pective' in the sense of oriental philosophy [4], and because of our experience in research supported by grants from the Research on Health Technology Assessment, Ministry of Health, Labor and Welfare, Japan from 2000 [5, 6].
To support plural ontologies in one system, we decided to utilize an ontological framework called CSX that we originally developed as a metamodeling environment [7]. Then we developed an experimental CIS based on the model of the clinical thinking process to capture clinical empirical knowledge. We also developed a node-focusing tool for abstracting a kind of partial graph of the clinical course being examined.

Methods and Designs

The Clinical Thinking Process Model

Model Outline

A clinical course model should have two aspects: the clinical course itself and the health care provider's thinking process at point-of-care. We had already developed the latter, as a *decision* process model, along with the problem-transition model known as a problem-oriented system (POS) or the problem-oriented medical record (POMR) [8]. Generally speaking, this model is an *intention* realizing process model; therefore, each *reason* in the thinking process and the *goals* of interventions are clearly delimited. One cycle of the thinking process in a clinical session (i.e., encounter) is illustrated in the following:

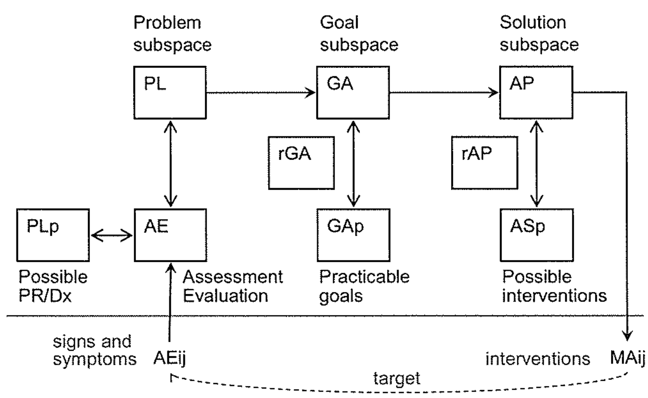

Figure 2 – The Clinical Thinking Process Model

The decision process is placed in three spaces: problem, goal and solution. Each space contains elements that represent an 'assorted step' in the thinking process. Each is a container that holds child objects (e.g., each problem or disease (PRi) in 'ProblemList' (PL), and each assessment and evaluation (AEi) in 'AssessmentEvaluation' (AE)). AEi may contain a physician's inference and/or reasoning for diagnoses, with referring atomic data of signs and symptoms. These are called S/O in SOAP in POMR. The 'Goal' (GA) is decided due to PRi or PL with reasons of each goal item (GAi), and those reasons are held in reason of GA (rGA). The action plan (AP) consists of some protocols and/or particles of interventions (ASi/MAi). They are adopted to gain GA with reasons held in reason in rAP.

Then, any clinical course is composed of a series of clinical sessions, where each phase connects to another with a screw structure or spiral binding through PL as an axis.

In this research, we carried out the implementation by focusing mainly on problem list and problem transitions, and on the problem-intervention relation.

Some requirements for a representation framework

The representation framework should have the capability (i) to represent the hypergraph structure and to support n-arity, (ii) to discriminate between 'semantic roles' and 'semantic relations', and (iii) to represent perspective for handling plural ontologies. At the same time, these are the reasons for adopting the ontological framework CSX.

Those three are coupled to each other in knowledge operation and system functions. A complicated semantic graph becomes more complicated because there are multiple interrelationships among nodes with plural perspectives of plural ontologies. Consequently, the usual semantic link does not work well when finding an appropriate path to a target node.

One has to take a notice of the degree or valence of the node, i.e., number of arcs of a node, with respect to data processing, because they may become too much tasking to control a 'path walk' in a knowledge graph. Simply stated, one needs a strategy to find out correct 'semantically grouped links' within an appropriate processing time. This is not clearly known as yet because, in some sense, each application module in CIS 'knows' all arcs and their target information objects. However, it is quite another story to find out the exact path to the target node from the starting node that has many arcs, and some arcs may belong to a different 'semantic group' i.e., 'semantic relation'.

For example, there are elements in AE or PL or 'signs and symptoms' referred to and 'semantic roles' of 'semantic relations' among them: [cardiac silhouette size in thorax] (reason) conclude (object) [cardiac hypertrophy], [decreased ejection fraction] (reason) [oliguria] (reason) conclude (object) [dysfunctional pump], [[cardiac hypertrophy], [dysfunctional pump]] (reason) define (object) [cardiac failure]. Here, [] is a node, () is an arc, and the underlined is the meaning or scope of the 'semantic relation'. In this sample, a relation represents predicate and an arc represents a 'semantic role' as a deep case that is required in each predicate.

Therefore, one solution is that the separation of 'semantic link' into 'semantic relation' and 'semantic role'. The ontological framework CSX provides this capacity.

The Ontological Framework CSX

The outline of this framework is as follows:

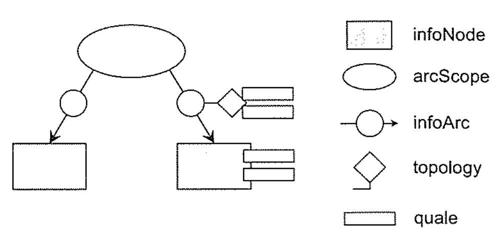

Figure 3 – The Ontological Framework CSX

O=<P, S, N, vr>, P{dm, sg}, S=<A..A, sg, id>, A=<N, N, T, sg>, N{C, Q, sg, id}(t), C{cs, ci, vr}, T{dr, cd, Q}, Q{dn, ms, ut, eq}, where O:ontology, P:perspective, dm:domain, sg:designation, id:identifier, S(arcScope):semantic relation that integrates A and represents the predicate or copula, A(infoArc):rhetorical role or semantic role in a semantic relation, N(infoNode):information object that represents 'thing' or 'event', C:code that identifies what a element is, T(topology):represents the topological relationship between N, Q(quale):represents quantity/quality, vr:version, t:timestamp, cs:code system that defines the combination of code/content /designation, ci:identifier in cs, dr:direction, cd:coordinate, dn:dimensionality, ms: measure, ut:unit, and eq:equivalence.

S, A and N have the attributes of category and family. Those two attributes hold the value that represents the position of meaning in the ontological category. Please refer to Figure 1 and the preliminary works [5, 9].

Here, ontology means 'a framework or methodology that manifests concepts/entities and relationships between/among them in the target world'; and, the representation of relationship is weighted in this research. On the other hand, building a vocabulary/concept repository is beyond the scope of this paper; thus, positively referring vocabularies are defined in terminologies, especially in C held in N.

Implementation Scope in This Paper

System Environment

To evaluate our approach, we implemented an experimental CIS with two edit/browse windows (Disease/Problem Transition and Clinical Chart) and four supporting entry tools (problem/diagnosis, prescription order, laboratory order, and operation and procedure). Edit/browse windows were designed to imitate Japanese unique regulated forms of No.1 and No.2 respectively. In this system, controlled vocabularies and identifiers in following code systems are used: ICD-10 based disease code system, JLAC10 (resembles LOINC) based laboratory code system, HOT based drug code system, and operation/procedure code system for reimbursement. The history of the clinical course is output as xml defined for CSX, which is used as an input file for the nodes-focusing tool.

Visualization of Clinical Course and Focusing

This tool is designed to facilitate the browsing of the whole image of a graph that illustrates a clinical course, then to abstract the nodes and arcs that are focused on according to the end user's purpose. With this tool, the model of a clinical course or empirical knowledge from a certain case might be clarified, although it has large numbers of encounters in a very long course; for example, only four essential PLs and its transition illustrated in Figure 4. Such a summary would be found through the trial and error process of comparing, masking and tracking.

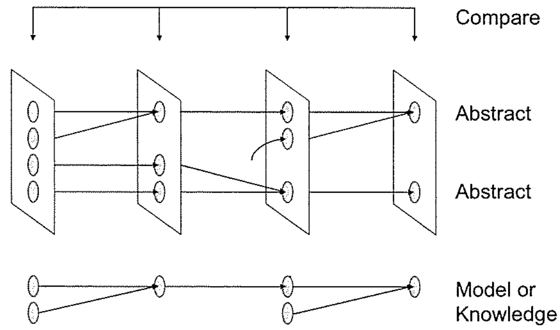

Figure 4 – Abstraction with nodes-focusing tool

Extracted data (or knowledge or pre-knowledge) is output as xml defined for CSX. The image of graph can also be output in JPG format.

Results

Disease/Problem Transition and Relevant Care Information

The Disease/Problem transition window has a maximum of three panes. One pane view is for a usual Dx/PRi list, and the three-pane view (Figure 5) is for editing and browsing disease/problem transitions. In the three panes, an end-user can control the pane linking which one is connected or unconnected. The latter provides end-users with the capability to look discretely at problem lists.

The kinds of semantic roles in each PRi is automatically determined due to a partial graph between the PRi in the former PL and PRi in the latter PL: proceeded, diverged, converged, promoted, demoted, and terminated in semantic role A in CSX and 'transition' or 'transmute' in a semantic relation S in CSX.

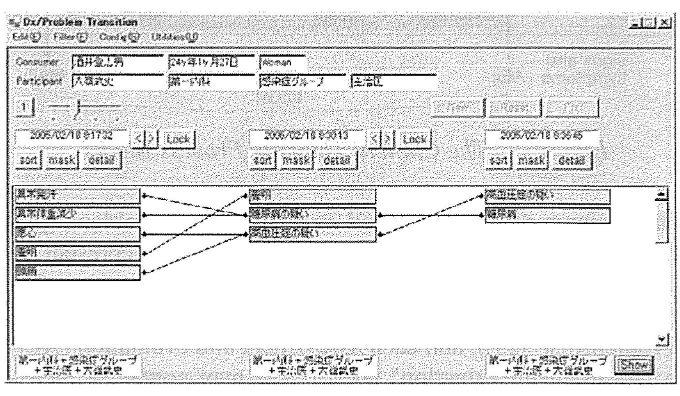

Figure 5 – Sample of the Disease/Problem transition window

Each PRi is selected in the problem/diagnosis entry tool by the end-user operation, often to be compiled with prefix and/or suffix. Then the PRi is inserted into the Disease/Problem transition window when the problem/diagnosis selecting operation is fixed. Therefore, the PRi node has three codes in C held in N: main, prefix and suffix.

Each problem (again, including diagnosis) has the attributes ofpriority, activity and 'Basso Continuo'. They are also editable in this window. 'Basso Continuo' means the problem with the attribute influences other problems and their course, including the available interventions for those problems.

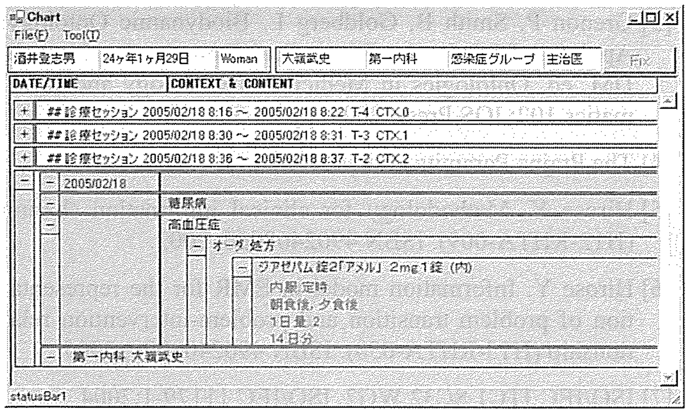

Figure 6 – Sample of the Chart window

In the Chart window, interventions are semantically linked to a problem, as a 'reason' or 'object' in a sense of deep case in A; a 'cure' or 'intervene' in a semantic relation S. Of course, one can list various patterns in such a relation; for example, a single problem holds many interventions, a group of problems is linked to a set of interventions, and different problems hold the same intervention. All of them are implemented in the system, and the latter one is realized as an *alias* in the GUI. The application runs appropriate responses.

Highlighting Significant Clinical Course

Figure 7 shows a sample of a bird's eye view of a clinical course in expressed in a graph.

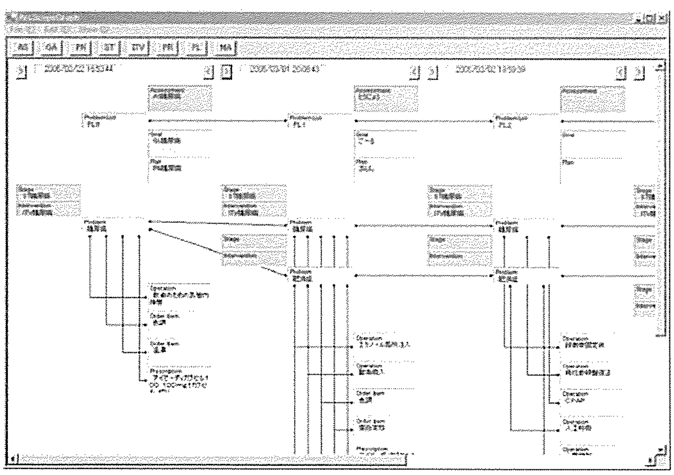

Figure 7 – Sample of a whole graph

The number of panes for each encounter is unlimited (or depends on the system environment). An end-user can control the pane linking in the same way as the Disease/Problem transition window.

It is worth noting that the path tracking function is available. An end-user selects a start node, then selects the 'path walk' policy, then clicks the extract button, and finally gets to the situation shown in Figure 8, for example.

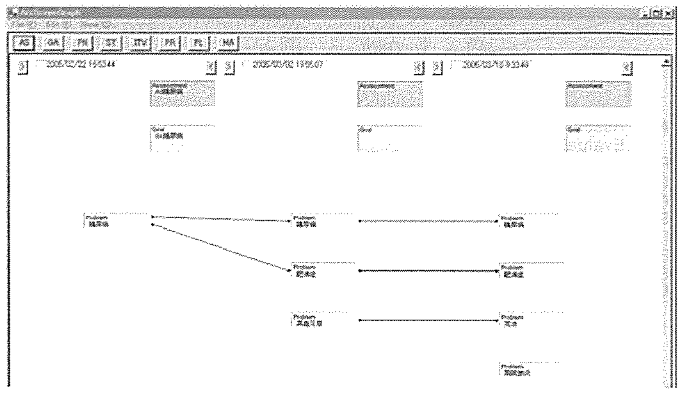

Figure 8 – Sample of a focused and abstracted

In this experimental implementation of the node-focusing tool, four kinds of tactics are independently available: start and end date, tracking direction (backward, forward, or both), code matching in problem (main code, whole codes, or any when linked), and selectable 'divergence walk' (track whole path, track if targeted on 'Basso Continuo', or no track).

Discussion

Visualization and Knowledge Acquisition

This tool provides the visualization capability of a clinical course by focusing nodes and arcs on the various purposes of end-users. As it is enabled to trace the focused nodes and arcs through the crowd, it is obviously useful for case review, clinical research, clinical education, the creation of a new clinical path or the consideration of the revision of it, and variance analysis for financial management in a hospital. Using the visual tracing function, inexperienced residents or medical students could refer to experienced doctors' successful processes, which contributes to appropriate decision-making and therefore better outcomes. Hence, we believe this tool will help health care providers in certain cases, especially for the compromised patient.

Such advantages follow the output from the POMR system, a file is in xml format defined for CSX, and data represent the clinical course according to the ontological framework CSX.

Some functions might be insufficient but others can be added to this tool.

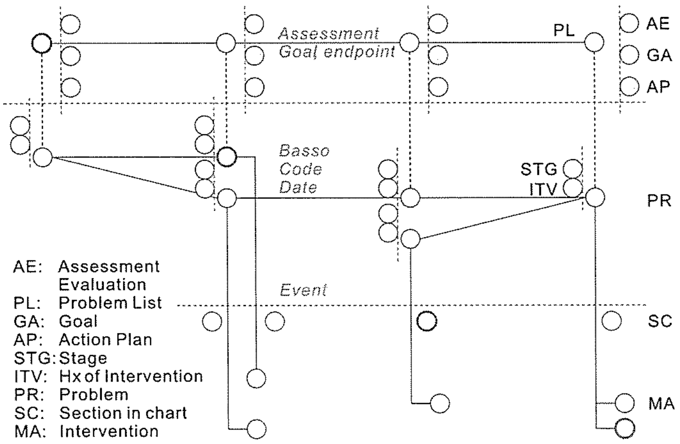

Figure 9 – Graph of clinical course data

In this framework, we used designations for entities and semantic relations that resemble or parallel ISO/CD TS 22789 in the implemented model, given the need for this experimental implementation.

Evaluation of the Experimental Implementation

Six domain experts (all were physicians and their subject was clinical trials) and a hundred of intern students showed great interest. When the authors showed medical students this tool, most immediately understood its idea. They also stated that they wanted to use this tool at clinical conferences, especially for complicated cases. Therefore, we believe that such an empirical knowledge acquisition tool is useful for clinical research and education.

Conclusion

We developed the experimental POMR based on the clinical thinking process model with the ontological representation framework CSX, which has the capability of handling plural ontologies, and the nodes-focusing tool for clinical course data in a hypergraph structure to capture and acquire or mine some portion of health care providers' empirical knowledge at point-of-care, including their intent. Then some domain experts and intern students showed great interest. Therefore, the authors concluded that such empirical knowledge acquisition environment is useful for research, education and so on.

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先ずは研究の機会を与えてくださった所轄省庁ほか各位に衷心より感謝申し上げます．また，分担研究者，研究協力者，委託業者の担当者および管理者各位，協賛協力会社の担当者および管理者各位，種々の仲介の労をお執り下さった方々，本研究の基盤となった過去の研究や事業などに御協力御支援を下さった方々，所属機関の長と担当事務官ならびに補佐員ほか一連の研究に関わる環境を与え御支援くださった方々には改めて篤く御礼申し上げます．
本研究ほか関連研究の成果が活用されて，本邦の市民と行政とに利することを願って已みません．
そのうえで本書を，我が妻子と母，今は亡き敬愛する父そして祖父母に捧げます．

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