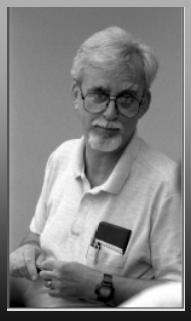
What is Information?

John Perry and David Israel on
Semantic Information



What underlies the phenomenon of information is the fact that reality is lawlike; that what is going on in one part of reality is related to what is going on in some other part of reality [...] In a world knitted together by constraints - whether these be constant conjunctions or some more metaphysically potent connections, - situations carry information.

What is Information?

The fact that the x-ray has such and such a pattern indicates that Jackie has a broken leg.

Informational context

The fact that the x-ray has such and such a pattern indicates that Jackie has a broken leg.

Information verb (verb phrase) + preceding noun phrase

Informational content

The fact that the x-ray has such and such a pattern indicates that Jackie has a broken leg.

proposition designated by the 'that'-clause

Carrier of the information

The x-ray indicates that Jackie has a broken leg.

object designated by the initial noun-phrase

Indicating fact

The fact that the x-ray has such and such a pattern indicates that Jackie has a broken leg.

fact designated by the initial noun-phrase

(A) Facts carry information

If the report is true, the informational content is true too. If the x-ray indicates that Jackie has a broken leg, then she does.

This gives us (B).

(B) The informational content of a fact is a true proposition.

As we've learned from Dretske already, what underlies the phenomenon of information is the fact that reality is lawlike; that what is going on in one part of reality is related to what is going on in some other part of reality, by laws, nomic regularities, or constraints:

(C) The information a fact carries is relative to a constraint

Events carry information due to their imbeddedness in our world, with the constraints of our world holding:

(D) The information a fact carries is not an intrinsic property of it.

Information typically involves a fact indicating something about the things are elsewhere and elsewhen, and this is what makes information useful and interesting:

(E) The informational content of a fact can concern remote things and situations.

But now we get into problems explicating how the indicating facts can connect to the remote things and situations. The following seems to be true:

(F) Informational content can be specific; the propositions that are informational contents can be about objects that are not part of the indicating fact.

That a fact about the x-ray can tell us something about Jackie who is not part of the indicating fact, is due to the connecting fact that the x-ray is of Jackie. The connecting fact connects the pure information that a dog had a broken leg to Jackie:

(G) Indicating facts contain such specific information only relative to connecting facts; the information is incremental, given those facts.

It seems we can make copies of the x-ray and send it to some other vet, thereby communicating the same informational content the x-ray carried before:

(H) Many different facts, involving variations in objects, properties, relations and spatiotemporal locations, can indicate one and the same informational content - relative to the same or different constraints.

(I) Information can be stored and transmitted in a variety of ways.

Information doesn't any good to the x-ray, but might be very valuable to Jackie:

(J) Having information is good; creatures whose behavior is guided or controlled by information (by their information carrying states) are more likely to succeed than those which are not so guided.

Framework

To see how pure information and incremental information, information flow and the helpfulness of information can be treated in situation semantics, we will repeat some definitions (briefly - everything should be more or less familiar to you now).

Anchors

An anchor f satisfies an infon i relative to a situation s iff s |= i[f].

An anchor f satisfies an infon i *simpliciter* iff |= i[f], i.e. if there is a situation s such that s |= i[f].

Compound infons

meet of a set of infons $\bigwedge I$:

f satisfies $\bigwedge I$ iff i[f] is factual for each $i \in I$.

Compound infons

existentialization of an infon with respect to parameter **x**, $\exists\mathbf{x}(i)$

f satisfies $\exists\mathbf{x}(i)$ iff for some object a, $i[f_{x/a}]$ is factual.

Types of situation, parametric types, conditioning infons

Where σ is a state of affairs,

[s| s |= i] is the *type of situation* that supports σ.

Where i is an infon (i.e. a parametric state of affairs),

[s| s |= i] is a *parametric type*, and i is the *conditioning infon* of T (*cond(T)*).

A situation s is *of* parametric type T relative to f if

s |= i[f], where i is the conditioning infon of T and f is defined on all of the parameters of i.

Constraints / Simple involvement

We take constraints to be states of affairs with types of situations as constituents.

Simple involvement is a binary relation. If T involves T', then for every situation of type T, there is one of type T'. We write:

<<Involves; T, T', 1>>

Information

Now we can construct a theory of information within the framework of situation semantics:

Pure Information

Let C be some constraint. The fact σ *carries the pure information that* P *relative to* C iff

1. C = <<Involves, T, T', 1>>.

2. For any anchor f such that σ = cond(T)[f], P = the proposition that $\exists s'(s' \models \exists a_1,...a_n(\text{cond}(T')[f]))$.

(We'll flesh this out in a minute...)

Incremental Information

Let C be some relative constraint, then the fact σ *carries the incremental information that* P *relative to* C *and the fact* σ' iff

1. C = <<Involves$_R$, T, T', T'', 1>>.

2. For any anchor f such that σ = cond(T)[f], ∧ σ' = cond(T'')[f], P = the proposition that ∃s'(s' |= ∃a_1,...a_n(cond(T')[f])).

(We'll flesh this out in a minute...)

Relative involvement

Relative involvement is a ternary relation. If T involves T' relative to T'', then, for any pair of situations of the first and third types, there is a situation of the second type.

We write:

<<Involves$_R$; T, T', T'', 1>>

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Application

To see how fine this beautiful theory deals with the case of Jackie, the x-ray and the broken leg, we will apply everything now formally.

Let's first consider the x-ray case as a case of pure information.

In this case we have in mind a simple constraint: whenever there is a state of affairs consisting of some x-ray's having such and such a pattern at some time *t*, then there is a state of affairs involving a dog's leg having been the object of that x-ray and that leg's being broken at *t*.

So the indicated proposition is that there is a dog of which this is the x-ray, and it has a broken leg. The pure information is about the x-ray, but not about Jackie, or her leg.

The constraint

T = [s| s |= <<X-ray, **x**, **t**; 1>> ∧ <<Has-pattern-Φ, **x**, **t**; 1>>]

T' = [s| s |= <<Is-xray-of, **x**, **y**, **t**; 1>> ∧ <<Has-broken-leg, **y**, **t**; 1>>]

C = <<Involves, T, T'; 1>>

This gives us the constraint. Now we need the indicating situation, to satisfy T.

The indicating situation

The indicating situation, σ, is

<<X-ray, a, t'; 1>> ∧ <<Has-pattern-Φ, a, t'; 1>>

where a is the x-ray and t' the time. We assume that is factual, that is that ∃s(s |= σ).

Pure Information

Now let f be any anchor defined on **x** and **t** (at least) such that

σ = cond(T)[f] = <<X-ray, **x**, **t**, 1>> ∧ <<Has-pattern-Φ, **x**, **t**; 1>>[f]

(Thus, f(**x**) = a and f(**t**) = t'.) Then P = the proposition that
∃s'(s' |= ∃y(<<Is-xray-of, **x**, y, **t**; 1>> ∧ <<Has-broken-leg, y, **t**; 1>>)[f])

Thus P is the proposition that the state of affairs which consists of some dog being the object of a, the x-ray in question (at t', the time in question) and that dog's having a broken leg (at the time in question) is factual. Or, more simply, it is the proposition that there is some dog whose leg is depicted by a at t' and whose leg is broken at t'.

Incremental Information

Now that we have seen how to get at the pure information, we want to get at the incremental information that Jackie has a broken leg. We know already that we need the connecting fact that the x-ray was of Jackie.

Relative Constraint

When we consider the incremental information our constraint is simply this: if an x-ray is of this type, and it is the x-ray of a dog, then that dog had a broken leg at the time the x-ray was taken.

Relative Constraint

The relevant relative constraint is:

C' = <<Involves$_{R,}$ T, T', T''; 1>>

where T, the indicating type is as before.

T', the indicated type is

[s| s |= <<Has-broken-leg, **y**, **t**; 1>>]

and T'', the connecting type is:

[s| s |= <<Is-xray-of, **x**, **y**, **t**; 1>>]

The connecting state of affairs

As before, σ is:

<<X-ray, a, t'; 1>> ∧

<<Has-pattern-Φ, a, t'; 1>>

Again, we assume that σ is factual. Further, we assume that the connecting state of affairs, σ' is factual. Where b is Jackie, σ' is

<<Is-xray-of, a, b, t'; 1>>.

Incremental Information

Any anchor f, such that σ = cond(T)[f] and σ' = cond(T'), must be defined on the parameter **y** of the connecting type, in particular, it must anchor **y** to Jackie.

Thus,for any such anchor f, the proposition carried incrementally by σ relative to C and σ' is the proposition that

∃s"(s" |= <<Has-broken-leg, b, t'; 1>>).

The Flow of Information

Given backwards constraints which are relative to the occurrence of connecting facts and the occurrence of these facts, we can easily explicate what we mean by information flow. Given connceting types, we can generalize:

(K) There are laws of information flow.

Such laws involve compound infons and relations among the parameters of those infons.

The Helpfulness of Information

Now, we want to develop an account of having information as being in a state that plays two roles. First, the agent's being in the state carries certain information relative to a constraint. Second, an agent's being in that state has an effect (relative to some other constraint) that is appropriate given the information. In that case, we want to say that the agent not only carries but has the information.

The Helpfulness of Information

Let's consider a simple example. I stick a pencil in an electric pencil sharpener; a lever is depressed; a circuit is closed; the motor turns on, the blade spins; the pencil issharpened. In this case, the insertion of the pencil caused the pencil sharpener to be in a certain state, having a lever depressed, that carried information. Under normal usage, this state only occurs when a pencil is inserted, and so carries the information that this is so.

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The Helpfulness of Information

This state causes things to happen inside the pencil sharpener: the circuit closes, the motor starts, the blades spin. So, the state of having the lever depressed plays two roles. It carries information, relative to constraints, about the wider circumstances in which the system finds itself—that a pencil has been inserted. And it causes things to happen in the system.

The Helpfulness of Information
Pure Information

1. G is a goal, say of sharpening pencils.
2. *lever-depressed*, *circuit-closed*, and *blades-spinning*, etc. are states of systems of a certain kind K.
3. There is a constraint $C_{pure\text{-}info}$: if a system a of kind K is in *lever-depressed* at location l, then there is a pencil inserted in a at l.
4. There is a constraint C_K that governs the internal workings of the system: if a is in state *lever-depressed* at l, a will go into state *circuit-closed*, then into state *blades-spinning*.
5. There is a constraint $C_{pure\text{-}result}$: if a is in state *blades-spinning* then if there is a pencil in contact with the blades of a, that pencil will be sharpened.

The Helpfulness of Information
Pure Information

Thus there is no particular problem about how an agent or device may be caused,by the state that carries remote information, to respond in ways appropriate to that information, and so be said not merely to carry but to *have* that information.

The Helpfulness of Information
Incremental Information

1. G is a goal, say of sharpening pencils.
2. *lever-depressed*, *circuit-closed*, and *blades-spinning*, etc. are states of systems of a certain kind K.
3. There is a constraint C_{inc}-info: if a system a of kind K is in *lever-depressed* at location l, then pencil c is inserted in a, given that c is depressing the lever of a.
4. There is a constraint C_K that governs the internal workings of the system: if a is in state *lever-depressed* at l, a will go into state *circuit-closed*, then into state *blades-spinning*.
5. There is a constraint $C_{inc\text{-}result}$: if a is in state *blades-spinning* pencil c will be sharpened given that c is in contact with the blades of a.