CSci • B607 **Week #5 (b)** **Feb 8, 2001**

 Last edited Thursday, February 8, 2001

Unbundling the Transducer

I. Preliminaries

A. Status
   1. Next week: we'll complete our analysis of the FSM construal. We will spend one day talking about independence (in several varieties), and one day summarizing what we have learned. We could spend more time on FSM, but we need to move on to the second construal (EC).
   2. Last time, summarized the conceptual structure coming out of the empirical critique (the analysis of the ontological sub-reading of the negative reading of the FSM claim).
   3. Today: look at transducers
   4. Next week: we will also talk about
      a. The property sub-sub-reading of the negative sub-reading of formality, and
      b. The conceptual reading of the negative reading.

B. Review
   1. We've been interested in first construal (FSM) because, alone of the six, it deals with semantics & effectiveness (both constitutive, in some way or other, of "computation in the wild")
   2. We said, at the outset, that, for each construal, we wanted to know (in brief) two things:
      a. What about it was *right*; and
      b. What about it was *wrong*.
   3. What is right about FSM? Two things:
      a. First has already been said: it deals with both aspects
      b. Second:
         i. Haven't really got there yet
         ii. Will get to (next week) when we considering syntactic/semantic independence at the level of properties.
         iii. In brief: positive claim will be that semantics is *ineffective*.
   4. What is wrong with FSM? Also two things:
      a. First, two two-way confusions:
         i. Between positive and negative readings
            α. Essentially an assumption that syntax & semantics don't overlap
         ii. Between conceptual (vertical) and ontological (horizontal) readings
            α. Essentially an assumption that explanatory and causal boundaries line up.
            β. Combined with a confusion between independence and naturalistic reduction
      b. Second: *involvement*
         i. (As said at beginning of empirical critique): FSM takes the syntactic and semantic realms to be *separate* or in some sense *independent*.

ii. But as we saw in the examples: that separateness does not obtain in practice.
iii. Computers don't just *reason* about their subject matters Rather, they are *involved* in them. They **actually participate**. This *participation* is the first (of two) major morals from the first critique.
iv. The participation also defeats (the negative reading of) the formality claim.

C. Transducers
1. So far, that is all review. What does it have to do with transduction?
2. Because of something that on the surface looks perverse.
3. Transducers are viewed by many (cf. Harnad, defenders of embedded or reactive computing, Kirsh, recent issue of the *AI Journal* edited by Agre, etc.) as *paradigmatic of systems that are involved in the world around them.*
4. So you might think I would *love* transducers: valorize them, as absolutely constitutive of what a comprehensive theory of computing should deal with.
5. But the opposite seems to be the case!
6. In fact I think of transducers as "*the shame of cognitive science*"! They are theoretical constructs that arose out of—yet at the same time paper over—a plethora of untenable theoretical presuppositions.
7. So instead of *valourising* transducers, I am *indicting* them
8. What is going on?

D. This is a contradiction that I want to unpack today.

II. Cross-cutting boundaries

A. Go back to the conceptual summary, that we looked at on Tuesday.
B. We formulated it in terms of two distinctions and two theses:
1. Two "boundaries":
a. **Physical:** between the system and its surrounding environment—i.e., a distinction between "inside" and "outside"; and
b. **Semantic:** between symbols and their referents
2. Two theses or propositions, stated in terms of these boundaries:
a. **Alignment:** that physical and semantic boundaries line up, with all the symbols inside, and all the referents outside.
b. **Isolation:** that this putatively aligned boundary is a "moat"—a barrier or gulf across which "dependence" of various forms (causal, semantic, explanatory) does not reach.
3. We saw that paradigmatic examples of FSM (Plato, Pluto) honoured both theses: a pristine inner world of symbols thought both to work (ontologically) and to be analysable (theoretically) in isolation, without distracting influence from the messy, unpredictable exterior

C. Critique, part I
1. Easier: retain ALIGNMENT (coincident boundaries), relax ISOLATION (no interaction).
2. Classical realm of I/O, of transduction, etc.
3. Admitted in philosophy (Fodor, Devitt), cognitive science (Harnad's "Total Turing Test"), and AI ("robot" reply to Searle's Chinese room) to challenge standard "formal" model.
4. As we said, it is not entirely clear whether this alone is strong enough to challenge FSM. If

transducers violate *formality*; maybe they should thereby be counted as not *computational*—saving an "inner sanctum" of "pure" (formal) computing.

D. Critique, part II
   1. Deeper: challenge ALIGNMENT.
   2. False in the wild: physical and semantic boundaries *cross-cut*
   3. Does breaking down ALIGNMENT defeat FSM? No!
   4. Rather, denying ALIGNMENT undermines ISOLATION—thereby defeating formality
   5. Look at how this goes in a little more detail

E. Cross-cutting boundaries
   1. It takes four types of *state* to show that the two boundaries cross-cut (i.e., that ALIGNMENT is false)
      a. II ≡ Internal symbol, internal referent (quotation, meta-levels, e-mail)
      b. IE ≡ Internal symbol, external referent (internal representation of Plato, Pluto)
      c. EI ≡ External symbol, internal referent (correctness proofs, hardware timing diagrams)
      d. EE ≡ External symbol, external referent (road signs, maps, skull-and-crossbones signifying radioactivity)

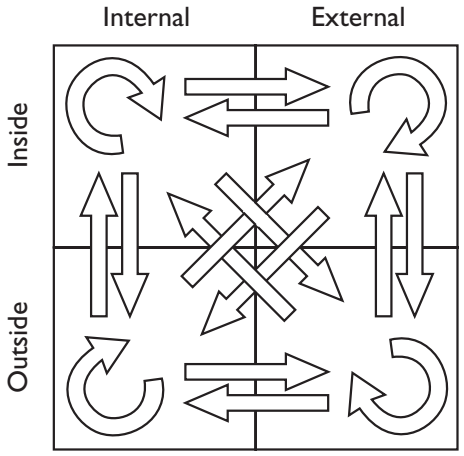

Figure 1 — Sixteen transformations

   2. But what's relevant to the nature of computing is not so much the existence of these states, but rather *state-change transformations* between and among them (since computing has to do with *processing*)
   3. Four quadrants ⇒ sixteen possible cases of state change (see figure 1)
   4. Four of these sixteen transformations are quadrant-internal:

Transition	*Example*
II ⇒ II	Meta-level reasoning
IE ⇒ IE	NASA system's calculation of planetary orbits
EI ⇒ EI	Calculation on scratch paper of heat produced by a chip
EE ⇒ EE	Calculation of shortest path by lengths of string

   5. Other twelve also exist (see figure 2, on the next page):

F. Transducers
   1. Again, what does this all have to do with transducers? Just this: "transduction" is the name for crossing between/among these categories.
   2. But given that ALIGNMENT is false, must break down the notion of transduction (that about which Fodor is too busy to think) into two kinds:
      a. Physical transducers: operations or modules that mediate (cross the boundary) between inside and outside—i.e., between system and its surrounding environment;
      b. Semantic transducers: operations or modules that mediate (cross the boundary) between symbols and their referents

Transition	*Computational Example*	*Human Example*
II ⇒ IE	Disquotation: ((EVAL '(+ 2 3)) ⇒ 5)	Deciding to believe something ("It must be true, what John said: that 'Oswald killed Kennedy' " ⇒ "Oswald killed Kennedy")
II ⇒ EI	Printing out error message on screen	Recounting thoughts (" … and I was, like, 'What's this guy doing here?' "); Writing a letter ("I've been thinking about you … ")
II ⇒ EE	Warning: "Charge battery"	Putting up a sign: "Don't bother me"
EI ⇒ II	Reading in ↑C	
… etc …		

Figure 2 — Additional transitions between types

3. The only remotely plausible notion of transducer, in practice, are physical.
   a. Cf. vision, touch, smell, articulation, wheels, muscles, and the like
   b. Systems that mediate between the internals of a system and the "outside" world
4. The notion of transducer that challenges FSM, however (and vexed Fodor), are semantic (antisemantics is challenged as much by disquotation as by driving around)
5. So the only way to preserve the FSM construal would be to exclude, from the province of the computational, any processes that crossed a *semantic* boundary. I.e., to restrict the notion of computing to exclude operation of semantic transducers.
6. Claimed last time that this is a spectacularly bad idea.

G. Today, set aside the formality critique (temporarily), and focus directly on the implications for the notion of transduction.

III. Transducers

A. Classically, "transduction" has two meanings
   1. "Move from one thing to another"—this is the basic sense, which we'll look at more today
   2. Also a second reading or "use", in theories of the sort we're looking at (computing, and also psychology), as something of a derivative notion:
      a. Theoretical core is α
      b. Full situation is β
      c. Generates a gap: β–α.
      d. Transducers: *whatever will fill that gap*

B. What gaps are there in current theories?
   1. *Causal* gap
      a. How do we use computers, how do they fit into the world?
      b. Traditional theories (Turing machines, anything else that takes them to be a closed sys-

tem) doesn't account for that interaction
   c. So maybe transducers can bridge that gap (cf. sensors and effectors)
2. *Semantic* gap
   a. How are symbols attached to what they mean?
   b. Model theory assumes the answer (obviously for all primitives, but also for what *ensures* the reference of complexes)
   c. Maybe transducers can bridge *that* gap too (and solve the symbol grounding problem)

C. Have already seen that these roles may need separation (into physical and semantic transducers)
D. Physiology (the home of the notion of transducer)
1. Transduction is not viewed as having to do with mediating inside–outside and symbol–referent boundaries at all!
2. Rather, a third type: mediate boundaries of *medium*.
   a. Paradigmatically: mechanisms that converts energy or information into and out of electrochemical form
   b. E.g., thermal transducers in the skin, mechanisms that convert the level of gastric acidity into a neural encoding or signal, etc.
3. Cf. following definition, taken from a representative neurophysiology text:
   a. "*Information is distinct from the form in which it is represented. Transduction is the process of translating information from one physical form to another.*"
4. Call this third type: **medium transducer**
   a. Only lines up with a physical transducer if there is a medium boundary at the edge
   b. True of people, but not of computers (cf. the internet)

E. What is going on?

IV. The formal world

A. Transducers, we saw, are *brokers of boundaries*
B. So far, in the course, we have talked about five different kinds of "boundaries" or "differences":
1. **Physical,** between the insides and outsides of physically realised systems
2. **Semantic,** between symbols and their referents; and
3. **Medium,** of the sort that physiologists are concerned with, between different forms of information or energy.
4. **Digital,** between
   a. Vague or continuous realms, such as presented in classical or lay models of physics, and
   b. The allegedly precise, discrete world of digital systems (including, it is usually assumed, the computational realm of symbols); and
5. **Abstraction,** between
   a. The concrete world of spatio-temporal particulars and
   b. A realm of relatively abstract or at least medium-independent structures (of which, again, symbols are taken to be paradigmatic exemplars).

C. Hyper-cube
1. These generate a five-dimensional cube, with dimensions as shown in figure 3 (next page)
2. On the paradigmatic model (NASA system for calculating planetary orbits), the computer

		<0>		<1>
1	physical	outside	⇔	inside
2	semantic	referent (content)	⇔	symbol (form)
3	digital	continuous	⇔	discrete
4	abstract	concrete (medium-dependent)	⇔	abstract (medium-independent)
5	medium	one medium	⇔	another medium

Figure 3 — Conceptual dimensions of a symbolic system

system is identified as being at the *upper right corner*

3. That is, what is computational (according to the traditional story) is at <1,1,1,1,1>
4. For example: consider the NASA system:
   a. An *internal* realm of …
   b. *Discrete,* …
   c. *Medium-independent* …
   d. *Symbols*, in a
   e. Different "medium" from …
   f. The domain of planets (which, in turn, are at <0,0,0,0,0>: *continuous*, *concrete*, *external*, *referents*)
5. I.e., a generalisation of ALIGNMENT

D. Transducers, again
   1. Given this model, it is not hard to see the role of transducers
   2. They are **ferries**, that shuttle back and forth between
      a. The <1,1,1,1,1> "formal" or computational corner and
      b. (At least paradigmatically), the opposite <0,0,0,0,0> corner of concrete, continuous, external reference in a different medium
   3. Moreover: the transducers are *express trains*, making no stops along the way!
      a. Transduction widely thought to be monolithic process, immune to external intervention
      b. "Cognitively impenetrable," in Pylyshyn's phrase.
   4. Cf. Marr's model of vision: glossing all details, output of the very first "module" in the model (the cells or circuitry that calculates the zero-crossings of the second derivative of light intensity) is thought to produce an *internal*, *discrete*, *medium-independent symbol*, of an *continuous external referent.*
      a. Complexities: "stimulus" often thought to be impinging optic array, rather than distal (though that changes as soon as one gets to the 2-1/2-d sketch.
      b. But the claim is not that this is *exact*, so much as that this is something of a basic orienting assumption underlying the FSM tradition.

V. Cross-cutting boundaries

A. As before, I want to argue that these four (or five) boundaries cross-cut
B. Numerology
   1. In general, if **k** boundaries cross-cut, then there will be
      a. $\Rightarrow 2^k$ distinct regions
      b. $\Rightarrow 2^{2k}$ species of boundary-crossing mechanism
   2. Last time, had two boundaries (physical and semantic), so **k** = 2
      a. $\Rightarrow$ 4 regions
      b. $\Rightarrow$ 16 species of boundary crossing
   3. This time, have five boundaries, $\Rightarrow$ **k** = 5
      a. $\Rightarrow$ 32 regions
      b. $\Rightarrow$ 1024 species of boundary crossing
   4. Can't enumerate them all!
   5. So we'll just look at a few examples
   6. Start with the inner regions; turn to *physical* boundary crossing mechanisms in a moment.
C. Case 1: SEMANTIC (symbol-referent) vs. ABSTRACTION (concrete-abstract)
   1. One direction: hold SEMANTIC fixed (on referent), vary ABSTRACTION
      a. Can as easily designate abstract phenomena (numbers, types, détente) as concrete entities (tables and chairs)
      b. If meta-level representation is possible, in fact, (i.e., we can successfully refer to symbols, thinking, deduction, language, perception, etc.) then there *must* not be any necessary difference between symbol and referent (sign and signified) as regards concreteness or medium-independence
      c. That is, can designate things that (wrt computational symbols) are
         i. More abstract: pure numbers or types
         ii. Same degree of abstraction: other symbols
         iii. More concrete: tables and chairs
   2. Other side: hold SEMANTIC fixed on *symbol*, vary ABSTRACTION
      a. Concrete: marks on a page (or Turing machine tape), spoken utterances, words on the written page, stop signs, names in lights
      b. Intermediate: data structures, web pages
      c. Abstract: can use sets or numbers as models or representations of other structures
D. Case 2: SEMANTIC (symbol-referent) vs. DIGITALITY (digital–continuous)
   1. Discrete (digital) symbols: the paradigmatic case
   2. Discrete reference: integers, chess positions, states of a digital computer, etc. (some inside, some outside; some concrete, some abstract, etc.)
   3. Continuous referents: paradigmatic, such as orbits
   4. Continuous symbols
      a. *Human*: line drawings; marks inscribed by lab thermometer recording temperature over a continuous interval, such as a day or week; oil paintings; utterance of "*Well … "*, said with a sigh, in answer to a question of how the qualifying exams were this year.

   b. (Some of these are concrete, such as curve worn over many years into the monastery step; some abstract, such as the hyperbolic tangent function that models it.)
   c. *Computational*: this is nothing other than *analogue computing* (cf Part IV of course).

E. Isolation and Operations
   1. As before, not just that the boundaries cross-cut (ALIGNMENT* is false)[1]
   2. Rather, ISOLATION* is false, because (again) exist processes that cross all five boundaries
   3. Cf. medium
      a. Not limited to human physiology
      b. Cf. phonograph cartridge: takes a mechanical signal (from the record groove, embedded in plastic) and converts it to an electrical signal. *All the other four distinctions remain fixed (continuous, external, symbol)*
      c. Digital-analog converters: converts analogue to digital, but keeps *medium* the same (as well as internal and symbolic)
   4. Other examples
      a. Internal deliberation
      b. Disquotation
      c. Recognition of anxiety
      d. Temporal sensors
      e. Proprioception
      f. Etc.

VI. Middle Region

A. Summary
   1. One advantage of splitting these dimensions out ("unbundling the transducer"), is to allow each to be dealt with on its one
   2. But we have been a bit too number-theoretic, as if this was an algebraic structure
   3. Turns out that different issues affect different ones (will presage in the book)
   4. But there is one more moral to be extracted, before turning to them
   5. To get at it, look a little harder at the concrete/abstract distinction

B. Abstractness
   1. Note something said above: we can designate things that (wrt the designating symbols) are
      a. More abstract (pure numbers or types)
      b. Same degree of abstraction (other symbols)
      c. More concrete (tables and chairs)
   2. Moral: abstractness is not an *all-or-nothing* affair
   3. Cf. architecture (e.g., of a hospital)
      a. Can deal with the hospital at various degrees of abstraction
      b. As 2" × 4"s, as rooms, as services, etc.

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[1] By ALIGNMENT* I mean a generalisation of ALIGNMENT—i.e., the thesis that *all five* of the boundaries we are talking about here line up. Similarly, ISOLATION* would be the thesis that this allegedly five-way aligned boundary is a causal and explanatory moat.

   c. Also, wrt any given level of abstraction, there are multiple ways in which it could be implemented, at a lower level of abstraction
   d. "Same" 2×4 could be constituted by different arrangements of proteins
   e. Can build 2 × 4s out of metal, or concrete, or ceramic, or used newspapers
   f. I.e., have "multiple realisability" at all kinds of levels
   g. Just because something is (relatively more) abstract, that doesn't render it *totally* abstract—divorced from material reality altogether
4. So too of computers
   a. Will generally abstract away from some aspects (whether on vacuum tubes or transistors or gallium arsenide)
   b. But no reason to infer that results are *completely* abstract (or virtual)
5. In sum, the virtue of breaking out the abstractness boundary is:
   a. Not to treat it as "yet another instance of boundary-crossing",
   b. But instead to treat it as an **issue in its own right**, complete with distinctive concerns, properties, questions, etc.

C. Other cases
1. So too with inside-out—cf. cornea, or perception, or caches in disk controller
2. Same with digitality: a wealth of issues (not just a binary distinction), as we will see in Part IV of the course.
3. Ditto symbol/referent.
   a. All kinds of issues of meaning, memory, inference, perception, etc.
   b. Best to treat without distraction of whether the referent is internal or external
   c. Though whether the referent is *accessible* will turn out to matter a lot

D. Theoretical treatment
1. How are we to analyse these?
2. Could say: because there is a spectrum, from 0 to 1, analyse it as a continuum, in terms of the limit notions that have generated the space.
3. But that would miss the point
4. Cf. (black and white) photographs
   a. They, too, are limited, at each end, by black and white
   b. Does that mean that, from a theoretical perspective, we should analyse them in terms of pure blackness, and pure whiteness (and treat all the greys in the middle as the inevitable messiness of practice)?
   c. No, that would be crazy
   d. The *appropriate governing abstractions* (shadows, texture, specular reflection, greys, colours, etc.) aren't illuminated by dealing only with *all* (white) or *no* (black) colours.
   e. Rather, they have to be treated as the important constitutive notions.
5. So too, no reason to suppose that the useful cases—even the useful scientific idealisations—of our hypercube will be limit cases

E. Leads to the ultimate picture
1. That the realm of computing lies in the *middle region* of this hypercube
2. Not at <0,0,0,0,0>, or at <1,1,1,1,1>, but in *textured center*

3. *That*, ultimately, is what is wrong with transducers
4. That, too, is why I called them a "rug" under which interesting issues are swept.
5. *Yes*, participation is crucial—one of the two main results of this critique
6. But *no*, transducers aren't the right way to understand participation
7. What it is that transducers did is **too important** for that
8. Don't get at the essence of the territory by taking an express shuttle from one corner to the other, blind to the structure of the intermediate region (ISOLATION)
9. Nor by conflating all the constituent dimensions (ALIGNMENT)

F. Instead

1. **Eschew limit cases!**
2. Open the territory up
3. First, by unfolding the various constituent dimensions
4. Second, by recognizing that the essential phenomenon inhabits the middle of the resulting region.
   a. That is where we will find the structure of the computer we build.
   b. That is the positive picture we want to take with us, in assembling an alternative account.
5. Moreover, this region won't any longer be understood as boundary crossing
   a. For when you tease the five dimensions apart, the individual bases have more to do with the particular of each dimension than they do with boundary-crossing activity *per se*.
   b. That's why, ultimately, the notion of transduction is no longer useful.

—— *end of file* ——