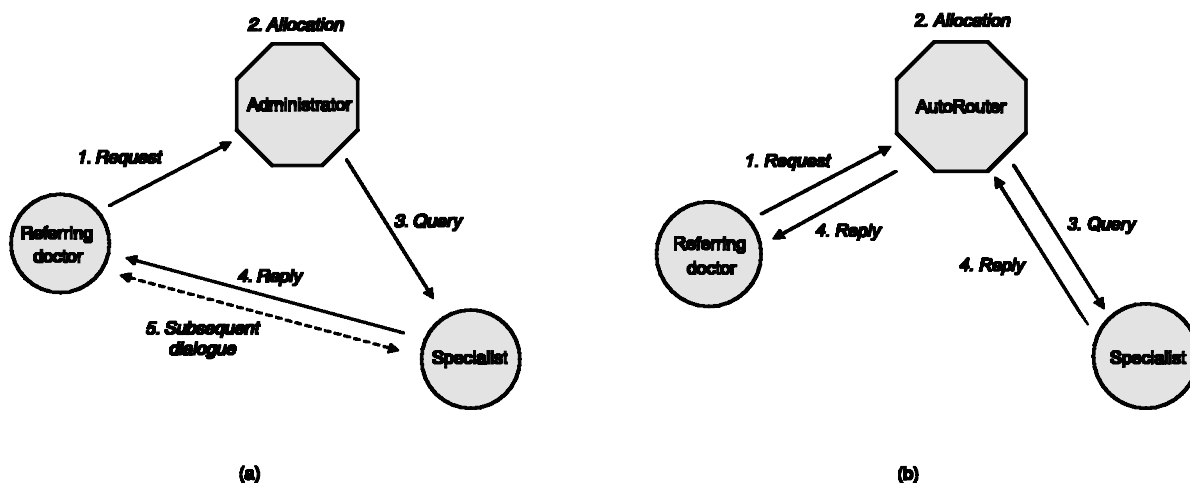


Fig 2 Message traffic. (a) Manual operation. (b) AutoRouter.

- (2) in progress, when at least one reply has been received from the specialist;
- (3) closed, for example when the query has been answered, or the specialist concerned has stated that the query is beyond his/her expertise.

Because a specialist who receives a query is not always able to answer it—and may therefore suggest that it be passed on to someone else—a given case may generate more than one query.

## Results

### Early experience — automatic case allocation

Automatic case allocation was tried early on; a few radiology cases were automatically allocated in early 2002. This is not especially difficult to do technically, but experience showed that:

- (1) making a decision about whom to send a case to does not represent a major workload for the system operator;
- (2) to mimic the complex decision making of the human operator involves a considerable programming effort.

Automatic case allocation has therefore been deferred for the time being.

### Semi-automatic operation

During a four-month study period in 2002, the AutoRouter processed a total of 485 incoming messages (Table 2). The majority were system operator messages (76%), a fact reflecting the development work being carried out on the system at that time, rather than the need for continual intervention in a largely automated operation.

The system dealt with 31 referrals from eight hospitals in three countries. These referrals were handled by 25 volunteer

Table 2 Message traffic: numbers of messages received during a four-month study period in 2002

Sender type	July	August	September	October
Referring doctor	6	9	9	17
Specialist	5	8	11	19
System operator <sup>a</sup>	68	54	127	122
Other	9	12	4	5
<i>Total</i>	<i>88</i>	<i>83</i>	<i>151</i>	<i>163</i>

<sup>a</sup>The high numbers of system operator messages reflect system development work, rather than routine operations.

Table 3 Statistics on cases/queries (July–October 2002, inclusive)

	Median	Lower quartile	Upper quartile
Interval from receipt to allocation (days) (n=30 cases <sup>a</sup> )	1.02	0.67	2.37
Interval between allocation and first reply (days) (n=34 queries <sup>a</sup> )	0.67	0.26	2.29
No. of messages per query (n=37 queries)	2	2	3

<sup>a</sup>Certain missing date/time information for one case and three queries.

specialists from a panel of 42. Two system operators, located 10 time zones apart, managed the system. The median time from receipt of a new referral to its allocation to a specialist was 1.0 days and the median interval between allocation and first reply was 0.7 days (Table 3). The 31 referrals resulted in a total of 37 queries, a mean of 1.2 queries per case. The number of messages generated by the AutoRouter during the same period was 1075; this total includes routine (daily) case-load reports sent to the system operators.

## Discussion

The AutoRouter has been in operation since early 2002. It has run almost uninterrupted, except for scheduled server maintenance, and availability has been almost 100%.

## Problems that the software was designed to solve

The AutoRouter was designed to solve a number of problems associated with manual email systems, many of which are problems inherent in asynchronous telemedicine, not specific to telemedicine in the developing world. The aims included:

- (1) providing a single point of contact for all users;
- (2) removing the need to maintain multiple lists of email addresses at all sites;
- (3) avoiding the need to install and maintain special software at the user sites (referrers or specialists);
- (4) allowing automatic tracking of cases and queries, for example to alert the system operators if a specialist did not reply within, say, two working days;
- (5) providing a system that could be operated by multiple system operators in different time zones, for example to speed up case allocation;
- (6) reducing the decision making and the procedural requirements at the user sites;
- (7) permitting the system operators to monitor all traffic.

Experience during 2002 suggests that these problems have been solved successfully.

## Problems that have not been solved

Experience during 2002 also suggests that a number of problems remain:

- (1) If the specialist in receipt of a query sends the referral on to another consultant without notifying the system operator, then it looks as though the query has been answered (because there has been message traffic about that case) when in fact it has not.
- (2) If the referrer sends the same case a second time (perhaps in the belief that the first message has gone astray) then it may be treated as a new referral and allocated for response, which is a waste of resources. This is not easily soluble without some way of uniquely identifying the case at the referrer's end and not all hospitals in developing countries maintain unique hospital numbers for their patients. The patient's name could be included in a new referral, but this is undesirable since the referrals are supposed to be anonymized.

In addition, as was pointed out by Lord Swinfen<sup>4</sup>, the Internet is not a perfect communications medium. Thus a message may be sent by the AutoRouter, but this does not guarantee that the intended recipient actually receives it.

## Conclusion

The AutoRouter is one of a number of ways that the problems of a manually operated email telemedicine system can be addressed. It represents a centralized system from the point of view of its users, but a distributed system from the point of view of its operators, who can be located anywhere in the world. Early experience of its operation with a small number of hospitals has been good. Two system operators, located 10 time zones apart, have run it successfully for nearly a year. The AutoRouter represents a potentially scalable way of doing low-cost telemedicine in the developing world.

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