The Web上の情報システム ： 局所情報の大局的統合

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The Web 上の情報システム
－局所情報の大局的統合－

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The Web 上で、一日に一国の国内総生産(GDP)に匹敵する金融取引が行われる e-business が盛んになるに至り、The Web 上の情報システムについての研究が重要性を増してきている。本報告では、The Web 上の sites の局所情報をネットワークグローバルに活用する「The Web 上の情報システム」の特徴を、セル空間理論により端的にモデル化できる事を示す。

1．はじめに

「The Web 上の情報システム」には、少なくとも二つほどの典型がある。The Web 上の情報は絶えずその sites における活動により変化しているから、The Web 上の情報空間上に何が存在するか全く分からないと言う状況が、一つの典型である。この場合は、「The Web 上の情報システム」構築は、Web 上の情報空間における要素情報の探索、その組み合わせの探査と組み合わせ情報空間の構築、この繰り返しで任意の複雑度の情報空間の構成と言うように、セル空間の帰納的構成により行われる。もう一つの典型は、e-business に見られる。ビジネスの実行主体が、ビジネスの対象である顧客、商品との共通部分を特定して、共通部分を中心に、顧客情報、商品情報の統合を行う場合がそれである。共通部分の情報の分離をセル分割で行い、セル接合により情報統合を行うものである。

2．セル空間構造

セル空間構造については、前報[1]で紹介した。例えば、我々の住む宇宙の空間構造については、Hawking と Penrose による、特異点理論(singularity theory)に準拠した空間時間理論等が知られている[2]。しかしこれは、より一般的なサイバー空間を構築する上では、直接有効ではない。より一般的な空間構造は、セル構造空間(cellular structured spaces)として知られており[3]、もっとも一般的なのは filtration spaces である。さらにそれが closure finite であり、かつ weak topology を満たす場合は、CW-spaces となる。もっと厳しい、diffeomorphic であるという条件を満たす場合は、多様体空間となる。Hawking と Penrose の空間時間理論は、この、極めて制約条件が厳しい場合のセル構造空間の一例になる。

３．セル空間構造

セル構造空間 *cellular structured spaces*、略して *cellular spaces* について、概略を説明する。まず セルは、トポロジー的に n 次元の開ボール $Int\,\mathcal{B}^n$ と同等なトポロジー空間 X であり、n-cell e^n と表記する。　X から、セル接合により、有限あるいは無限のセルの列 X^p を inductive に構成することが出来る。X^p は X の部分空間であるように構成し、 整数$\mathbb{Z}$で索引付ける。このようにして得られる$\{X^p \mid p \in \mathbb{Z}\}$ を *filtration* と呼ぶ。記法では、

X^p *covers* X (or, X^p is a *covering* of X),
すなわち
$X = \bigcup_{p \in \mathbb{Z}} X^p$,
X^{p-1} は X^p の部分集合
すなわち
$X^0 \subseteq X^1 \subseteq X^2 \subseteq \ldots \subseteq X^{p-1} \subseteq X^p \subseteq \ldots \subseteq X.$

このようにして X から得られるセル構造空間$\{X;\ X^p \mid p \in \mathbb{Z}\}$ を *filtration space* と呼ぶ。

４．セル接合によるセル空間構造構築

開 n-cell e^n を、すでに構築されたトポロジー空間 X に surjective かつ連続な写像 f により接合する事により、セル構造空間 Y を構築できる。言うまでもなく、写像 $f\colon X \to Y$ が surjective であるとは

$(\forall y \in Y)\ (\exists x \in X)\ [\ f(x) = y\ ]$

を意味する。 写像 $f\colon X \to Y$ が連続であるとは、
“a subset $A \subset Y$ is open in Y if and only if $\{f^{-1}(y) \mid y \in A\}$ is open in X”
を意味する。

$Y \sqcup_f X = Y \sqcup X / \sim$

は attaching space (an adjunction space, an adjoining space)とも呼ばれる。transitivity から、同値関係により、空間を *equivalence classes* の排他的和に分割できる。一つの equivalence class を $x / \sim$ と表記しよう。すると

$x / \sim\ = \{y \in X \mid x \sim y\}$

である。

すべての equivalence class の集合を $X / \sim$と表記すると、それは X の *quotient space* あるいは *identification space* とよばれ

$X / \sim\ = \{\ x / \sim\ \in 2^X \mid x \in X\} \subseteq 2^X$

である。

５．セル接合によるセル空間構造構築とその応用

空間構築のコンピュータ支援システムは一般にCAD(computer aided design)systemと呼ばれる。情報共有を実現するシステムは、これまでそれとは別のデータベース・システムとして独立に発展してきた。

思えば、空間が０次元空間から始めて、１次元、２次元と、inductive に任意の次元までセル接着により矛盾無く構築できることを示したのは、１９５０年に至るまでの J. H. C. Whitehead の研究功績であった[4]。これについては、Baues も１９９６年にその著書で紹介している[5]。この方法は，サイバー空間構築に於いて極めて有益である。

商用 CAD システムにおいては、もっとも進んだものはグラフ理論に Euler index を応用し、グラフ理論上の有効性は検証できる[6]。データベース・システム分野においては、直積による関係モデルが主流であるが[7]、意味論の記述の必要上 Entity-Relationship モデル[8]により擬似的にグラフをひょうげんし、グラフ理論による定式化はかなり遅れた[9]。しかし、グラフは、空間構造を、上記のようには明確に定義していない。従って、The Web 上の情報空間を厳密に取り扱うには十分でない。このような理由で、セル理論による「The Web 上の情報システムの研究を行い、一定の成果を見た。以下、文献[10]に基づき、その概要を英文で報告する。

6. Modeling cyberworlds

Cyberworlds are information worlds being formed on the web *either intentionally or spontaneously, with or without design*. Cyberworlds as information worlds are either *virtual* or *real*, and can be both. New worlds such as cyberworlds demand a theoretical ground to get them modeled properly. In terms of information modeling, the ground is far above the level of integrating spatial database models and temporal database models. We take invariants as the ground. Considering cyberworlds as a type of spaces that include time as an irreversible space, we show that an appropriate choice of invariants that consists of *dimensions* as *degrees of freedom* and their *connectivity* to tell how different dimensional spaces are connected.

Generally speaking, what we need to do to model cyberworlds consists of the following four steps.

First, we characterize cyberworlds to identify the differences from and commonality with the real world we live. The most distinct difference is in the speed of growth, and hence in the complexity. This means extreme concurrency linking *local* worlds into *global* web worlds and also speed close to that of light. Light speed on the web signifies the web power far beyond any great powers in human history [11]. Everybody working on the web in the world is a constructor and destructor of cyberworlds.

Secondly, we then find appropriate modeling methods to characterize the differences and commonality. Because of the extreme complexity and the speed of changes, the modeling methods need to be based on *a hierarchy of abstractions* to minimize the size of modeling, and also the hierarchy needs to be *an incrementally modular abstraction hierarchy of invariants* to identify the unchanging properties from the rapidly varying cyberworlds.

Third, we then turn the modeling methods into a design. It is a challenging task to realize such invariants-based modeling methods into one design. Generally, the design requires an appropriate choice of invariants, followed by a particular information structures and operations. For instance, an abstraction hierarchy of invariants is designed as an *inheritance hierarchy of invariants*. Still researches on this belong to open problems. So far, our researches have led us to a pair of invariants: *dimensions* as degrees of freedom and their *connectivity*. The information structures are *cellular spatial structures* and their operations such as *cell composition* and *cell decomposition* [12, 13].

Fourthly and finally, we implement the design as an information model named cellular model. The cellular model encompasses the capabilities of existing various data models, and also guarantees the continuity to preserve cell boundaries, cell dimensionality and cell connectivity. It is expected that the cellular model represents cyberworlds consistently and proves their validity. The ways the cellular model works include bottom up, top down, and middle to top and bottom approaches.

7. An abstraction hierarchy of invariants

We need to confirm the way we are looking at information modeling. Modeling stands for a key step in scientific research. Science, natural science in particular, has been built around the notion of invariants to model the real world we live. Science models objects by classifying objects and phenomena by *invariants*. In physics, energy and mass had been invariants until the relativity theory broke the boundary. In mathematics, modeling of mathematical objects is conducted to classify mathematical objects into *equivalence classes* as a disjoint union of the subsets of objects by an *equivalence relation* that represents a mathematical invariant. An example of an abstraction hierarchy of equivalence relations is:

1 Set theoretical equivalence relations;
2 Extension equivalence relations, homotopy equivalence relations as a special case;
3 Topological equivalence relations, graph theoretical equivalence relations as a special case;
4 Cellular spatial structure equivalence relations;
5 Information model equivalence relations;
6 View equivalence relations.

In terms of the abstraction of invariants hierarchically organized from general to specific to realize *modular and incremental design* and hence an *inheritance hierarchy of invariants* of cyberworlds, the following is a reasonable case of an abstraction hierarchy based on the abstraction hierarchy of equivalence relations in mathematics:

1 A set level;
2 An extension level, a homotopy level as a special case;
3 A topology level, a graph theoretical level as a special case;
4. A cellular structured space level;
5 An information model level;
6 A presentation level.

8. A cellular model

For cyberworlds modeling, “a cellular structured space level” based on *cellular spatial structures* [3, 4, 12, 13] such as CW-spaces gives a far more versatile basis than those based on a graph theoretical level that is common in conceptual- and data-modeling [8, 9], allowing an information model to specify objects in cognitive- and computational- spaces as cells with or without boundaries. Cells with boundaries are closed, and cells without boundaries are open. Here an *n*-dimensional cell, an *n-cell*, is a space topologically equivalent to an *n*-dimensional ball where *n* is an integer $\mathbb{Z}$, namely $n \in \mathbb{Z}$. We denote an open *n*-cell e^n and a closed *n*-cell $\mathcal{B}^n$. An *interior* of $\mathcal{B}^n$ is denoted as $Int\, \mathcal{B}^n = \overset{\circ}{\mathrm{B}}{}^n$, and

$$\partial\mathcal{B}^n = \mathcal{B}^n - \overset{\circ}{\mathrm{B}}{}^n = S^{n-1}$$

is the *boundary* of $\mathcal{B}^n$, and it is an (*n-1*)-dimensional *sphere* S^{n-1}. Cellular modeling allows *cell composition* and *decomposition* while maintaining cell dimensions and connectivity as invariants; object identification is carried out systematically through an *identification mapping* (often called a *quotient mapping*) [12]. Here, *dimensions* mean the *degrees of freedom*. Later we show that database schema composition (also called schema integration) and schema decomposition (also called schema disintegration) are special cases of cell composition and cell decomposition.

Let look at examples of *dimensions*. For instance, in cyberworlds an object with one attribute has no degree of freedom to go from one attribute to another and hence the dimension of an attribute is *0*, and we present it as a point at a presentation level. *Attributes* are mutually independent sets to specify qualities or characteristics inherent to objects. Given an object with two attributes, we can go from one attribute to another in a direction and hence the degree of freedom and the dimension is *1*; we can present this case as a line. Likewise, objects with three and four attributes have two and three degrees of freedom (dimensions) are *2* and *3*, and can present them as a surface and a ball. An object with *n* attributes has *n-1* degrees of freedom, and hence its dimension is *n-1*; we can present it as an (*n-1*)-dimensional ball. The relational model presents an object with n attributes as a relational schema and instantiates it as a table with *n* columns [7]. The relational model is based on Cartesian products of sets, and hence it is a presentation, theoretically at a set theoretical level.

The *connectivity* is defined by a continuous and surjective mapping called an *attaching map* (an *adjunction map*, an *adjoining map* or a *gluing map*). "A map $f: X \rightarrow Y$ is *surjective*" means $(\forall y \in Y)\ (\exists x \in X)\ [\ f(x) = y\ ]$. "A map $f: X \rightarrow Y$ is *continuous*" means "a subset $A \subset Y$ is open in Y if and only if $\{f^{-1}(y) \mid y \in A\}$ is open in X".

Given two disjoint topological spaces X and Y,

$$Y \sqcup_f X = Y \sqcup X / \sim$$

is an attaching space (an adjunction space, or an adjoining space) obtained by *attaching* (*gluing*, *adjuncting*, or *adjoining*) X to Y by an *attaching map* (*adjunction map*, or an *adjoining map*) f (or by identifying points $x \in X_0 \mid X_0 \subset X$ with their images $f(x) \in Y$, namely by a surjective map f)

$$f: \quad X_0 \rightarrow Y.$$

$\sqcup$ denotes a disjoint union and often a + symbol is used instead (sometimes it is called an "exclusive or"). $\sim$ is an equivalence relation. An *equivalence relation* is simply a relation that is reflexive, symmetric and transitive. It can be a set theoretical equivalence relation, a topological equivalence relation, a geometrical equivalence relation or a homotopic equivalence relation. The transitivity divides the space naturally into a disjoint union of subspaces called *equivalence classes*.

Let us look into equivalence relations and equivalence relations here a little bit in more detail as a foundation to model cyberworlds clearly. For a binary relation $R \subseteq X \times X$ on a set X, R is:

reflexive if $(\forall x \in X)\ [xRx]$: *reflexivity*;

symmetric if $(\forall x, y \in X)\ [xRy \Rightarrow yRx]$:*symmetry*;

transitive if $(\forall x, y, z \in X)\ [[xRy \Rightarrow yRz] \Rightarrow xRz]$:*transitivity*.

R is called an *equivalence relation* (in a notation $\sim$) if R is reflexive, symmetric and transitive.

A subset of X defined by $x / \sim\, = \{y \in X: x \sim y\}$ is called the *equivalence class* of x. Here a class actually means a set; it is a tradition, and hard to be changed at this stage. The set of all the equivalence classes $X/\sim$ is called the *quotient space* or the *identification space* of X.

$$X / \sim\, = \{x / \sim\, \in 2^X \mid x \in X\} \subseteq 2^X.$$

From the transitivity, for each $x \in X$, $x /\sim\, \neq \phi$, the followings hold:

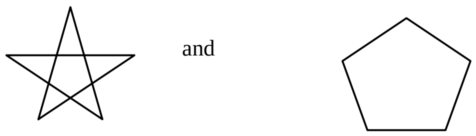
$$x \sim y \Leftrightarrow x /\sim\, = y /\sim, \text{ and}$$

$$x \nsim y \Leftrightarrow x /\sim\, \cap\, y /\sim\, = \phi.$$

This means a set X is *partitioned* (also called *decomposed*) into non-empty and *disjoint* equivalence classes. If we denote an equivalence class by $x / \sim$, it is, then,

$$x / \sim\, = \{y \in X \mid x \sim y\}.$$

Let us look at simple examples. *Cardinality* is a case of set theoretical equivalence relations, and divides sets into a disjoint union of the sets of the same cardinality. In graph theory, *isomorphism* is an equivalence relation, and divides a set of graphs into a disjoint union of *isomorphic* graphs. Popular isomorphic graphs are:



In Euclidean geometry, given a set of figures, a *congruence relation* divides them into a disjoint union of the subsets of congruent figures as a quotient space; a *similarity* relation divides them into a disjoint union of the subsets of similar figures as a quotient space. Congruence and similarity relations are cases of affine transformations. A *symmetry* relation in group theory divides a set of figures into a disjoint union of the subsets of symmetric figures as a quotient space. In finite state automata, an *accepted language* defined as the set of all strings accepted by automata serves as an equivalence relation and divides the automata into a disjoint union of equivalent automata.

We have already seen a case of an attaching map already. Now, let us state a general definition of an attaching map here. The set of all equivalence classes is denoted as $X / \sim$, and is called the *quotient space* or the *identification space* of X

$$X / \sim\, = \{\ x / \sim\, \in 2^X \mid x \in X\} \subseteq 2^X.$$

An *attaching map* f is a surjective (onto) and continuous map

$$f: \quad X_0 \rightarrow Y,$$

where $X_0 \subset X$.

$X \sqcup Y / \sim$ is a quotient space, and

$$X \sqcup Y / \sim\, = X \sqcup Y / (x \sim f(x) \mid \forall\, x \in X_0) = X \sqcup_f Y.$$

Here is a special case for later use for information schema integration and information integration by information mining on the web. Let S^{n-1} be the boundary of a closed *n*-cell $\mathcal{B}^n$, namely $\partial\mathcal{B}^n$. That is,

$$S^{n-1} = \partial\, \mathcal{B}^n = \mathcal{B}^n - Int\, \mathcal{B}^n = \mathcal{B}^n - e^n.$$

Let an attaching map f be a surjective (onto) and continuous map

$$f: S^{n-1} \quad \rightarrow \quad X.$$

An adjunction space Y is defined as a quotient space

$$Y = X \sqcup_f \mathcal{B}^n = X \sqcup \mathcal{B}^n / \{f(u) \sim u \mid u \in S^{n-1}\}.$$

Given two homotopic maps f and g

$$f, g: S^{n-1} \rightarrow X,$$

then $X \sqcup_f \mathcal{B}^n$ and $X \sqcup_g \mathcal{B}^n$ have the same *homotopy type* (or, are *homotopically equivalent*)

$$X \sqcup_f \mathcal{B}^n \simeq X \sqcup_g \mathcal{B}^n.$$

Given a cyberworld X as a topological space, from X, we can *inductively* compose, according to J. H. C. Whitehead [4], a finite or infinite sequence of cells X^p that are subspaces of X, indexed by integer $\mathbb{Z}$, namely $\{ X^p \mid X^p \subseteq X, p \in \mathbb{Z}\}$ called a *filtration*, such that

X^p covers X (or X^p is a *covering* of X), namely,

$$X = \bigcup_{p \in \mathbb{Z}} X^p,$$

and X^{p-1} is a subspace of X^p, namely,

$$X^0 \subseteq X^1 \subseteq X^2 \subseteq \ldots \subseteq X^{p-1} \subseteq X^p \subseteq \ldots \subseteq X.$$

(this is called a *skeleton*). The skeleton with a dimension at most p is called a *p*-skeleton. $X^0, X^1, X^2, \ldots, X^{p-1}$, and X^p are sub-cyberworlds of a given cyberworld X. A space topologically equivalent to a filtration is called a *filtration space*.

There are important cellular spaces in applications. They include CW-complexes and manifolds. If a filtration space is finite, it is equivalent to a *CW-space*. Further, if a CW-space is diffeomorphic, it is equivalent to a *manifold space*.

9. Web information modeling, inductive web-information schema integration, and web-information integration via information mining based on a cellular model

The first thing we have to do in web information modeling is the characterization of the nature of the formation of cyberworld as shared information worlds on the web to see how the cyberworlds are emerging and what they are. It is often the case that a cyberworld X is created on the web as a result of varieties of local activities at many web sites. Unlike corporate information, we usually cannot assume that there is an information administrator to give us the initial set of schemas. Through *information mining*, we can dig up particular information at local web sites to reveal what X is. Of course, we do no conduct information mining arbitrarily. After information browsing at web sites, we gather idea on what to be mined and what are expected to emerge from the information at scattered sites on the web by integrating them. This is a type of information mining to be called generally "*information mining by design*" because there is a certain set of rules to apply as *integration guides* regarding what to mine and what not to mine. Such *integration guides* work as *design guides* of what to be integrated and how.

Information mining on the web works perfectly to integrate local web worlds to a global cyberworld, based on the *Whitehead inductive scheme* stated above. To illustrate more concretely how the *inductive integration* goes to obtain an *n*-dimensional cyberworld X^n, we explain web search and integration processes.

The *inductive integration* consists of two phases: the information schema integration phase and the information integration phase. The first phase, the *information schema integration* phase, proceeds as follows:

1. Retrieve every attribute $\mathcal{B}^0_i$ of interest at web sites to create a *0*-dimensional cyberworld X^0 such that
   $$X^0 = \{ e^0_1, e^0_2, e^0_3, \ldots, e^0_j \}.$$
2. Retrieve every combination of two attributes of *interest* $\mathcal{B}^1_i$ at web sites to create a *1*-dimensional cyberworld X^1 such that and we attach their disjoint union
   $$\sqcup_i \mathcal{B}^1{}_i = \mathcal{B}^1{}_1 \sqcup \mathcal{B}^1{}_2 \sqcup \mathcal{B}^1{}_3 \sqcup \ldots \sqcup \mathcal{B}^1{}_k$$
   to X^0 via an attaching map F by identifying each boundary element (in this case an attribute of $\mathcal{B}^1{}_i$) $x \in \partial\mathcal{B}^1{}_i$ of a *1*-cell $\mathcal{B}^1{}_i$ with an attribute in F(x). Then, we obtain a valid *1*-dimensional cyberworld X^1 such that
   $$X^1 = X^0 \sqcup_F (\sqcup_i \mathcal{B}^1{}_i) = X^0 \sqcup (\sqcup_i e^1{}_i)$$
   where $i = 1, \ldots, k$, and an attaching map F is
   $$F: \sqcup_i \partial\mathcal{B}^1{}_i \rightarrow X^0.$$
3. Suppose, after repeated retrievals and integrations, we have dug up an (*n-1*)-dimensional cyberworld X^{n-1} through information mining. X^{n-1} has *n* attributes. To integrate an *n*-dimensional cyberworld X^n that has *n+1* attributes, we retrieve every combination of *n+1* attributes of interest $\mathcal{B}^n{}_i$ as before at web sites. Then we attach their disjoint union
   $$\sqcup_i \mathcal{B}^n{}_i = \mathcal{B}^n{}_1 \sqcup \mathcal{B}^n{}_2 \sqcup \mathcal{B}^n{}_3 \sqcup \ldots \sqcup \mathcal{B}^n{}_m$$
   to the already build (*n-1*)-dimensional cyberworld X^{n-1} via an attaching map G by *identifying* each boundary element (n attributes out of *n+1* attributes of $\mathcal{B}^n{}_i$) $x \in \partial\mathcal{B}^n{}_i$ of an *n*-cell $\mathcal{B}^n{}_i$ with *n* attributes in G(x). Then, we obtain a valid *n*-dimensional cyberworld X^n such that
   $$X^n = X^{n-1} \sqcup_G (\sqcup_i \mathcal{B}^n{}_i) = X^{n-1} \sqcup (\sqcup_i e^n{}_i)$$
   where $i = 1, \ldots, k$, and an attaching map G is
   $$G: \sqcup_i \partial\mathcal{B}^n{}_i \rightarrow X^{n-1}.$$

This completes the information schema integration.

The second phase, the *information integration* phase, is fairly simple but computationally intensive. It proceeds in checking every instance at each step of cell attachment during the schema integration to judge and decide, based on the design guides, whether the instance should be included in the cyberworld being created by cell attachment.

The cyberworld we construct based on the *Whitehead inductive scheme* guarantees the following relation to hold:

$$X^0 \subseteq X^1 \subseteq X^2 \subseteq \ldots \subseteq X^{n-1} \subseteq X^n \subseteq \ldots \subseteq X.$$

From a cyberworld validation point of view, this means given a validated cyberworld, any cyberworlds having the lower dimensions are included in the given cyberworld and valid.

In the above, *identification* is by equivalence classes based on equivalence relations. Clearly "*identification by equivalence classes*" is a *generalization of a join operation* in the relational model [7]. Hence one of the real powers of a cellular model is seen on this aspect. Having highly complex and fast changing cyberworlds on the web, the integration power of cellular model provides web information model with a true theoretical foundation. Also when we said "attributes of interest" to exercise the design guides, "*interest*" means, at least partially, the *choice of equivalence relations for identification*. So "*the choice of equivalence relations for identification*" is the major part of *design guides*. For web-based information systems, *design guides* are either local to govern local sites as intranets (also as community nets) or global to work in borderless cyberworlds. Design guides are *reusable resources* of web-based information systems.

10. A situation modeling of web information as non-inductive information schema integration and information integration based on a cellular model

On the web, usually we encounter with situations where we need to create new cyberworlds from given cyberworlds. This situation is more common in e-business including e-commerce on the web than the previous situation that carries out information mining through induction. Let us look at e-commerce situations to *model web situations* that vary in space and time. There are general needs to find out commercial trading structures on the web in terms of information schemas to build an e-commerce information system. Typical e-commerce situations include:

> Situation 1. An e-customer wishing to buy an e-merchandise browses the web to find an e-shop that offers the best price;
>
> Situation 2. An e-shop selling e-merchandises browses e-customer lists to expand the sales.

On the web, in the above situations, we are not interested in finding out the precise information of an e-shop, an e-customer and an e-merchandise. Let an e-shop, an e-customer and an e-merchandise be *s*-, *c*- and *m*- dimensional cyberworlds and are hence an *s*-cell e^s, a *c*-cell e^c and an *m*-cell e^m.

In Situation 1, an e-customer identifies the merchandise name of an e-shop with that of interest of the e-customer when the e-merchandise has the best price at the e-shop. This situation is characterized by cell decomposition operations followed by identification operations. A *cell decomposition operation* is a map f that maps a given *n*-dimensional cell e^n to a disjoint union of two cells $e^u \sqcup_g e^v$ ($u, v \leq n$) such that the attaching map g is preserved

$$f: \mathcal{B}^n \rightarrow \mathcal{B}^u \sqcup_g \mathcal{B}^v = e^n \rightarrow e^u \sqcup e^v.$$

As we explain later, attaching map preservation at each cell decomposition is to make cell decomposition homotopic. What we do now in this Situation 1 is to come out with a *situation model* of the Situation 1 as follows:

1. Cell decomposition: Decompose an *s*-cell e^s as an e-shop, a *c*-cell e^c as an e-customer and an *m*-cell e^m as an e-merchandise such that we separate an equivalent cell e^q from the rests to identify e-commerce trading related attributes: a merchandise name, a merchandise identifier and merchandise price, for example, to turn e^q into e^2.
2. Cell composition via cell attachment: To a *c*-cell e^c as an e-customer, attach an *m*-cell e^m as an e-merchandise and an *s*-cell e^s as an e-shop, via attaching maps by identifying equivalent cells e^q.

Situation 2 is modeled similarly as a situation model as follows:

1. Cell decomposition: This is similar to that of Situation 1.
2. Cell composition via cell attachment: To an *s*-cell e^s as an e-shop, attach *m*-cells $\{e^m{}_i\}$ as e-merchandises and *c*-cells $\{e^c{}_i\}$ as e-customers, via attaching maps by identifying equivalent cells e^q.

11. A homotopy theoretical framework of a cellular model for spatial/temporal information and spatial/temporal operations

Standing at the gate of the next millennium, it is truly fortunate to live at this critical moment to be able to influence the real world we live in a fundamental way. Establishing the science of the web and cyberworlds that are expected play the major roles in the next millennium will eventually be the most important to build the web-based information technology. Information models for the web and cyberworlds are key elements in that context because cyberworlds are information worlds.

It is also fortunate that we have necessary mathematical frameworks to create the science we are talking about as cellular spatial structures, and also homotopy theory that we sketch below.

Homotopy theory serves as the foundation of cellular spatial structures in the sense that we rely on it when we deal with cyberworld change in space and time [12] to accommodate spatio-temporal information and spatio-temporal operations. Let us consider the changes of a mapping function f relating a topological space X to another topological space Y. After the change, f becomes another mapping function g. In short, we are designing the continuous deformation of f into g where

$$f, g: X \rightarrow Y.$$

We consider the deformation during the normalized interval I = [0, 1] that can be a time interval or a space interval. Let us denote the unchanging part A of the topological space X as a subspace $A \subset X$. Then, what we are designing is a *homotopy* H, where

$$H: X \times I \rightarrow Y$$

such that

$$(\forall x \in X)\ (H(x, 0) = f(x) \text{ and } H(x, 1) = g(x)), \text{ and}$$

$$(\forall a \in A, \forall t \in I)\ (H(a, t) = f(a) = g(a)).$$

f is said *homotopic* to g *relative to* A, and denoted as

$$f \simeq g \text{ (rel A)}.$$

Now here is a new design problem. That is, how we can design two topological spaces X and Y to be *homotopically equivalent* $X \simeq Y$, namely *of the same homotopy type*. It is done by designing

$$f: X \rightarrow Y \text{ and } h: Y \rightarrow X$$

such that

$$h \circ f \simeq 1_X \text{ and } f \circ h \simeq 1_Y,$$

where 1_X and 1_Y are identity maps

$$1_X: X \rightarrow X \text{ and } 1_Y: Y \rightarrow Y.$$

We can change cell dimensions homotopically. Homotopy equivalence is more general than topology equivalence. Homotopy equivalence can identify a change of any cyberworld that is topologically not any more equivalent after the change. While a cyberworld goes through changes by various operations and processes, the changing processes are specified by a homotopy and validated by homotopy equivalences. For instance, we can see why we preserve an attaching map when we perform each cell decomposition; it is to make cell decomposition homotopic so that we can reverse the decomposition.

As a matter of fact, researching on homotopic information models is a challenging area to find out the science of information models. It provides an interesting subject to see what information operations are homotopically equivalent.

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キーワード.

セル空間構造、サイバー空間、The Web **情報システム**

Summary.

A Cellular Model for Information Systems on the Web
- Integrating Local and Global Information -

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Cyberworlds are being formed on the web either intentionally or spontaneously, with or without design. Widespread and intensive local activities are melting each other on the web globally to create cyberworlds. What is called e-business including electronic financing has been conducted in cyberworlds and has crossed a national finance level in its scale. Without proper modeling, cyberworlds will continue to grow chaotic and will soon be out of human understanding. A novel information model we named “a cellular model” serves to globally integrate local models. As an information model, it is applicable to the category of irregular data models that capture spatio-temporal aspects as situations. Mathematically it is based on cellular spatial structures in a homotopy theoretical framework and is an extension of graph theory.

Keywords.

a cellular model, cellular spatial structures, a web information model, a cyberworld model, integrating local models globally, a situation model, web information mining, homotopy theory