EXTENDED ABSTRACT: A FORMAL FOUNDATION FOR CYBERSPACE

William Bricken
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A clear understanding of cyberspace requires a foundational mathematics which abstracts the essential structure of this new field. This paper will identify the fundamental concepts of a theory of cyberspace and provide a calculus which specifies the relations and transformations between these concepts. The formalization of cyberspace permits us to interpret our ideas with rigor and to differentiate the various philosophical positions regarding the ontology, epistemology and metaphysics of cyberspace. Mathematical foundations are a desirable necessity, providing structure for computational implementations, tools for identification and composition, and techniques for interactivity.

DEFINITIONS

Cyberspace:
: electronically mediated experience.

Virtual Reality:
: broad bandwidth first-person participation in cyberspace.

Artificial Reality:
: third-person virtual reality.

Virtual Worlds:
: virtual reality configured and presented for natural perception.

Virtual Body/Virtual Environment:
: the coupled subjective/objective components of virtual worlds.

The paper will expand and justify these definitions, focusing on the proposed fundamental concepts of participant, inclusion, and information:

Participant:
: environmentally interactive sentience.

Inclusion:
: subjective experience of environmental closure.

Information:
: comprehendible symbolic structure.

Using this vocabulary, cyberspace is electronic information which mediates by inclusion the experience of participants; it is being inside symbolic structure.

BOUNDARY MATHEMATICS

Boundary mathematics is an extension of techniques introduced in Spencer-Brown's Laws of Form. As a pure formal system, boundary mathematics is the calculus of inclusion, it specifies the structure and relationships of closure. A simple boundary, ( ), identifies two aspects of the space underlying it: the context, on the outside, and the content, on the inside.

Boundary mathematics can be interpreted as a formal foundation for cyberspace. The simple boundary, ( ), is the distinction between virtual and actual:

actual (virtual)

From outside, ( ) can represent the cyberspace participant that we observe. From inside, ( ) can represent the inclusive environment of cyberspace that the participant observes. The boundary has object/subject polymorphism. Which side of the boundary is context and which is content depends upon where we choose to place our focus of attention. Like quantum mechanics, boundary mathematics is not independent of its user (participant). Incorporating the participant actively into a mathematics provides three critical tools for cyberspace: object/environment dualism, dynamic interaction, and pervasion.

1. Cyberspace makes apparent the object/environment dualism of information (the observer/participant dualism of experience). Conventionally, we position ourselves outside a representation, treating it an as object. In cyberspace, we place ourselves inside the representation, treating it as an environment. By dwelling within information, we redefine the concept of meaning in symbols. Not only do we process and interpret representations, we can also experience them directly. The paper will discuss implications for representation and for semantics, and will describe techniques to convert the foundations of mathematics (logic, set theory, integer theory) to experiential form.

2. Cyberspace permits dynamic interaction with information, eroding the distinction between description and process. Conventionally, representation is passive to interpretation, we do not change words when we read them. In cyberspace, we interactively participate within a representation, treating it as an experience. By interacting with information, we humanize our use of symbols. Rather than learning symbol processing skills (the three Rs of Education), we can expect symbol processing systems to accommodate to natural human behavior. Rather than symbolic objects that support manipulation by only a single person, symbolic environments (like physical environments) can support social activity. The paper will discuss implications for knowledge and for the activity of learning, and will describe the techniques of divergent virtual realities (multiple, concurrent, inconsistent worldviews).

3. Space (and experience) are pervasive rather than dualistic. A pervasive space is one which is diffused throughout every portion of itself, including those portions occupied by other spaces. Objects are those boundaries of spaces that we can sense from the outside. In cyberspace, the actual pervades the virtual. When we enter a virtual world, we always bring our physical body. Pervasion permits both/and inclusions rather than either/or dichotomies, resolving the dualism which plagues Western philosophy (mind/body, participant/observer, subject/object, good/bad, us/them). The paper will discuss implications for cyberspace experience, and will demonstrate the power of pervasion for computation.

FORMALIZATION

The central contribution of the paper is an equational calculus which specifies the transformational invariants of the fundamental concepts of cyberspace (participant, inclusion, information).

Let the boundary ( ) represent the distinction between object and environment. Let i represent a participant. Without introducing variable configurations (patterns which define information), an axiomatic basis for inclusive participation is:

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OBSERVE:          i  (   )  =  (   )
PARTICIPATE:       (  i  )  =
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The equality sign identifies an algebra, a familiar structure which permits computation using match and substitute. The left-hand-side of each equation is descriptive (objective), explicitly mentioning the participant. The right-hand-side is experiential (participatory), implicitly using the participant's perspective. We read the left-hand-side from our traditional externalized, objective perspective. The right-hand-side refers to our experience, from the subjective perspective. When we OBSERVE an empty environment, we perceive its external boundary. When we PARTICIPATE in an otherwise empty environment, we perceive emptiness.

APPLICATION

The paper will provide examples of the utility of boundary mathematics for cyberspace. Boundaries both separate and connect, providing an innovative model of interface. Applied to multiple participant cyberspace, boundary mathematics provides a bookkeeping mechanism for the maintenance of space sharing. Applied to the structure of particular cyberspaces, boundary mathematics provides spatial logic, a formal technique for embedding control structure in space rather than in tokens. Applied to programming, boundary mathematics provides a visual, 3D, participatory programming language (experience).

An appropriate formalization will also provide guidance and insight into the meaning of concepts. Boundary mathematics provides a calculus of communication which guides the implementation of parallel cyberspaces, a theory of information sharing to regulate the semantics of virtual information exchange, and a formal model of reality which supports multiple inconsistent worlds.