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The middleware-based architectural approach for opening and evolving healthcare information systems

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Abstract

The integration of legacy systems represents one of the most urgent priorities of healthcare information systems in order to allow the whole information system to meet the evolving clinical organisational and managerial needs of the healthcare organisation. This paper discusses how the introduction of a middleware of common services providing functionalities addressing specific needs of the healthcare business domain reduces the effort necessary for allowing existing systems to interwork, and automatically establishes a functional and information basis common to the whole organisation, on top of which also new applications can be rapidly developed, natively integrated with the rest of the system.

An actual implementation of the architectural structure described in this paper has been developed during the EDITH/Italy project, carried out in 1992-1994 by a group of hospitals and industries with the contribution of the European Union under the Esprit programme. Through this initiative the DHE®[1] middleware and a set of applications already operational in the live environment has been developed.

This approach is also the basis of the HANSA project, presently running under the Telematics Application Programme, with the objective of installing and demonstrating the DHE middleware in approximately 20 hospitals from nine European countries, as a common platform for a migration strategy for evolving and opening existing systems.

The evolution need of Healthcare Information Systems

By nature, healthcare organisational structure in European countries is distributed, being a geographical spread of centres at different levels of complexity: from the general hospitals down to individual GPs. Also the structure of the individual healthcare centre, and particularly of the hospitals, is evolving from a vertical, aggregated organisation, towards the integration of a set of specialised departments, which are characterised by diverse logistic, organisational and clinical requirements and aspects. The ultimate objective of such a structure is to build a network of complementary centres (hospitals, laboratories, ambulatories, co-ordination centres, etc.) spread over the territory and capable of interworking to meet effectively the health and social needs in the area, and to provide seamless care.

As a consequence, preserving the individual specialities and autonomies, the various units must be able to interwork, with the aim of increasing the overall effectiveness of the activities carried out, in terms of prevention, caring and costs. Not only such evolution is required to improve the clinical treatments, but it is also pushed (even through the introduction of new laws) by the urgent necessity of all European countries of controlling and optimising the current level of the expenditure for health, nevertheless ensuring the necessary qualitative level of services to all patients.

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[1] Distributed Healthcare Environment

From the information technology point of view, such overall scenario is presently supported by a huge number of different, heterogeneous and mutually incompatible applications, which are already installed and operational in the individual centres, to support specific needs of particular groups of users.

Both at local and territorial level, therefore, the objective is to allow the evolution, integration and the consistent interworking of different (heterogeneous) applications, even if they have been developed in different moments, by different vendors and with different technologies. Only by solving this problem it will be possible to incrementally construct the healthcare information systems (both of the individual centres and of the whole healthcare organisations) as an open federation of autonomous but interworking systems, capable of meeting the following two objectives:

- to provide an optimised support to the specific needs of the individual centres and units (which are intrinsically different from the organisational, clinical and logistic viewpoints) by enabling different vendors to offer specialised applications and allowing the users to select the most effective solutions for their needs;
- to permit the different centres and units to co-operate on the basis of a substantial functional and information consistency, capable of ensuring that overall consistency of the healthcare organisation, which is necessary to increase the effectiveness and the reliability of the clinical, administrative, epidemiological and managerial activities carried out both at local and at territorial level.

It can be emphasised that the possibilities which are currently offered by the technology make the physical connection of different systems (relatively) easy, even if they are heterogeneous and running on different environments. However, such type of connection just relates to technical aspects and does not provide any contribution to the real inter-operability and inter-working of the systems from the point of view of application-oriented support to user needs.

The integration which is necessary is to make it possible by different systems to actually cooperate according to the overall requirements and workflow of the whole healthcare organisation, both at local and regional level. This implies each system be able to invoke complete processes offered by others and the possibility of interchanging common sets of clinical, organisational and managerial information, being understood, analysed and processed by the individual systems according to local needs, nevertheless ensuring the integrity of the overall scenario. In a word, they must fit into a consistent, comprehensive open and standard **architecture**.

All of that, by securing the investments already made, permitting the continuity of the service and facilitating a gradual evolution of the existing legacy systems towards new approach.

The role of the architecture

The American Heritage Dictionary defines the word architecture as *'Orderly arrangement of parts; structure'*. As a consequence, the goal of the information system architecture is to define a decomposition of the structure of the whole HCIS through a set of components, each of them to be clearly identifiable in the overall structure and described in terms of its objectives, scope and interactions with the rest of the system.

From the practical point of view, such decomposition has to simplify and to make various phases of the overall life-cycle of the information system more reliable and cost-effective, from planning, to the design, to the development and maintenance activities. In fact, once the characteristics of each component are defined in enough detail, it becomes possible to modify and even replace individual pieces of the system, without the need of changing other parts of the whole picture, as shown in figure 1.

Due to the diversity of the individual healthcare centres, also the architecture itself must comply with characteristics of openness and modularity, by allowing to optimise the functional and information characteristics of the individual components to the specific needs of each real scenario, nevertheless ensuring the stability of those fundamental aspects, which are necessary to ensure the compatibility and integrability of the individual modules.

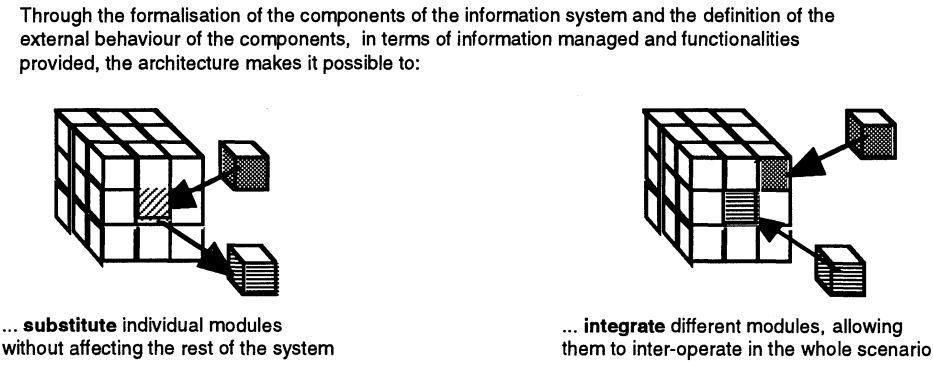

Figure 1. The architecture as an instrument for ensuring the modularity of the information system

Only in such a way it will be possible to allow each sector of the organisation to select the solutions most appropriate for its needs, while ensuring the functional and information consistency of the whole healthcare organisation.

Such considerations are not only valid for the implementation of new systems, but also for the evolution of existing systems, even if based on proprietary solutions. In fact, on the basis of the overall decomposition provided by the architecture, it will be possible to proceed incrementally, both by substituting parts of the existing system with new, more effective components, and by complementing the functions already available with new capabilities implemented with new modules, as indicated in figure 2.

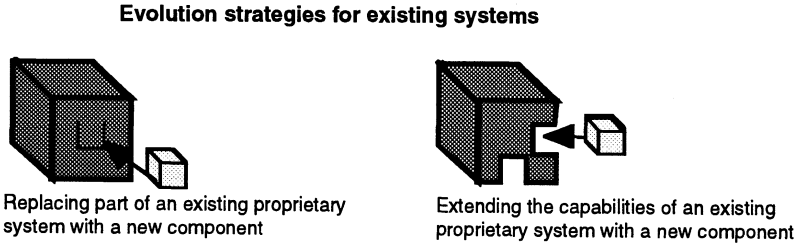

Figure 2. The architecture as an instrument to define the evolution strategy for existing systems

The middleware-based structure of the architecture

The objectives and requirements discussed in the previous paragraphs may be effectively satisfied and supported by structuring the architecture of the healthcare information system through three cooperative layers, individually responsible for addressing specific needs of the organisation, as shown in Figure 3:

APPLICATIONS	consisting of a set of components responsible for interacting with the users, providing a specialised support to the various activities carried out in the various sectors of the healthcare organisation.
MIDDLEWARE	consisting of a set of components[2] which support the applications with services relating to the peculiar activities of the healthcare business domain and which are relevant to information and procedures whose consistency and integrity is considered to be of paramount relevance for the correct functioning of the healthcare organisation as a whole.
TECHNOLOGICAL PLATFORM	providing facilities enabling the various modules of the information system to interact through common mechanisms, hiding the diverse technologies adopted for their implementation and the mutual location over the (distributed) environment.

This architectural structure has been also adopted by the CEN/TC251/PT013 'Standard healthcare information systems architecture', which has formalised the standard characteristics -in terms of information to be managed and services to be provided to the rest of the system- of the following six components of the middleware[3]:

Patient HCC	responsible for providing services for defining and managing personal, administrative and epidemiological data on the patients, with their cases and contacts
Activity HCC	responsible for providing services for defining and managing the life-cycle of the activities performed in the organisation, from the initial request, to the planning, execution and reporting.
Health datum HCC	responsible for providing services for defining and managing health data of the patients
Resource HCC	responsible for providing services for defining and managing the resources of the organisation
Authorisation HCC	responsible for providing services for defining and managing the specification of the users allowed to operate with the system and their authorisations with respect to the execution of the various processes and access to the data
Concepts HCC	responsible for providing services for defining and managing rules and properties involving multiple types of data.

It is worthwhile to emphasise how this approach (which is basically an evolution of the concept of the technological platform, identifying a level of 'application', business-specific

2 e.g. (but not necessarily) server

3 called 'Healthcare-specific Common Components' (HCC)

platform in the information system) satisfies the needs that have been discussed before, in fact:

- the functional and information consistency of the overall organisation is ensured through the presence of the middleware, which is actually responsible for dealing with those activities and information which exceed the level of responsibility of the individual units (or complete centres);
- the individual characteristics of the individual units may be satisfied by leaving users free to select the most appropriate applications capable of supporting their needs, and just requesting that such applications are federated on top of the middleware through its public, standard API's;
- the existing legacy systems may continue to be used and may be federated on top of the middleware, by invoking its services through the relevant (public, standard) API.

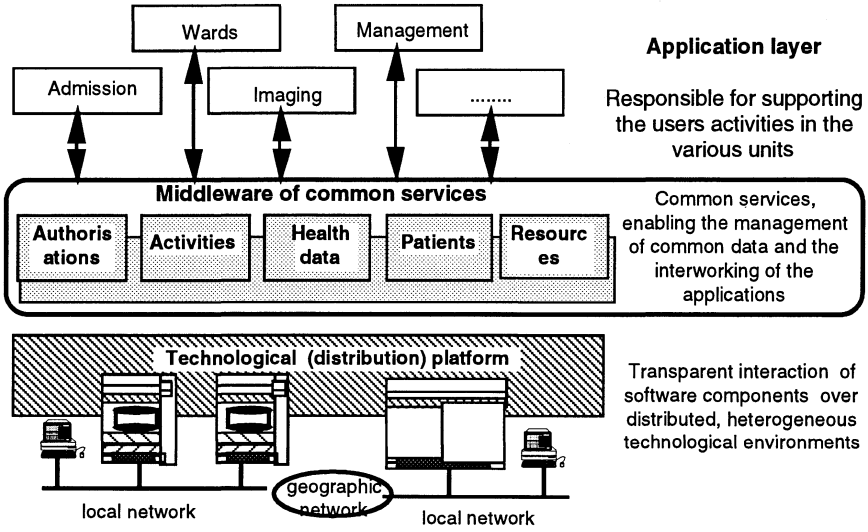

Figure 3. The 3-layers structure of the architecture of healthcare information systems

The integration of legacy systems through the middleware

Through its services for the definition and management of the information common to the whole organisation, the middleware represents both the key element for ensuring the openness and modularity of the information system, and an operational infrastructure suitable for the integration of legacy systems and for the development of new modules.

In fact, the existing systems can be connected to the middleware just by adding the calling to the middleware services in the appropriate sections, without the need of modifications neither in the functional aspects nor in the data organisation. As a result of such connection:

- the individual applications continue working as before, relying on their own data and functionalities;
- the direct connections between different applications can be eliminated, since the services of the middleware provide a set of common mechanisms (e.g. API) for accessing all information which are relevant to the whole organisation;
- a common information structure, suitable to support also the need of new applications, is created and automatically fed by the existing applications during the daily activities.

It is stressed that the level of flexibility and the openness provided by a middleware are completely different from those which can be obtainable through the sole implementation of a distributed database. In such a case, in fact, the criteria and the rules for manipulating the data are still built-in in the applications, which must also know the logical structure of the data, the distribution criteria and the rules to maintain the integrity of the information..

On the opposite, a middleware is a set of complete functions, individually capable both of embedding an internal logic and of encapsulating data elements. As a consequence, those functionalities which implement common business rules need not to be replicated in all application, with the consequence of making it easier and more reliable the maintenance and the integrity of the overall system. Furthermore, since the applications do not interact directly with the data storage(s) (e.g. the DBMS), but access and manipulate the data through the services of the middleware, also the physical configuration of the overall information system can be optimised and evolved during the time without the need of introducing modifications in the applications. As a consequence, different products (e.g. DBMS) can coexist, distributed environment can be (gradually) implemented and evolved, and even existing legacy modules of the information system -once encapsulated with proper services- can be used as components of the middleware, accessible from all other applications.

Finally, new applications can be developed without the need of implementing local databases, but natively using the services of the middleware for accessing and manipulating the totality of the relevant data, both those directly generated by them and those created by other applications of the system. Figure 4 shows the complete scenario, integrating both legacy systems and new applications.

This approach not only ensures the automatic integration of the new application in the overall system, but also permits to dramatically reduce the development time. With this respect, it is worthwhile to consider that -in any generic project- only one third of the total development time is -in average- devoted for the implementation of those functionalities supporting specific business activities of the addressed sector. More than two third of the total development time is spent for the implementation of those basic but fundamental functionalities necessary for the definition and management (i.e. enter, modify, delete) of the data. Through the adoption of a middleware, this cost can be dramatically reduced, by reducing it to the sole development of marginal extensions in the middleware, to permit the management of those data which are not already supported.

Finally, it can be considered that, in addition to the benefits for the individual users, this approach also has a significant effect on the market, not only for large organisations but also for small companies, which are those -in the European scenario- having the largest share of the market of the vertical applications, supporting specific healthcare activities.

In fact, it must be stressed that the major difficulty and cost in the installation of healthcare systems presently is the effort for their integration with the other applications already operational in the healthcare centre[4]. On the opposite the availability of a middleware, providing stable and standard interfaces[5] supporting not only the execution of generic technological interactions but also more complete activities[6], will permit to reduce the complexity of the installations which will be possible also without accessing and modifying the source code of the system. This represents a fundamental pre-requisite for the establishing of commercial networks of organisations, using, exchanging and distributing the mutual products in the various countries.

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4 by analysing the breakdown of the costs in the actual commercial contracts in almost all European countries, it can be noted that the cost for 'customisation and integration' in most cases is up to three times the cost of the license of the product !!!

5 defined not only conceptually, but also up to the level physical API, as it is the case of the technological platforms (e.g. TCP/IP) and the DBMS (e.g. the SQL language)

6 e.g. requesting exams, identifying patients, retrieving the healthcare record of the patient, etc.

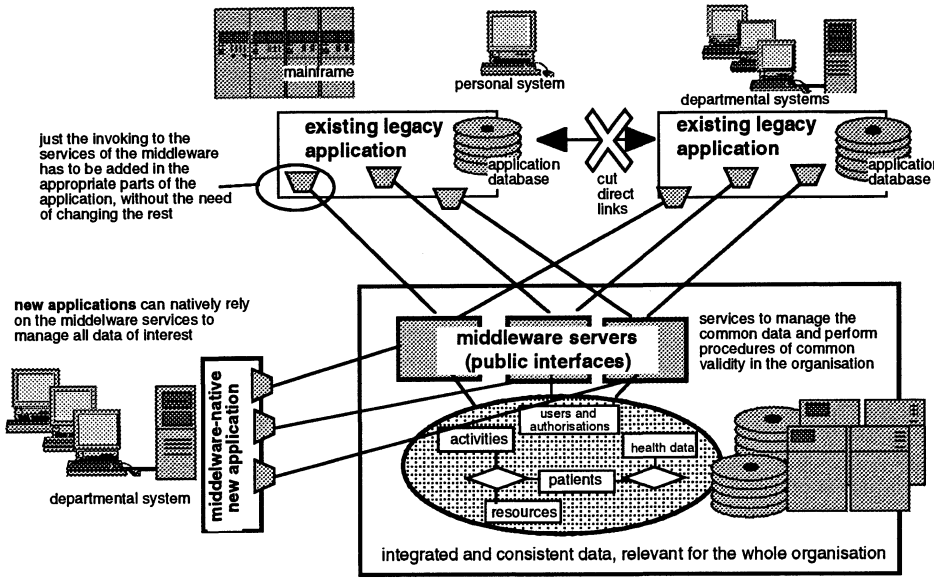

Figure 4. The complete scenario, integrating both legacy systems and applications on top of the middleware

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