AN APPROACH TO ACQUIRING AND APPLYING KNOWLEDGE

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ABSTRACT

The problem addressed in this paper is how to enable a computer system to acquire facts about new domains from tutors who are experts in their respective fields, but who have little or no training in computer science. The information to be acquired is that needed to support question-answering activities. The basic acquisition approach is "learning by being told." We have been especially interested in exploring the notion of simultaneously learning not only new concepts, but also the linguistic constructions used to express those concepts. As a research vehicle we have developed a system that is preprogrammed with deductive algorithms and a fixed set of syntactic/semantic rules covering a small subset of English. It has been endowed with sufficient seed concepts and seed vocabulary to support effective tutorial interaction. Furthermore, the system is capable of learning new concepts and vocabulary, and can apply its acquired knowledge in a range of problem-solving situations.

I INTRODUCTION

Virtually any nontrivial artificial intelligence (AI) system requires a large body of machine-usable knowledge about its domain of application. Construction of a knowledge base is currently a tedious and time-consuming operation that must be performed by people familiar with knowledge representation techniques. The problem addressed in this paper is how to enable computer systems to acquire sets of facts about totally new domains from tutors who are experts in their own fields, but have little or no training in computer science. In an attempt to find a practical solution to this problem, we have developed a pilot system for knowledge acquisition, which, along with several related research issues, is discussed below.

The kinds of information we are most interested in acquiring are those needed to support what have been called "question-answering" or "fact-retrieval" systems. In particular, our interest is in collecting and organizing relatively large aggregations of individual facts about new domains, rather than in acquiring rules for judgmental reasoning. This is in contrast to previous work on such systems as those of Davis [1] and Dietterich and Michalski [2], that treat knowledge not so much as a collection of facts, but as a set of instructions for controlling the behavior of an engine.

The type of acquisition process we are exploring is "learning by being told," in contrast to the idea of "learning by example." It is this latter concept which has formed the basis of research by other investigators in this area, such as Winston [11] and Mitchell [8].

Our interest in knowledge acquisition is motivated by the desire to create computer-based systems that can aid their users in managing information. The core idea is that of a system that can talk to a user about his problems and subsequently apply other types of software to meet his needs. Such software would include data base management systems, report generators, planners, simulators, statistical packages, and the like. Interactive dialogs in natural language appear the most convenient means for obtaining most of the application-specific knowledge needed by such intelligent systems.

II KNOWLEDGE ACQUISITION THROUGH ENGLISH DIALOGS

Systems that acquire knowledge about new domains through natural-language dialogs must have two kinds of special capabilities. First, they must be capable of simultaneously learning both new concepts and the linguistic constructions used to express those concepts. (This need for simultaneous acquisition of concepts and language reflects the integral connection between language and reasoning.) Second, such systems must support interactive, mixed-initiative dialogs. Because a tutor may provide new knowledge in an incremental and incomplete manner, the system must keep track of what it has already been told so that it can deduce the existence of missing information and explicitly ask the tutor to supply it.

We are exploring the feasibility of such ideas by developing a series of Knowledge-Learning and -Using Systems (KLAUS). A KLAUS is an interactive computer system that possesses a basic knowledge of the English language, is capable of learning the concepts and vocabulary of new subject domains, and has sufficient expertise to apply its acquired knowledge effectively in problem-solving situations.

III RESEARCH ISSUES FOR KNOWLEDGE ACQUISITION

To create systems capable of acquiring knowledge through tutorial dialogs in English, several fundamental research problems must be resolved:

A powerful natural-language processing capability is required. Although much progress has been made in recent years, previous work has assumed a complete knowledge base. Knowledge-acquisition dialogs require several adaptations and extensions.

Seed concepts and seed vocabulary must be identified for inclusion in a core system. It is not at all obvious which words and concepts will be most useful in helping tutors describe the concepts of new domains.

A structure for lexical entries must be specified so that the system can acquire new lexical information. Because such information provides a key link between surface linguistic form and underlying meaning, structural specification is a very challenging task for certain categories of words, particularly verbs.

The linguistic constructions that people use in introducing new concepts must be identified and analyzed so they can be interpreted correctly by the natural-language processing system. Such constructions range from simple syntactic patterns to complex uses of analogy.

A flexible scheme of knowledge representation is necessary. The representation must have general expressive power, since it may be applied to many different domains and must support the addition of new information. It should include inherent features that can aid in organizing knowledge and in supporting the incremental acquisition of knowledge.

An efficient problem-solving capability is needed to answer questions and to draw inferences for integrating newly acquired information. This capability must be based on general principles, because no application-specific problem-solving procedures will be included in the system. (How to acquire such procedures is a separate and interesting research question.)

A methodology is needed for integrating new concepts into the system's knowledge base. Because tutors will often provide only partial descriptions of new concepts, methods have to be devised for ascertaining what additional facts must be sought from the tutor to insure proper linkage between the new concepts and those previously acquired.

A set of readily understandable questions is needed for eliciting information from tutors. The length and number of questions should be minimized to impose as small a burden on tutors as possible.

These problems must be dealt with in an integrated manner, balancing the requirements of one facet of the system against those of others. Our initial attempts to cope with this complex of issues are presented below.

IV THE NANOKLAUS SYSTEM

A. Overview

We have recently developed and tested a pilot KLAUS, called NANOKLAUS. A sample transcript of interactions with this system is contained in the appendix. The principal components of NANOKLAUS are a natural-language processing module based on LIFER [4], a formal deduction module that operates on a data base of well-formed formulas (wffs) in a many-sorted first-order logic, and a number of support procedures that aid in acquiring knowledge about new subject domains and maintaining the data base. First-order logic was chosen as the basis for our knowledge representation scheme because of its generality and because of the computational soundness and power of problem-solving systems that use it.

B. Seed Concepts and Vocabulary

NANOKLAUS comes preprogrammed with a fixed set of syntactic and semantic rules covering a small subset of English. It also comes with seed concepts and a seed vocabulary, which are to be extended during tuition. For example, the system knows about such things as PHYSICAL OBJECTS, PERSONS, MEASURES, and the like. It has a knowledge of the basic function words of English, as well as of such words as "unit," "kind," and "plural" that are used frequently in stating definitions of new words and concepts. These seed concepts allow the untutored NANOKLAUS to engage in conversations like the following:*

```
73> A length is a measure
You're saying that anything that is a
  LENGTH is also a MEASURE.
OK, now I have assimilated LENGTH.
74> A foot is a unit of length
FOOTS are the first units of LENGTH you've
  defined. Now I have assimilated FOOT.
75> The plural of foot is feet
FEET - got it. Thanks.
76> A meter is a unit of length
```

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* The tutor's inputs are underlined in these examples. All other text is produced by NANOKLAUS.

How is it related to FOOT? >> There are 3.3
  feet in a meter
Now I have assimilated METER.
77> A physical object has a length
So PHYSICAL OBJECTS have LENGTHS.

Exactly what to use as seed concepts is problematical for a system that must bootstrap its entry into a new domain. Most of the seed concepts in NANOKLAUS are classes of THINGs and RELATIONs. They have been included in the system either simply to avoid forcing tutors to relate everything to the most general concept (THING), or because they have a special status in English. For example, because pronominal usage depends on gender, the class MALE-BEING is defined and associated with the pronoun "he." One might consider defining as seed concepts a set of primitives, to which all other concepts must be reduced, but such a reductionist approach is probably unworkable [3].

NANOKLAUS uses five principles of knowledge organization to integrate new knowledge: (1) there are things; (2) there are subclasses of things (i.e., things can be subclassified); (3) there are relations among things; (4) there are subclasses of relations; (5) some of the relations are functions. The concepts of uniqueness and equality also play important roles. NANOKLAUS is not programmed to hold explicit conversations about these concepts, but rather to use them in its internal operations.

C. The Natural-Language Component

The natural-language component of NANOKLAUS uses a pragmatic grammar in the style of LADDER [6]. Although most of the linguistic processing performed by the system follows fairly standard practice, the pragmatic grammar is distinguished by its explicit identification of a number of syntactic structures used principally to define new concepts. As an oversimplified example, NANOKLAUS might be thought of as looking for the syntactic pattern

<S> => <A> <NEW-WORD> <BE> <A> <KNOWN-COUNT-NOUN>

to account for such inputs as

A CARRIER IS A SHIP.

When one of these concept-defining patterns is recognized, an acquisition procedure associated with the pattern is invoked. This procedure generally adds new facts to the system's set of wffs and generates new entries in its lexicon. The various acquisition procedures also have provisions for responding to the tutor. Response generation is accomplished through the use of preprogrammed phrases and templates.

D. Using Dialog to Aid Acquisition and Assimilation

By and large, it is unreasonable to expect tutors to volunteer all the information NANOKLAUS needs to assimilate new concepts. In particular, tutors cannot be expected to know what conclusions NANOKLAUS will draw about a newly taught concept from its previous knowledge, since they know neither the details of its knowledge nor the even more esoteric details of its assimilation procedures. NANOKLAUS must ask the tutor for the information it needs. But wording the system's questions in an understandable form involves a number of human engineering difficulties.

The acquisition of new verbs offers a cogent illustration of the problem. English verbs are highly idiosyncratic; making proper entries for them in a lexicon can be a formidable task. Among other considerations, one must ascertain a verb's passivity and transitivity, determine whether its indirect object can become the object of a FOR or TO prepositional phrase, whether it is reflexive or nonreflexive, and how the syntactic cases of its arguments may be "normalized" when the verb appears in different syntactic constructions. NANOKLAUS's tutors, of course, cannot be expected to describe verbs in linguistic terms, so the system asks a series of questions tutors can understand to elicit the same information. The following is a typical verb-acquisition exchange:

```
92>An officer can assign a unit
Give the -ed and -en forms of ASSIGN
 (for example, for GO: WENT GONE):
    >>assigned assigned
If an OFFICER can ASSIGN a UNIT something,
  type the most general description of that
```

```
  something, otherwise <return>
  >>          (user typed a carriage return)
If an OFFICER can ASSIGN something a UNIT,
  type the most general description of
  that something, otherwise <return>
  >>a task group
Can an OFFICER ASSIGN an UNIT TO a
  TASK GROUP ? >>yes
Could an UNIT be ASSIGNED a TASK GROUP by
  an OFFICER ? >>yes
Can an OFFICER ASSIGN an UNIT with a
  TASK GROUP ? >>no
Can an OFFICER ASSIGN a TASK GROUP ? >>no
Can an OFFICER ASSIGN ? >>no
```

Verbs that produce rather different answers to the above questions include GIVE, BUY, RUN (run a machine), SERVE and SUPPLY.*

E. The Knowledge Representation System

NANOKLAUS's knowledge representation system uses a many-sorted first-order logic, that combines features from [9] and [5]. The backbone of the system is a treelike data structure reflecting the hierarchy of sorts (or classes) used by the system. This tree is "tangled" in that any given sort may have multiple ancestors. It is no accident that a sort hierarchy should serve as the primary data structure for an English-speaking acquisition system. "ISA" hierarchies are used by many natural-language processing systems; it appears that something very similar to a sort hierarchy plays a central role in the way humans organize _their_ knowledge [7].

A fundamental task of the deductive system is to determine whether or not a given entity belongs to a particular sort. To aid in this task, NANOKLAUS maintains information about the direct descendants of each sort, such as whether some or all of the descendants of an ancestor exhaust (span) it, and whether two or more sibling sorts are mutually exclusive.

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* NANOKLAUS does not consider modal verbs (e.g., "want" and "know"), or verbs with particles (e.g., "pick up", "preside over") or sentential objects (e.g., "The captain requested _that the ship change course_").

The utilization of sort information is clearly illustrated in the following dialog with NANOKLAUS, and in the extended dialog shown in the appendix:

```
80>A ship is a unit
You're saying that anything that is a SHIP is
  also an UNIT. What is an UNIT?  >>a thing
You're saying that anything that is an UNIT is
  also a THING. Which of the following, if
  any, are proper subclasses of UNIT:
  PHYSICAL OBJECT, LEGAL PERSON, or MEASURE?
  >>none of them
Which of the following classes, if any, could
  never have any members in common with UNIT:
  PHYSICAL OBJECT, LEGAL PERSON, or MEASURE ?
  >>none
OK, now I have assimilated UNIT.
OK, now I have assimilated SHIP.
81>A ship is a physical object
You're saying that anything that is a SHIP is
  also a PHYSICAL OBJECT. Is ANIMATE OBJECT a
  proper subclass of SHIP? >>no
IS ANIMATE OBJECT necessarily composed of
  entirely different members from SHIP?
  >>yes
Do ANIMATE OBJECT and SHIP span the set of all
  PHYSICAL OBJECTS >>no
OK, now I have assimilated SHIP.
82>A submarine is a ship
You're saying that anything that is a SUBMARINE
  is also a SHIP. OK, now I have assimilated
  SUBMARINE.
83>A destroyer is a ship
You're saying that anything that is a DESTROYER
  is also a SHIP. Is SUBMARINE a proper
  subclass of DESTROYER? >>no
Is SUBMARINE necessarily composed of entirely
  different members from DESTROYER?  >>yes
Do SUBMARINE and DESTROYER span the set of all
  SHIPS?  >>no
OK, now I have assimilated DESTROYER.
84>A carrier is a ship
You're saying that anything that is a CARRIER
  is also a SHIP. Which of the following, if
  any, are proper subclasses of CARRIER:
  SUBMARINE or DESTROYER?  >>neither of them
Which of the following classes, if any, could
  never have any members in common with
  CARRIER: SUBMARINE or DESTROYER ?
  >>both of them
What combination of the following subclasses,
  if any, together with CARRIER, span the
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  class of all SHIPS  (with or without
  overlapping): SUBMARINE or DESTROYER ?
  >>neither of them
OK, I have assimilated CARRIER.
85>A Kittyhawk is a carrier
You're saying that anything that is a KITTYHAWK
  is also a CARRIER. OK, now I have assimilated
  KITTYHAWK.
.
.
.
98>A carrier has a doctor who is a person
So CARRIERS have PEOPLE for DOCTORS.
Must a CARRIER have exactly one DOCTOR?  >>no
99>The Constellation is a Kittyhawk
You're saying that CONSTELLATION is one
  instance of a KITTYHAWK.
OK, now I know about CONSTELLATION.
100>The JFK is a Kittyhawk
You're saying that JFK is one instance of a
  KITTYHAWK. OK, now I know about JFK.
1>The JFK is commanded by Moffet
ASSERTING THAT (MOFFET COMMAND JFK)
2>The length of the JFK is 1072 feet
```

V FUTURE PROSPECTS

At this time NANOKLAUS can be best described as a fragile proof-of-concept system still in its early developmental stage. During this coming year, we plan to greatly expand its linguistic coverage by replacing our current pragmatic grammar with Robinson's [10] DIAGRAM grammar. Once this has been accomplished and NANOKLAUS's verb acquisition package extended to accept particles and prepositional phrases, we believe NANOKLAUS can serve as a useful tool for aiding AI researchers in the construction of knowledge bases for other AI systems--a task that currently consumes an inordinate proportion of research effort.

As suggested in the introduction, one of our long-term objectives is the extension of KLAUS to knowing about diverse types of external software packages. Given knowledge of such packages, a KLAUS could serve as an agent that interacts with them on a user's behalf. To explore these possibilities, we plan in the near future to provide NANOKLAUS with the capability of using a conventional data base management system. In this configuration, a user should be able to tell NANOKLAUS about a new domain, about a data base containing information pertaining to that domain, and about the interrelationship of the two. The new system would then be able to use the data base in answering questions regarding the domain.

Our work in the area of knowledge acquisition per se has really just begun. As development proceeds, we plan to turn our attention to making provisions for learning by analogy, for acquiring and reasoning about the internal structures of processes, for dealing with causality, and for dealing with mass terms.

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APPENDIX

Training NANOKLAUS About Aircraft Carriers

What follows is a transcript of a dialog with the NANOKLAUS system. The consecutive numbers at the left of some lines are NANOKLAUS prompts; the sentences on those lines are typed by the user. Subsequent utterances by NANOKLAUS and the user are clearly distinguishable, so are not specially marked. Sentences in braces are descriptive annotations added "after the fact".

```
@nanoklaus
 Welcome to Nanoklaus !
 Just say 'Help' if you need help.

 1_what do you know about?                      {The user asks NANOKLAUS
                                                 what classes of things
                                                 have been defined to it.}
 I know about PHYSICAL OBJECTS, PEOPLE, MEN, WOMEN, LEGAL PERSONS,
 MEASURES, and THINGS (of course).

 2_A length is a measure                        {The user defines Length.}
 You're saying that anything that is a LENGTH is also a MEASURE.
 Ok, now I understand LENGTH.

 3_A foot is a unit of length                   {And Foot.}
 FOOTS are the first units of LENGTH you've defined.
 Now I understand FOOT.

 4_The plural of foot is feet
 FEET - got it. Thanks.
```

5_A meter is a unit of length
How is it related to FOOT? There are 3.3 feet in a meter

{Whenever an additional unit of a measure is defined, NANOKLAUS asks for the conversion factor to one of the previously defined units.}

Now I understand METER.
6_A physical object has a length

{The user gives the domain over which an attribute named LENGTH is defined, and implicitly indicates that the value of this attribute must be an element of the set of lengths, defined in (2).}

So PHYSICAL OBJECTS have LENGTHS.
Must a PHYSICAL OBJECT have exactly one LENGTH? yes

{NANOKLAUS determines that the relationship between physical objects and lengths is functional.}

7_A ship is a physical object
You're saying that anything that is a SHIP is also a PHYSICAL OBJECT.
Is PERSON a proper subclass of SHIP? no

{When a new subset of an existing set is created, NANOKLAUS queries the user to determine how it relates to that set, and to other previously defined subsets of that set.}

Is PERSON necessarily composed of entirely different members from SHIP? yes
Do PERSON and SHIP span the set of all PHYSICAL OBJECTS? no
Ok, now I understand SHIP.
8_A ship is a unit

{Sorts may be subsets of more than one set.}

You're saying that anything that is a SHIP is also an UNIT.
What is an UNIT? a thing

{NANOKLAUS always wants to know how the set and superset relate to the existing taxonomy (the taxonomy is always a connected graph). Note that it generated the incorrect indefinite article in the question.}

You're saying that anything that is an UNIT is also a THING.
Which of the following, if any, are proper subclasses of UNIT:
PHYSICAL OBJECT, LEGAL PERSON, or MEASURE? none of them
Which of the following classes, if any, could never have any members in common with UNIT:
PHYSICAL OBJECT, LEGAL PERSON, or MEASURE ? none of them
Ok, now I understand UNIT.
Ok, now I understand SHIP.

9_A unit {The user corrects NANOKLAUS' English.}
OK, A UNIT
10_A submarine is a ship
You're saying that anything that is a SUBMARINE is also a SHIP.
Ok, now I understand SUBMARINE.
11_A destroyer is a ship
You're saying that anything that is a DESTROYER is also a SHIP.
Is SUBMARINE a proper subclass of DESTROYER? no
Is SUBMARINE necessarily composed of entirely different
members from DESTROYER? yes
Do SUBMARINE and DESTROYER span the set of all SHIPS? no
Ok, now I understand DESTROYER.
12_A carrier is a ship
You're saying that anything that is a CARRIER is also a SHIP.
Which of the following, if any, are proper subclasses of CARRIER:
SUBMARINE or DESTROYER? neither of them
Which of the following classes, if any, could never have any members
in common with CARRIER:
SUBMARINE or DESTROYER ? both of them
What combination of the following subclasses, if any, together with
CARRIER, span the class of all SHIPS (with or without overlapping):
SUBMARINE or DESTROYER ? neither of them
Ok, now I understand CARRIER.
13_A Kittyhawk is a carrier
You're saying that anything that is a KITTYHAWK is also a CARRIER.
Ok, now I understand KITTYHAWK.
14_A Forrestal is a carrier
You're saying that anything that is a FORRESTAL is also a CARRIER.
Is KITTYHAWK a proper subclass of FORRESTAL? no
Is KITTYHAWK necessarily composed of entirely different
members from FORRESTAL? yes
Do KITTYHAWK and FORRESTAL span the set of all CARRIERS? no
Ok, now I understand FORRESTAL.
15_A Hermes is a carrier
You're saying that anything that is a HERMES is also a CARRIER.
Which of the following, if any, are proper subclasses of HERMES:
KITTYHAWK or FORRESTAL? neither of them
Which of the following classes, if any, could never have any members
in common with HERMES:
KITTYHAWK or FORRESTAL ? both of them
What combination of the following subclasses, if any, together with
HERMES, span the class of all CARRIERS (with or without overlapping):
KITTYHAWK or FORRESTAL ? neither of them
Ok, now I understand HERMES.
16_A task group is a unit
You're saying that anything that is a TASK GROUP is also a UNIT.
Is SHIP a proper subclass of TASK GROUP? no
Is SHIP necessarily composed of entirely different members from
TASK GROUP? yes
Do SHIP and TASK GROUP span the set of all UNITS? no
Ok, now I understand TASK GROUP.

17_An officer is a person
You're saying that anyone who is an OFFICER is also a PERSON.
Which of the following, if any, are proper subclasses of OFFICER:
MAN or WOMAN? neither of them
Which of the following classes, if any, could never have any members
in common with OFFICER:
MAN or WOMAN ? neither of them
What combination of the following subclasses, if any, together with
OFFICER, span the class of all PEOPLE (with or without overlapping):
MAN or WOMAN ? neither
Ok, now I understand OFFICER.
18_An officer can command a ship
Give the -ed and -en forms of COMMAND
(for example, for GO: WENT GONE):
commanded commanded

{Here the verb COMMAND is defined as mapping into a predicate over (officer, ship) pairs.}

If an OFFICER can COMMAND a SHIP something , type in the most general
description of that thing, otherwise type <carriage return>

{NANOKLAUS tried to determine if COMMAND doesn't in fact take a third argument.}

If an OFFICER can COMMAND something a SHIP, then please type in
the most general description of that thing,
otherwise type <carriage return>
If an OFFICER can COMMAND something to a SHIP, then please type in
the most general description of that thing, otherwise <carriage return>

{In this context, "to" marks an indirect object, not the destination of a motion verb.}

If an OFFICER can COMMAND a SHIP to something , then please type in
the most general description of that thing, otherwise <carriage return>
Can a SHIP be COMMANDED by an OFFICER ? yes

{NANOKLAUS acquires information enabling it to map into the canonical predicate calculus form both passive occurrences of the verb, and occurrences in which some of the noun phrases are omitted.}

Can a SHIP COMMAND ? no
Can an OFFICER COMMAND ? yes
19_An officer can assign a task group a unit
Give the -ed and -en forms of ASSIGN
(for example, for GO: WENT GONE):
assigned assigned

{Another example, this time a ditransitive verb.}

Can an OFFICER ASSIGN a UNIT TO a TASK GROUP ? yes
Could a UNIT be ASSIGNED a TASK GROUP by an OFFICER ? yes
Can an OFFICER ASSIGN a UNIT with a TASK GROUP ? no
Can an OFFICER ASSIGN a TASK GROUP ? no
Can an OFFICER ASSIGN ? yes

20_Some ships can be nuclear {NANOKLAUS is taught an adjective that it maps into a unary predicate ranging over ships.}

You're saying that at least one SHIP could be NUCLEAR.
21_A nationality is a thing
You're saying that anything that is a NATIONALITY is also a THING.
Which of the following, if any, are proper subclasses of NATIONALITY:
PHYSICAL OBJECT, LEGAL PERSON, MEASURE, or UNIT? none of them
Which of the following classes, if any, could never have any members
in common with NATIONALITY:
PHYSICAL OBJECT, LEGAL PERSON, MEASURE, or UNIT ? all of them
Ok, now I understand NATIONALITY.
22_A ship has a nationality
So SHIPS have NATIONALITIES.
Must a SHIP have exactly one NATIONALITY? yes
23_A rank is a thing
You're saying that anything that is a RANK is also a THING.
Which of the following, if any, are proper subclasses of RANK:
PHYSICAL OBJECT, LEGAL PERSON, MEASURE, UNIT, or NATIONALITY? none of them
Which of the following classes, if any, could never have any members
in common with RANK:
PHYSICAL OBJECT, LEGAL PERSON, MEASURE, UNIT, or NATIONALITY ? all of them
Ok, now I understand RANK.
24_A officer has a rank
So OFFICERS have RANKS.
Must an OFFICER have exactly one RANK? yes
25_A carrier has a doctor who is a person
So CARRIERS have PEOPLE for DOCTORS.
Must a CARRIER have exactly one DOCTOR? no

{Here the attribute named DOCTOR takes values that must be members of the set of persons.}

26_The JFK is a Kittyhawk
You're saying that JFK is one instance of a KITTYHAWK.
Ok, now I know about JFK.

{First introduction of an individual.}

27_The JFK is a Forrestal
You're saying that JFK is one instance of a FORRESTAL.
Sorry, but JFK is an individual of the following types: KITTYHAWK,
and one of them conflicts with FORRESTAL.

{NANOKLAUS used its subset relationship knowledge to discover an inconsistency in its tutor's assertions.}

28_The Saratoga is a Forrestal
You're saying that SARATOGA is one instance of a FORRESTAL.
Ok, now I know about SARATOGA.
29_The Enterprise is a carrier
You're saying that ENTERPRISE is one instance of a CARRIER.
Ok, now I know about ENTERPRISE.
30_The Bulwark is a Hermes
You're saying that BULWARK is one instance of a HERMES.
Ok, now I know about BULWARK.

31_US is a nationality
You're saying that US is one instance of a NATIONALITY.
Ok, now I know about US.
32_UK is a nationality
You're saying that UK is one instance of a NATIONALITY.
Ok, now I know about UK.
33_US is the nationality of the JFK
Proving (US is the nationality of JFK)
Asserting that (US is the nationality of JFK)

{Asserting the value of an attribute. Note that instead of blindly entering the fact in the fact store, NANOKLAUS first looks to see if it already knows the fact.}

34_The nationality of the Saratoga is US
Proving (US is the nationality of SARATOGA)
Asserting that (US is the nationality of SARATOGA)
35_The nationality of the Enterprise is US
Proving (US is the nationality of ENTERPRISE)
Asserting that (US is the nationality of ENTERPRISE)
36_The nationality of the Bulwark is UK
Proving (UK is the nationality of BULWARK)
Asserting that (UK is the nationality of BULWARK)
37_Moffet is an officer
You're saying that MOFFET is one instance of an OFFICER.
Ok, now I know about MOFFET.
38_Brown is an officer
You're saying that BROWN is one instance of an OFFICER.
Ok, now I know about BROWN.
39_Captain is a rank
You're saying that CAPTAIN is one instance of a RANK.
Ok, now I know about CAPTAIN.
40_The rank of Brown is captain
Proving (CAPTAIN is the rank of BROWN)
Asserting that (CAPTAIN is the rank of BROWN)
41_Captain is the rank of Moffet
Proving (CAPTAIN is the rank of MOFFET)
Asserting that (CAPTAIN is the rank of MOFFET)
42_The JFK is commanded by Moffet
Proving (MOFFET commanded JFK)
Asserting that (MOFFET commanded JFK)

{Describing an event or situation through verb usage. Note transformation from passive to active by NANOKLAUS.}

43_Brown commands the Saratoga
Proving (BROWN commanded SARATOGA)
Asserting that (BROWN commanded SARATOGA)

{NANOKLAUS employs an untensed logic; its canonical expression of its knowledge is always past tense.}

44_Moffet commands the JFK.
Proving (MOFFET commanded JFK)
I already knew that.

{NANOKLAUS detected that it had previously been told this, even though the previous assertion had been in a different voice.}

45_Brown commands.
Proving (BROWN commanded Some ship) {NANOKLAUS filled in the omitted argument, and then determined that it had been told of an event or situation which conceivably could be a description of the same event or situation.}
Is any one of the following statements true, concerning this event:
the SHIP is SARATOGA ? Yes
46_Brown commands a Forrestal.
Proving (BROWN commanded Some forrestal)
Is any one of the following statements true, concerning this event:
the FORRESTAL is SARATOGA ? Yes.
47_1072 feet is the length of the JFK
Asserting that (1072 FEET is [equal to] the LENGTH of JFK)
48_the length of the Bulwark is 650 feet
Asserting that (the LENGTH of BULWARK is [equal to] 650 FEET)
49_ctg18 is a task group
You're saying that CTG18 is one instance of a TASK GROUP.
Ok, now I know about CTG18.
50_ctg36 is a task group.
You're saying that CTG36 is one instance of a TASK GROUP.
Ok, now I know about CTG36.
51_Moffet assigned the Saratoga to ctg36
Proving (MOFFET assigned CTG36 SARATOGA)
Asserting that (MOFFET assigned CTG36 SARATOGA)
52_The Saratoga was assigned to ctg18 by Brown
Proving (BROWN assigned CTG18 SARATOGA)
Asserting that (BROWN assigned CTG18 SARATOGA)
53_The Enterprise is a nuclear ship {Using an adjective to predicate.}
Asserting that (ENTERPRISE is a nuclear ship)
54_What are the ships? {The user interrogates NANOKLAUS to see that it has assimilated what it has been told. Note that the user had not explicitly described any of the answers as ships.}
ENTERPRISE, JFK, SARATOGA, AND BULWARK.
55_Who commands the Kittyhawks?
Proving (Some officer commanded Some kittyhawk) {NANOKLAUS uses its sort knowledge to find the correct domain for the wh word.}

(MOFFET JFK).

56_Who commands the JFK?
Proving (Some officer commanded JFK)
MOFFET.
57_Brown commands what?
Proving (BROWN commanded Some ship)
SARATOGA.

58_What is the length of the JFK?
Proving (Some measure is [equal to] the LENGTH of JFK)
1072 FEET.
59_How many meters is the length of the JFK?
Proving (Some length is [equal to] the LENGTH of JFK)
324.8485. {Using the unit conversion factors.}
60_What is the nationality of the Saratoga?
Proving (Some nationality is the nationality of SARATOGA)
US.
61_The nationality of what is UK?
Proving (UK is the nationality of Some ship)
BULWARK.
62_Brown assigned what ships?
Proving (BROWN assigned Some task group Some ship)
(CTG18 SARATOGA). {I.e., Brown assigned CTG18 Saratoga.}
63_Who assigned ships to ctg36?
Proving (Some officer assigned CTG36 Some ship)
(MOFFET SARATOGA).
64_Who assigned ctg18 the Saratoga?
Proving (Some officer assigned CTG18 SARATOGA)
BROWN.
65_Who assigned the Saratoga?
Proving (Some officer assigned Some task group SARATOGA)
(MOFFET CTG36) and (BROWN CTG18).
66_Which ships are nuclear?
Proving (Some ship is a nuclear ship)
ENTERPRISE.
67_What do you know about carriers?
US is the nationality of JFK.
US is the nationality of SARATOGA.
US is the nationality of ENTERPRISE.
UK is the nationality of BULWARK.
MOFFET commanded JFK.
BROWN commanded SARATOGA.
1072 FEET is [equal to] the LENGTH of JFK.
the LENGTH of BULWARK is [equal to] 650 FEET.
MOFFET assigned CTG36 SARATOGA.
BROWN assigned CTG18 SARATOGA.
ENTERPRISE is a nuclear ship.

{NANOKLAUS has access to its fact store indexed by sort, as well as by predicate. Here it reports all the atomic facts about carriers it has.}

68_The plural of Hermes is Hermeses
HERMESES - got it. Thanks.

69_Now describe ship
SHIP:
A SHIP is a PHYSICAL OBJECT and UNIT.
Therefore it is also a THING.
SUBMARINES, DESTROYERS, and CARRIERS are SHIPS.
SUBMARINES, DESTROYERS, and CARRIERS cannot have any members in common.
SHIP has the following attributes and types:
NATIONALITY.
SHIPS can be NUCLEAR.

{Here it describes all the generic and sort information it has about a given sort.}

70_What Hermeses are there?
BULWARK.
71_Please describe Moffet then describe Brown. {Giving all facts known about a particular individual.}

Moffet is an officer. His or her rank is CAPTAIN. MOFFET commanded JFK. MOFFET assigned CTG36 SARATOGA.
Brown is an officer. His or her rank is CAPTAIN. BROWN commanded SARATOGA. BROWN assigned CTG18 SARATOGA.
72_Now tell me about Saratoga.
Saratoga is a forrestal. Its nationality is US. BROWN commanded SARATOGA. MOFFET assigned CTG36 SARATOGA. BROWN assigned CTG18 SARATOGA.
73_,JFK {Using the parser's elliptical sentence facility, LIFER figures out and displays the complete sentence/query.}
NOW TELL ME ABOUT JFK

Jfk is a kittyhawk. Its nationality is US. MOFFET commanded JFK. 1072 FEET is [equal to] the LENGTH of JFK.
74_What do you know? {Listing all atomic facts in the fact store.}
US is the nationality of JFK.
US is the nationality of SARATOGA.
US is the nationality of ENTERPRISE.
UK is the nationality of BULWARK.
CAPTAIN is the rank of BROWN.
CAPTAIN is the rank of MOFFET.
MOFFET commanded JFK.
BROWN commanded SARATOGA.
1072 FEET is [equal to] the LENGTH of JFK.
the LENGTH of BULWARK is [equal to] 650 FEET.
MOFFET assigned CTG36 SARATOGA.
BROWN assigned CTG18 SARATOGA.
ENTERPRISE is a nuclear ship.

{Listing all the sorts.}

75_What do you know about?
I know about PHYSICAL OBJECTS, PEOPLE, MEN, WOMEN, OFFICERS, SHIPS, SUBMARINES, DESTROYERS, CARRIERS, KITTYHAWKS, FORRESTALS, HERMESES, LEGAL PERSONS, MEASURES, LENGTHS, UNITS, TASK GROUPS, NATIONALITIES, RANKS, and THINGS (of course).

76_Who commands what?
Proving (Some officer commanded Some ship)
(MOFFET JFK) and (BROWN SARATOGA).
77_good bye
See you later

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