Situations and You

It is uncommon for math people to come out of their shells and try to talk about things that everyday folk can understand. Unfortunately, a limit to the amount of material that can be expressed without preliminary foundations which are not a part of everyday knowledge is quickly found by most authors.

One way to proceed then is to present preliminary foundational material, and then move on. Another way is to embed the preliminary foundational material within the exposition in such a manner that the reader is unaware it's not a part of the exposition. For instance, before talking about meaning and partiality (Muskens, 1995) - which is what I'd like to present here in Situations and You, preliminary required could be a good exposition on Situation Semantics that is a very rudimentary, and elementary and which, when understood, can lead the way to an understanding of formal systems and models that deal with natural languages and the (worlds) situations we encounter. I include the following here, but there are many others that are easily Google searched.

A similar paper is

Formal Logic for Informal Logicians
http://ojs.uwindsor.ca/ojs/leddy/index.php/informal_logic/article/view/444/415

and a good follow up is

HHL_SituationTheory
http://profkeithdevlin.com/Papers/HHL_SituationTheory.pdf

Hawaii,1975

In 1975 I lived in Honolulu where I attended the University of Hawaii. I learned well the use of chop sticks, because at the fast food restaurants, that's all you had to scope up your rice. I saw roaches as big as small cats, and had a house lizard that ate the small ones unfortunate enough to come in to my apartment. I lived about a kilometer away from the University of Hawaii at Manoa, in Honolulu, and walked along Wilder Avenue to get there. Since it rains on and off in Hawaii, generally a light pleasant rain that refreshes the outdoor temperatures of around twenty five degrees Celsius, I often was drenched by the time I arrived for classes. It wasn't that I forgot my umbrella; it was that often it would rain without there being a cloud in the sky, as the fierce winds well above the island would carry the rain miles away from its cloud source. This was the world I lived in, quite different from my hometown of San Francisco, where not so many anomalies were found. The rain without clouds, chop sticks at fast food restaurants, and house lizards were all believable but in most cases not many would think these as being part of their normal world. In my Hawaiian world, not carrying an umbrella, not eating with chop sticks, and shooing out house lizards are all mistakes; and to live successfully in that world, one would want to do just the opposite. It should be easy to see that there is a connection between our action-events and the world that we live in, since our action-events are somewhat dictated by the world we live in. If you could write down all the things that you should do in a particular world to be successful and happy in it, and give the list of those things to someone that knows nothing about you, that someone would be able to understand the world you live in. The communication can take the form of you listing all the things you do in that world to make you happy. Another way to tell the person about your world is that you say "I live in Hawaii". The other person might be knowledgeable about Hawaii, and might be able to tell you things on the list you've made. If the person could do so – tell you how best to get along in your world, then you might think the person as having Knowledge about your world. Just how the person obtained the knowledge may not be known. Perhaps he/she is a psychic, or perhaps he/she lived in Hawaii at one time, or perhaps he/she has acquired knowledge by reading, or from a friend, or perhaps from living in or hearing about a place similar and making a guess. You have learned how to live in your world, and your friend learned that as well. So there is Learning, an acquisition of knowledge that can take many forms, and what is communicated is done so in a Language, and what is talked about are actualities, or Worlds, in this case tangible things that exist. These four ideas are separate, yet together they make up the idea of Knowledge Representation, and with Logic thrown in, we can get Reasoning.

Learning

Language World

Logic

Dan, Bill, Peggy and Catherine
My great friend Bill was a native, called a Kamaiina, for old timer. He didn't mind roaches, so he had no house lizards. A girlfriend, Peggy, from Texas, lived near Waikiki Beach, in a high rise, and wasn't aware of any cock-roach problems; but she did have to use chop sticks and did get caught in the rain without clouds, occasionally. The three of us were graduate math students at UH. Peggy never went to Bill's house, but the three of us often ate fast-food lunch together using chopsticks. I guess you could say we were three different types of people caught up in the same world, Hawaii, 1975. This world had unique geographic and cultural properties - rain without clouds, fast-food served with chopsticks, and cock-roaches, to name a few. Peggy was totally oblivious to the cock-roaches since the immediate surroundings she lived in were clean and void of the pests. Bill was totally oblivious to a world were fast-food wasn't served up with chopsticks. Each of us knew of different worlds, and each of us had are likes and dislikes in our current world; more importantly, each of us viewed our current world differently, yet for all us in Hawaii, 1975, there was only one world that we lived in. And perhaps that just wasn't Hawaii, but the entire world, and all of what we heard about the entire world, in places where we weren't, but in places where we were interested.

For most, it is a requirement of a good life to be knowledgeable, at least about certain things, things that interest you. Your immediate environment interests you, and so do certain other things, whether tangible or not. There is generally motivation that we all need to change. So everyone can achieve happiness in life, just by knowing about their worlds and how their worlds interact with other worlds, perhaps wondering about worlds unknown to them. However, there are problems that we experience in interpreting the worlds. There are physiological problems, which arise from age, like loss of memory, and there are all the evils that come into being, fear, guilt, etc., all psychological problems. Most are powerful enough to not only alter our perception, but also limit, or entirely block out, acquiring knowledge. Another limiter is denial, and the most obvious is missing information – one does not have access to most knowledge.

My friend Catherine from San Francisco knew nothing about Hawaii. She was the type that liked to experience things rather than hear about them. Before she came to visit, she was missing information. When she arrived, and it rained on her without her seeing any clouds, she experienced denial; when she went to the fast food restaurant for lunch, she had difficulty eating because she lacked the co-ordination to use chop sticks. And she couldn't sleep well in my apartment because she was afraid of lizards. To say the least, my world of Hawaii was not a very pleasant place for Catherine. She found staying with Peggy a bit more pleasant. The absence of the cockroaches pleased Peggy and because of that, Peggy was open to learning more about Hawaii. The absence of knives and forks, and the presence of house lizards didn't please Catherine, so she wasn't open to learning more about Hawaii; in fact she wanted to leave as soon as possible. There is a balance between the pleasing attributes and the displeasing ones that determines the amount of new information that one let's in - there is a range of amount of acquisition, starting with 0 and going to thriving.

At this point, it is clear that "belief" situations are the fodder of sociological and psychological complexity. And speaking of complexity, already we've experienced a headful of thoughts, and I've just started with a few beliefs. How complex is a life full of them? Yet we all have one, and expand it every day. How is this done?

Language
The acquisition of the natural language of a culture comes about by mimicking.
I believe that the mimicking comes before meaning for most – have you ever heard a 5 year old repeatedly repeat what you say, without having a clue as to what it means? That the language must provide a clear representation of the world is completely academia, and varies in degree from one natural language to the other. A sparse language, like Native American (Indian), which arises from a sparse environment, has one degree of complexity; while another, like French, has another degree, representing a higher complexity. No matter what the degree, we can disregard the actual mechanics of a language when dealing with meanings. The forming of sentences can be thought of as being written on a syntactical tablet, on your left, and the thoughts of the world they refer to as belonging to another semantic tablet, on your right. There is a good and proper mapping of the tablets, an isomorphism. The right tablet represents the world, and it is to be noted that the culture creates the natural language. So the mimicking must be mapped to the world before it can become a part of the individual's language. Thus, the language is created within the culture.

We find different cultures talk about the same worlds in different ways. The language belongs to the culture and those words and phrases that are limited to a particular culture are ported over to other cultures, intact, while things common to two cultures will most of the time differ in the languages, but the translations will be precise - as in "rain" in English and "pui" in French. However, many words, and phrases, in one language are not directly translatable into another language, simply because of the language. An example of this is the translation of sentences in English to French involving motion. In other cases there is no translation because the world of one culture is lacking an element in the world of another, as in "chopstick" being carried over from the Chinese word "kuaizi", being imported from the culture – not being part of the original western world.

Underscoring any language is logic, common to both parts, the syntax on the left tablet, and the semantic, on the right tablet. Along with it comes reasoning.

Logic and Reasoning
From our very early days as babies, we learn logic. We learn it from practical experiences. We learn the most primitive element of logic, called modus ponens; generally referred to as implication. While implication is not the same as causation, we learn about implication initially through causal occurrences of events. Events are instances of life that may, or may not, happen. Thus, one may say that if I touch a hot stove with my bare hand, I will feel pain because pain is caused by doing so. Alternately, touching a hot stove bare handed implies I will feel pain. Here, we use implication in place of casualty. And this type of implication is learned by all of us, by repeated application throughout our early growing up stages, in the learning to deal with nature, (like heat, cold, dry, wet), with acquaintances (like friend, enemy, authority, control), etc. "Implies" can simply be regarded as the phrase "it follows that". Topically, it is referred to as "entails". Classically, and in computer science, is can be replaced by If …, Then…., as in "If I touch a hot stove bare handed, then I will feel pain", "If I shout at my mother, I will be disciplined", "If I shove a friend, the friend may shove me back; but if I shove an enemy, I might have to fight"; the "then" is often left out. If, at a gathering of employees, I aloud to the the president of the company that he has lost weight, and I hear and see a dead audience, I know better next time around. It all has to do with learning!

Examples of implications that do not involve causality stem from the use of implication in describing logical consequences that are not action-events. Implication is not the same as causality when both statements do not represent (immediate) actions.

1. "Seeing a red balloon in the sky implies the sky was clear enough to see the red balloon"

Seeing the red balloon does not cause the sky to be clear. And the sky being clear does not cause me to see the red balloon. That the sky is clear enough to see the red balloon is not an action-event. If I'm looking into the sky, and there is a red balloon in the sky, and the sky is not clear, and then, the event happens that the sky clears, it can be said that the sky clearing caused me to see the balloon.

Seeing a red balloon in the sky <u>implies</u> many things. One is that I'm looking into the sky, but a more fundamental one is that something, or someone, has <u>caused</u> a red balloon to be in the sky (a child lost control of it on the ground, or it is a weather balloon and was release by weatherperson, or..). The causality has been left out of statement 1.

However,

2. "Seeing a red balloon in the sky implies that I was looking in the sky, and the sky was clear, and a red balloon is in the sky"

takes into account the causality missing in 1. Given any statement like 1., with implication given but casualty missing, a statement like 2. can be found that provides the missing causality, even if we have to use all possible statements that could be made (that is, we may not know what causes the event). Thus the difference between causality and implication can be seen as splitting hairs, but it is still necessary to distinguish between the use of the two words. We can think of implications as strings of sentences that combined via conjunction are a causal statement, the one that includes all of the "it follows that" statements. Given that A implies $B_1, \ldots, B_n$, A implies B_i, so that each B_i should be thought of as just a possible part of the cause of A. Vis a vis for $B_1, \ldots, B_n$ implies A. Care should be taken to exclude from the B_i statements that have no relation to A, but are nevertheless true. Note that a statement of causality can always be replaced by one of implication, but not visa-versa.

"If A implies B", written A→B, indicates that whenever A happens then so does B. If as well as B implies A, there are no occurrences of A without B, then B→A, and thus the two statements A & B are equivalent.

The use of "and", "or", and "not" is again given to us by childhood education and the learning of the language we use and how they relate to the validity (truth or fallacy) of the statements that they are used in.

We mean by the statement *Dan does not smoke*, we can write more formally as *it is not the case that Dan Smokes*. Equivalently, using ~ for "not", we can write ~ *(Dan Smokes)* to make it a formal, symbol sentence.

As I've said before, it is important to split the language into two, so to speak, and think of statements in the situation as written in everyday English, and formal symbolic sentences as being their counterparts in a formal language. I further separate the writing by putting sentences of the formal language on the left, and statements of the situation on the right. It should be clear that this can be done without ambiguity of which statements on the left are linked to which statements on the right. We will also go further to use the implication symbol "→" on the left linking to "If … Then", or entails, on the right, as in

P → Q ◇◇◇◇◇ *If P then Q* (, or *P entails Q)*

We use A,B,P,Q,R… (along with subscripts, if need be) to represent sentences on the left or right. We use the symbol

~ on the left for the counterpart of ***it is not the case*** on the right
v on the left for the counterpart of ***or*** on the right
& on the left for the counterpart of ***and*** on the right

By validate A, a statement on the right, it is meant to show by truth tables that A is true. Recalling truth table construction, and thinking that A is constructed by P & Q (A is in red),

P	Q	P or Q	P and Q	If P then Q
T	F	T	F	T
T	T	T	T	T
F	F	F	F	T
F	T	T	F	T

P	it is not the case that P
T	F
F	T

Validation is only done on the statements of the situation, the ones on the right. When A is valid, we write $\models$A.

By inference, it is meant the ability to derive (or prove) a sentence, on the left. A sentence A is inferred from a set of sentences K, if starting with all the sentences of K conjoined it is possible to apply the rules of logic to obtain A. The one rule most often used is that of detachment, or modus ponens, namely

From P→Q and P, infer Q. This is written formally as (P→Q) & P $\vdash$ Q

where "$\vdash$" is the symbol of derivability.

Among standard inferences are some familiar to you, like

FROM	INFER	
P	~(~P)	double negation
P & (Q v R)	(P & Q) v (P & R)	& distributive
P or (Q v R)	(P v Q) & (P v R)	v distributive
~(P & Q)	~ P v ~Q	De Morgan's Law
~(P v Q)	~P & ~Q	De Morgan's Law
P → Q	~Q → ~P	the Contrapositive

Actually, all the rules correspond to what are termed tautologies, in that they are universally valid statements – true under any interpretation of the symbols - ie. true in any situation, their truth being evaluated on the linked counterpart statements on the right.

It can be shown that all of these tautologies can be derived from modus ponens, by appropriate substitution, in certain sets of axioms of logic, most profoundly the smallest one discovered by Jan Łukasiewicz. Thus it is possible to derive the entirety of true statements given an initial set of sentences and the logic axioms by just using modus ponens and 3 axioms.

For more info: http://en.wikipedia.org/wiki/Propositional_calculus

However, most of us think using "&" and "v" and "~" and we might find ourselves reversing the idea and converting modus ponens strings into their equivalents using these connectives. It is common to just rely on the facts that:

$P \rightarrow Q$ is equivalent to $\sim(P \,\&\, \sim Q)$ is equivalent to $(\sim P \vee Q)$.

Easy examples:

$(P \rightarrow \sim Q) \,\&\, P \rightarrow \sim Q$:	$(P \rightarrow Q) \,\&\, P \rightarrow Q$	modus ponens
	$(P \rightarrow \sim Q) \,\&\, P \rightarrow \sim Q$	substitution of ~Q for Q
$(R \,\&\, (Q \vee R) \rightarrow P) \rightarrow P$:	$(Q \vee R) \rightarrow P$	given
	$R \rightarrow P$	given
	$R \,\&\, (R \rightarrow P)$	from preceding two
	$(R \rightarrow P) \,\&\, R$	commutative
	P	modus ponens

$(Q \vee R) \,\&\, P \rightarrow (Q \rightarrow P) \vee (R \rightarrow P)$ left as an exercise

Here's a derivation of $((P \rightarrow Q) \& (Q \rightarrow R)) \rightarrow (P \rightarrow R)$

1. $P \rightarrow Q$	Given
2. $Q \rightarrow R$	Given
3. $\sim P \vee Q$	1 Material Implication
4. $(Q \rightarrow R) \vee \sim P$	2 Addition
5. $\sim P \vee (Q \rightarrow R)$	4 Commutation
6. $P \rightarrow (Q \rightarrow R)$	5 Material Implication
7. $P \rightarrow (P \& (Q \rightarrow R))$	6 Absorption
8. $\sim P \vee (P \& (Q > R))$	7 Material Implication
9. $(\sim P \vee P) \& (\sim P \vee (Q > R))$	8 Distribution
10. $\sim P \vee P$	9 Simplification
11. $P \rightarrow P$	10 Material Implication
12. $\sim P \rightarrow \sim P$	11 Transposition
13. $(\sim P \rightarrow \sim P) \& (Q \rightarrow R)$	2,12 Conjunction
14. $\sim P \vee R$	3,13 Constructive Dilemma
15. $P \rightarrow R$	14 Material Implication

Phew !

Languages and Models

All languages can be split in two pieces. The syntactic part, and the semantic part; the first having to do with the rules of how sentences are formed, and later with rules on how to interpret the sentences formed using the rules of the first part. While separate pieces, they are conjoined at the hip and created bi-laterally, the rules of interpretation closely following the rules of syntax. As such, they are called Herbrand Interpretations, or minimal models, and are the ones used in most mathematics discussions on model theory, and formal systems (Doets, 1996). They give rise to the necessary conditions to define completeness and soundness, yet are artificial in that the evaluations involve compositionality interpretation which is guided by the syntax of the language. See (Partee, 1990; Chapter 13.) (I conjecture that this compositionality might be the true cause of the incompleteness of first order theories rich enough to define numbers.)

For everyday thinking it is advantages to keep syntax and semantics as far as part as possible, as the meanings of what we write or say are always at bay with the true meanings of the situation at hand; there is always a struggle to get it correct.

The part on the left may be

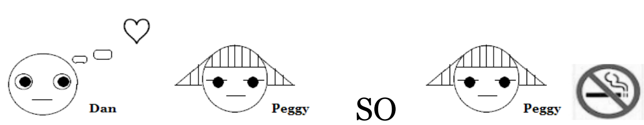
1. $P \rightarrow \sim Q$ (for Dan loves Peggy → Peggy doesn't smoke)

and on the right

2. [If Dan loves Peggy Then Peggy doesn't smoke]

or

3.



The idea is that there is a mapping from the 1 to 2 (or 3). And there is a difference between 1 and 2 (or 3). The difference is that 1 is a sentence in the description, and 2 and 3 are statements of the situation. The statements in 2 and 3 are thought of as true statements, so that, for instance, 1 being mapped to 2 (or 3) can be termed true. Thus the truth of a sentence in 1 is given by an object in 2 (or 3). This is a more robust idea of the formation of minimal model truth in formal systems, which is generally taken to be the truth table evaluation of the sentence in 1 interpreted in 2 (or 3), the evaluation relying on the satisfaction of atomic sentences of 1 in 2 (or 3) and compositionality.

As I've been saying, it's convenient to think of two tablets, one on the right that contains the set of natural English statements, S, of the account, or model, of the situation. The atoms of S are the givens of the situation, the statements of the situation. In S, a well-forming procedure can be performed to obtain every valid consequence of atoms, so we can think of every statement consequential of the atoms as belonging to the model; and there-in each is labeled with T or F using the truth table logic. However, for the most part, we view the model with just premise statements listed, knowing that the sets of statements mentioned can be generated if need be. Even in the case of pictures or sounds as the real objects of the situation, some sort of compositionality can often be achieved. And if it can't be achieved, then the mapping that links the description with the interpretation can be taken as the only source of indication of the truth of the sentences in the description. In situation semantics compositionality involving syntax to is not necessary bring forth meaning (Janssen, 2010).

Indeed here we provide a mapping of D into S in such a manner that each statement of S has a unique representation as a sentence in D.

Recapping, a small situation "Dan loves Peggy" entails "It is not the case that Peggy smokes".

MAP:	**Literal**	into	**Atom**
	P		Dan loves Peggy
	Q		Peggy Smokes

Map: **D** **S**

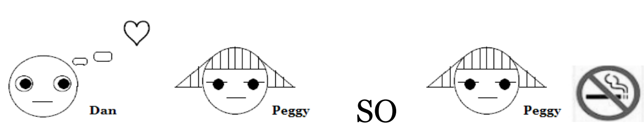
$P \rightarrow \sim Q$ [If Dan loves Peggy then it's not the case that Peggy smokes] T

S_1

$P \rightarrow \sim Q$ [It's not the case that Dan Loves Peggy] or [It's not the case that Peggy smokes] T

S_2

$P \rightarrow \sim Q$ a picture, reading, film, imagination, etc.



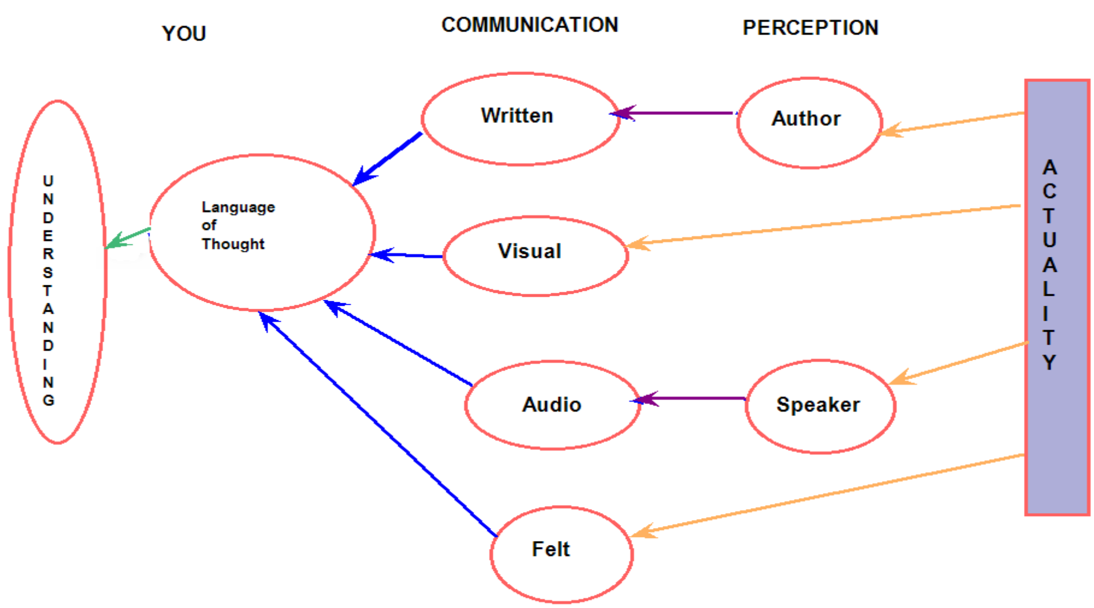
T

Note that we haven't assigned the atoms any T or F values. Out situation is not very interesting since our only premise in S is that <u>If Dan loves Peggy then it's not the case that Peggy smokes</u>. What can we infer in D? Only that ~P or Q.

There can be many representations of the situation, S, S_1,..., each isomorphic to S. In the above, S_1 and S_2 are isomorphic. And both are isomorphic to the minimal Herbrand Interpretation which is obtained by replacing P with "Dan loves Peggy" and Q with "Peggy Smokes".

We focus on only one S, and its description, D, even though there are many possible meaningful and elaborate models involving pictures, film, or even just imagination. Actually, using a model that lies in your imagination is common, and often called an interpretation, or perspective, of the situation. See (Barwise, 1990,#6)

A more striking expansion of these ideas lies in representing a language system as a sequence of models, along the lines of the following:



Here YOU is on the left, thinking that the language of thought is formal, and to the left of that is your mind. The situations are layered, through the various communication levels, visual and feeling, being the most direct. Visual and audio can also be combined in various degrees to get audio/visual. On the top row, the right most situation, S1, is the actuality, the next situation, S2, is the writer's perception S1, the next situation, S3, is the readers perception of S2, and finally the description of S3 ends up in the language of thought. Kind of like, What happened, What the writer thought happened, and What the Writer wrote is what is finally presented to YOU. The other rows are thought about analogously.

Yet another augmentation is to separate truth into varieties, like empirical truth, mathematical truth, legal truth, moral truth, etc. (See works by Wilfred Sellars)

So the diagrams for a robust system can get very complex and perhaps unfeasible to use except for the best computer representations.

As a final solidifier, let D be a description of a situation, S. Let ξ denote the injection which maps sentences of D into the statements of S. Since a model can be bigger than a minimal model, ξ is not isomorphic. Thinking in terms of situations S, or fragments, of the world, S never is a large model. Since most worlds are infinite, one would be hard pressed to be working in a natural language (or representative of one) with them, as is done with formal languages and models comprised of set theoretic structure designed to model the language needed to express mathematical ideas. Since, most generally, the sentences in D are the "same" as the statements in S, the mapping symbol is omitted. However, we could write

ξ (P) = [Dan loves Peggy], etc.

The description can be thought of as a theory, while the situation as the actuality, or model of the theory. On the left are the axioms of the theory and on the right are the true statements of the situation, statements that are true in the model. The left and right physical placement helps separate inference from validity, and syntax from semantics. The inferential engine is used on the left tablet to derive sentences that are logical consequences of the axioms using <u>logic axioms+modus ponens</u>; and the validity (or truth) engine is used on the right tablet to show that certain statements are valid (or true) consequences of the statements on the right by using <u>truth table evaluation</u>. That is, we infer on the left, and validate on the right.

In general, a situation's description, or theory D (in a logic calculus) is called complete when any true statement, any statement valid in every interpretation (model) of it, can be derived in it. If a statement, φ, is valid in the interpretation, S, it is written $S \vDash \varphi$.

So, D is termed a complete description (theory) if, for every interpretation (mapping) ξ from D into any model, S, whenever, for every φ in S, if $S \vDash \varphi$ then $D \vdash \xi^{-1}(\varphi)$. Otherwise said, without taking into account mappings from left to right, for every φ in D, $D \vdash \varphi$ whenever $D \vDash \varphi$

That for every φ in D, if D$\vdash$φ then D$\models$φ is termed soundness, and every theory is sound with respect to its models. That us, a theory D is called sound whenever any sentence derivable in it also maps to a valid statement in every interpretation of it.

For a theory, D, the question of being able to decide on the derivability of a sentence in D via an algorithmic procedure applied to the language of D, is called the decidability question. If there is such an algorithm that works for all sentences of D, then D is called a decidable theory. Completeness and decidability aren't the same and if interested, you can read the article by Curtis Brown on the decidability of propositional calculus at the following link
https://www.calculemus.org/MathUniversalis/NS/11/decidability.html

In higher order calculus systems, there are decidable theories which are not complete, and vice versa.

In Hawaii, 1975 we have listed sentences, in D, that are true in the model, and because propositional calculus is complete, these are derivable in D. The negations of these sentences are each false. So, using the sentences given, we have an interpretation, S, of them taken altogether. Since this is a true to life account of a situation, we know that there are no two statements in S that contradict each other. That is, no statement φ, in S, for which φ and its negation are both true. Thus, for no sentence φ, in D, is both φ and ~φ derivable. Such a set of sentences are said to be consistent, and have a model.

Putting the idea in reverse, a set of sentences has a model if the set is consistent. That is, here, we have gotten the sentences from the statements in the model, the situation Hawaii 1975. In reverse, one could write down any set of sentences and, if the set was consistent, it would not be possible to derive two sentences φ and ~ φ in the set and therefore, a model for the set exists. A model for the set is often taken to be the forced model, the one in which a symbolic form of the sentences is created, and then the symbols are considered as the elements of the model.

A very good and accessible account of the above concepts of completeness, soundness, decidability, and consistency can be found in (Stoll,1961), Chapter 9. It is a 12 euro book published by Dover !

The reader at this point might wonder what these ideas of completeness and decidability have to do with situations and where they can be used to evaluate situations. We can view the idea of truth in the model and derivability in the theory as a bases for practical investigation of evaluating situations. In our everyday worlds, it not so much a question of what's true or false, but more a question of what is most likely true or most likely false. It is not far from here that we will introduce the idea of a probabilistic logic system which provides this likeliness. In the mean time, we take the study of the elements of classical logic as the framework for applying the theory to everyday life.

Furthermore, and not in the scope of this paper, it is of considerable question as to the correctness of the aspect of truth in a model theoretic system. Right now, as I write this, on March 16, 2012, there is a conference in session in Munich, in which this very idea is being discussed. I include some reference to that work here, in the form of MP3 that have been posted on the conference's website. While most is very technical, listening to a little will give you the feel of the concern for the axiomatic versus non-axiomatic definitions of truth. As in my earlier conjuction, I favor the side of non-axiomatic truth.

The next higher order calculus we shall talk about is the predicate calculus along with quantification and what's commonly called first order logic (FOL), see (Stoll,1961) for a great reference. We will take our situation Hawaii, 1975 as the model, and create the theory (description) to talk about the model in FOL. But first, here's a brief look at Hawaii,1975 in propositional calculus, before we venture on.

Lizards eating with chopsticks, rain falling everywhere, and Catherine wants to leave.

In our model for Hawaii, 1975, the statements in S that Lizards eat cockroaches; fast-food is served with chopsticks; rain falls from the sky when clouds are not seen; Peggy is in denial, …, etc. are given as true. They map to the axioms of our description.

In what follows, we can and will mix the ideas of derivable and validity since theories framed in propositional calculus are complete.

Mapping "C" to "Clouds in the sky" and "R" to "Rain":

"There are no clouds in the sky implies it will not rain" is not true so that
$\sim C \rightarrow \sim R$ is derivable.

To say the same thing with the contrapositive
"It will rain implies there are clouds in the sky" is not true as well and so
$R \rightarrow C$ is derivable.

Thus the statement
"There can be no clouds in the sky, and it can still be raining", is true and $\sim C$ & R derivable. Given that $\sim C$ & R, infer that $\sim\sim(R\&\sim C)$ so that $\sim(R \rightarrow C)$.

We also feel free to work within the theory with statements taken from the situation, for instance, writing

> "Bill is accustomed to cockroaches → Bill doesn't have lizards and Bill can eat with chopsticks"
>
> in place of
>
> "$B \rightarrow \sim L$ & E".

I do this for readability in what follows, and for a check on your understanding thus far.

Peggy lives in a good area causes Peggy to be in denial so that

1) Peggy lives in a good area → Peggy is in denial (of cockroaches)
2) Bill is accustomed to cockroaches → Bill doesn't have lizards and Bill can eat with chopsticks

Actually, one might balk at 2) but since Bill doesn't have lizards and Bill can eat with chopsticks is true, the sentence is derivable.

3) Dan has lizards $\rightarrow$ Catherine wants to leave

Because Catherine wants to leave, 3) is derivable. But the reason that Catherine wants to leave is that she doesn't like cockroaches and can't eat with chopsticks. Again, we could say that what might cause a person to leave is the dislike of cockroaches and also the inability to eat with chopsticks, as in 4)

4) Catherine doesn't like lizards and she can't eat with chopsticks $\rightarrow$ she wants to leave.

However, it could be that

5) Catherine doesn't like lizards or she can't eat with chopsticks $\rightarrow$ she wants to leave.

where either of the two conditions causes the need to depart.

However, only 4) is given.

If we also knew that Catherine wants to stay with Dan, then along with 4), we know that Catherine leaves.

At any rate, if Peggy visits Dan or Bill enough, Peggy will not be in denial, and if 5) holds as a casual implication, she may depart. I leave the casual justifications of repeated visits to both Dan and Bill to your imagination; along with the differences of the effect of the visit to each of us.

Peggy's repeated visits to Dan or Bill can be formulated as

6) ((Peggy repeatedly visits Dan or repeatedly visits Bill) and (she doesn't like cockroaches)) $\rightarrow$ she wants to leave

$$((A \text{ or } B) \,\&\, C) \rightarrow E) \quad = \quad \sim((A \text{ or } B) \,\&\, C)) \text{ or } \sim E = \sim(\,(A \,\&\, C) \text{ or } (B \,\&\, C)) \text{ or } \sim E$$
$$= \;((\sim A \text{ or } \sim C) \,\&\, (\sim B \text{ or } \sim C)) \text{ or } \sim E = (\sim A \text{ or } \sim C \text{ or } \sim E) \,\&\, (\sim B \text{ or } \sim C \text{ or } \sim E)$$

where A is that Peggy repeatedly visits Dan; C is that Peggy doesn't like cockroaches
B is that Peggy repeatedly visits Bill; E is that Peggy wants to leave

In a theory, sentences can be expressed in the form of a conjunction of clauses, each clause being a disjunction of literals; the above is an example. In fact, all the axiomatic sentences can be expressed in a single sentence of this form. However, this doesn't generally give us more ways or an easier way to work with the system, unless we're a computer.

Replacing implementations with disjunctions is often helpful in remembering which literal must be true, since for every literal in a clause, at least one must be true to make the whole conjunction true, remembering that A_1 & … & A_n is true when and only when all the A_i are true. In other words, once a sentence is in normal form, CNF, it can be singled out to be false by finding a clause in it containing literals that are all are interpretable as false in the model.

Looking back at 6)

(~A or ~C or ~E) and (~B or ~C or ~E)

Since C is taken as true, ~C is false, so the above becomes

(~A or ~E) and (~B or ~E)

so that Peggy doesn't want to leave only when both ~A and ~B.

References (aside from the hyperlinks listed within the text)

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Wilfrid Sellars -- hard to find his work. However, Google searching does produce many results that are worth investigation. Christopher Gaufer was a student of his.