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A Typology for Resource Profiling and Modeling

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Abstract

A critical aspect of many simulation studies is the modeling of resources. A general typology, or multidimensional categorization, is proposed for characterizing resources. Such a characterization, or resource "profile," serves as a "meta–model" from which relevant properties may be identified and incorporated into a resource model. The typology is applicable across domains and is illustrated by example profiles of a mechanical resource (a tank), an electronic resource (a web service), and a living resource (an oilfield employee).

1. Introduction

The adoption of object orientation in discrete–event simulation and the creation of modular object–oriented simulation languages such as SIMSCRIPT III [1] offer the tantalizing possibility of creating modules of customizable, reusable resource models. Creating such modules, especially on a broad scale, requires an understanding of the properties of diverse resources drawn from a wide spectrum of domains. Though they may call resources by different names—supplier, server, service, employee, contractor, component, and so on—the following fields have something to say about resources:

- Discrete–event simulation and simulation languages
- Distributed and client–server systems, including web services (semantic or otherwise) and service–oriented architecture
- Computer architecture and computer operating systems
- Software patterns
- Database and document management
- Project management
- Networking, both social and electronic
- Supply chain management, logistics, and operations research
- Human resource management
- Natural resource management

After a survey of several of these domains, we propose and describe a typology or multidimensional categorization of resource properties. We then present examples of resource profiles using this typology.

2. Domain surveys

2.1. Discrete–event simulation languages

Programming languages designed specifically for discrete–event simulation paint fairly simple portraits of resources, though some languages offer a richer set of resource properties than others. In GPSS/H, single–server "facilities" or multi–server "storages" wait passively for client entities known as "transactions" to appear on their doorsteps, serve them as demanded, and retreat to idleness when finished [2]. In SIMSCRIPT II.5, resources likewise wait passively for client entities to demand their service. While clients come and go and sometimes wait in a server's queue, servers remain fairly static, unchanging in attributes or numbers during a simulation run [3].

In some languages, resources vary in their availability and mobility. A SLAM II resource may process multiple activities simultaneously and may fail while serving a client [4]. In SIMAN V, a resource may be composed of one or more servers and may move around its environment. While a resource may be busy or idle as in other languages, it may also fail according to a time– or count–based rule [5]. It may also starve waiting for other resources on which it depends or block due to an outside signal [6]. An Arena resource may be inactive—in working order, but unavailable [7].

Collecting properties across multiple languages yields a composite view of resources as persistent, but relatively passive entities that nonetheless own queues, participate in collections, contain and compete with other resources, pass through multiple states of availability, and experience preemption.

2.2. Client–server architecture on the Internet

Managers of systems that provide computer services over the Internet seek to balance their system capability against the demands of the clients. They observe that clients differ from each other in terms of network, hardware, and software capability [8], as well as in urgency of demand and service privilege [9].

The World Wide Web Consortium (W3C) defines a web service as "a software application … whose interfaces and bindings are capable of being defined, described and discovered … and [that] supports direct interactions with other software applications…" [10]. While current web services employ a variety of technologies and architectures, the proponents of Service–Oriented Architecture argue that a well–designed web service exhibits independence of other resources, adherence to a communications agreement, autonomy, hiding of details not essential to the service contract, reusability, composability, discoverability, and the discipline to forget what it knew of a client's business after fulfilling its obligations to the client [11].

2.3. Project management

Project managers necessarily concern themselves with acquiring and scheduling resources, which may be defined as "…any person, object, tool, machine or sum of money needed for work on a project" [12]. Resources may be exhaustible, replenishable, or reusable. In addition, the many techniques used for estimating project timing and identifying resource requirements, such as the Programme Evaluation and Review Technique (PERT), implicitly acknowledge time itself as a critical resource [12].

2.4. Software patterns

Software patterns represent best practices for the object–oriented design of parts of computer programs. Descriptions of software patterns shed some light on the properties of resources. For example, two different resources may implement the same interface and so appear the same to a potential client. Through Delegation, an entity can play multiple roles, as when an entity is now a resource and now a client. Through Composition, a resource may be composed of other resources, which may in turn be composed of other resources. Through the Strategy Pattern, two resources of the same type may achieve the same outcome in different ways. Finally, the Producer–Consumer pattern allows an entity to create products at one rate while one or more other entities take up the product at another rate. Other patterns provide for concurrency [13].

2.5. Human resource management

The related fields of Human Resource Development, Human Resource Management, and Human Resource Planning recognize human resources as changing through time (due to experience, education, training, fatigue, and aging), possessing different suites of competencies and stores of knowledge, as possessed of their own interests, motivations, and outlooks [14], and as participating in social networks that themselves affect resource value and effectiveness [14, 15].

Human resources understandably present great challenges to the creation of a comprehensive categorization of resource properties. A discrete–event simulation of personnel in the Royal Netherlands Navy laments, for example, that human resources may be sporadically and unpredictably unavailable. The study pointed out, though, that defining the needs of the personnel and the needs of the Navy in the same language facilitated direct comparison of the two. In addition, the job of matching personnel to the Navy's openings could be assigned to an independent third party—yet another resource [16].

2.6. Supply chain management

Supply chain management (SCM) seeks to optimize use of resources starting with the ultimate provider of raw materials and proceeding all the way to the end customer or user. It considers a complex network of suppliers, vendors, distributors, customers, facilities, and so forth, whose operations must be coordinated to achieve the best performance throughout the supply chain. Properties of the players (vendors, manufacturers, etc.) include location, the services provided, and the internal policies governing their operations. Properties of the goods and services include cost, size, weight, and the quantum of incremental productivity. Properties of the environment in which the players operate include duties and tariffs [17, 18].

Table 1: Resource Typology

Existential	Availability	Utility	Implementation

Identity
Origin
Living
Consumption
Make–up
Traits
	Status
	Location
	Schedule
	Delivery mode
	Failure mode
	Selectivity
	Exclusivity
		Competencies
		Size
		Performance
		  Deliverability
		  Reliability
		  Effectiveness
		  Efficiency
		  Cost
		  Quality
		Cognition
			Adaptability
			Activity
			Interactivity
			Autonomy
			Coupling
			Isolation
			Discoverability
			Composition
			Centralization
			Mobility
			Forgetfulness
			Preemptibility
			Standardization
			Risk
			Policy

3. Typology

Resources differ in many ways. We propose a typology for describing resources based upon who they are (their existential characteristics), when they provide their services (their availability), what they do and how well they do it (their utility), and how they do what they do (their implementation). The typology is depicted in Table 1.

3.1. Existential characteristics

The *Existential* category covers properties related to a resource's independent existence, including its identity and whether using the resource fundamentally changes it. This category describes who or what a resource is.

Identity: Whether one instance of a resource may be distinguished from another. Identifiable resources include persons, buildings, automobiles, ships, and books. Some resources may be distinguished by their physical characteristics such as fingerprints or by artificial characteristics such as names or serial numbers. A drum of solvent may be identifiable by serial number, though each liter of that solvent is not identified.

Origin: The source of a resource. Resources may be biological (those living at some time, such as soldiers or a bushel of wheat), material (those never alive, such as iron ore or water), intellectual (such as knowledge or art), electronic (such as networks and online services), financial (such as cash reserves or lines of credit), or psychological (such as good will or loyalty).

Living: Whether a resource is alive. A non–living resource, such as petroleum or lumber, may have a biological origin.

Consumption: Whether using a resource for a particular purpose normally reduces the quantity of the resource or otherwise renders it unsuitable for its original purpose. Consumable resources (time, funding, or munitions) diminish in quantity with use, while reusable resources (catalysts, skilled employees, equipment, or plant space) retain their utility (at least for a while) and may serve many times in succession. Consumable resources, furthermore, may be replenishable or exhaustible over a time frame of interest.

Make–up: The chemical composition or phase of a resource. Stainless steel differs from carbon steel, and steel differs from iron and carbon taken separately. Liquefied natural gas differs importantly from gas at the wellhead, and an oil–in–water emulsion differs from a water–in–oil emulsion.

Traits: The relatively fixed properties of resources. Among biological resources, traits include species, breed, ethnicity, gender, and place of birth. Among non–biological resources, traits include manufacturer, model, physical dimensions, and place of assembly.

3.2. Availability characteristics

The *Availability* category bears upon variations in when and to whom a resource provides service.

Status: A resource may be in service or out of service. While in service, it may be busy (partially or wholly committed to one or more clients) or idle (though perhaps engaged in useful activities). While busy, a resource may be active or inactive. While inactive, a resource may be blocked or starved. While idle, a resource may be accessible or inaccessible. A resource may be out of service because it is so scheduled, because it has removed itself from service, or because it has failed. Depending upon the failure mode, a failed resource may be resting, under repair, or awaiting repair or replacement.

Location: Where a resource may be found. Location may be specified exactly by street address, by latitude and longitude, or by URL. Location may also be specified less exactly by neighborhood, by city, or by continent. Location may also be specified in environmental terms, distinguishing, for example, areas of high or low population density, areas of high or low earthquake risk, or areas of desert or estuarine ecology. The location of a mobile resource varies.

Schedule: The time periods during which a resource may be used. Schedules may be regular, negotiated (appointment–based), rate–dependent, or unpredictable. Regular schedules may be event–driven (as in a bus on a regular route or a decennial census report) or interval–based (as in a teller who serves from 0900 until 1100). Rate–dependent resources provide services differently depending upon the demands they face. A water well may supply 500 gallons per minute continuously or 1000 gallons per minute for six hours. A soldier may provide effective combat duty for a couple of weeks, but effective guard duty indefinitely. Employees, medical care, and rain may be quite unpredictable.

Delivery mode: Whether a resource provides continuous or discrete service. Below limiting rates, aquifers and batteries provide continuous service until depleted. Fire and police departments, utilities, and insurance companies provide theoretically continuous service. A chef, however, may prepare a single dish at a time, but may alternate attention to different dishes. A forklift unloads one pallet at a time. A teller performs one transaction at a time, even while the bank provides continuous financial service.

Failure mode: Whether a resource fails instantaneously or gradually. Gradual failures may be smooth, as when a tire or gear wears evenly, or incremental, as when the strands on a wire rope break one by one or a platoon loses one soldier at a time. Gradual failure often manifests as increased error rates or decreased efficiency. It may lead to instantaneous failure, as when a worn tire bursts in a pothole that would not have destroyed a new tire or when a tired soldier fails to duck quickly enough. Resources may fail in more than one mode. To reduce the risk of failure, providers often manage their resources' availability to allow for rest, maintenance, and replacement.

Selectivity: Whether a resource chooses which clients it will serve. A non–selective resource, such as a drill press or gasoline station, serves any client. A selective resource prioritizes or screens prospective clients. A government assistance program may serve only families with combined incomes below the poverty line. A university may admit only students who pass an entrance examination. Selectivity of a resource may change with time or circumstances. A consultant may serve less profitable clients when underutilized.

Exclusivity: Whether more than one client may engage a resource's services at one time. A shared resource, such as an aquifer, a web server, or a large cargo ship, may serve many clients at once. An exclusive resource serves no more than one client at a time. A particular well in a shared aquifer may be piped to a single municipal water system, and a local area network may serve only a single company.

3.3. Utility characteristics

The *Utility* category deals with what a resource does, how much of a resource exists, how well the resource performs, and what cognitive properties the resource exhibits.

Competencies: The services a resource provides. Competencies may be enumerated, or they may be titular or implied. An automobile repair shop may advertise that it sells and repairs transmissions and exhaust systems. A job applicant may claim fluency in English, Urdu, and Chinese. A Java class enumerates its capabilities through its public interface. Titular competencies, however, presume some familiarity with a particular domain. A Loan Officer has different capabilities and responsibilities from a Teller. A colonel exercises more authority than a sergeant.

Size: A measurement along some dimension, typically physical, of the amount of service a resource can supply. Examples include currency, length, mass, time, and voltage.

Performance: How fast a resource delivers its service and at what cost, reliability, and efficiency. Deliverability captures the rate at which a resource provides its service and may be measured, for example, as speed, power, current, or bandwidth. Reliability addresses the rate at which a resource fails and may be expressed in terms of mean time to failure or percent up time. Effectiveness relates how well the resource does its job and may be expressed as an error or success rate. Efficiency refers to the rate at which the resource consumes another resource. Cost expresses the expenditure required to obtain the resource. The real cost of using a resource should reflect opportunities to salvage, recycle, or reuse the resource and factor in the effect of desirable and unwanted by–products. Quality may be taken as an independent property in its own right or as a combination of other performance properties.

Cognition: Measures of a resource's mental abilities, qualifications, and ways of processing information. Cognitive properties include intelligence, educational level, attitude, commitment, and personality.

3.4. Implementation characteristics

Implementation characteristics involve differences in the way two resources provide the same service.

Adaptability: The ease with which a resource may be improved to suit its original purpose better or modified to suit another purpose. Humans and neural nets become more proficient through exposure to training sets. A programmable conveyor can be rerouted or even learn a new route. A flood control lake, with little modification, can also serve recreational purposes. A National Guardsman may serve both in disaster recovery and in combat. A runway can be more easily converted into a parking lot than a pasture, and a hangar can be converted more easily into a hay barn than into office space.

Activity: The extent to which a resource contributes intentionally to its own use. A resource may exhibit a range of activity or passivity. Most human resources should be considered active, and most inert things should be considered passive.

Interactivity: The amount of give–and–take between client and resource during the provision of service. A computer operating system may interact with a new piece of hardware to determine how to incorporate that hardware into the system. A psychologist may engage a client in an ongoing dialogue. A sorting routine receives all the information it needs at the outset and produces its results without further interaction. A surgeon may determine in advance, through a very interactive process, exactly what surgery to perform, but then performs that procedure with little interaction with the client.

Autonomy: The extent to which a resource controls its own processing logic. The Vector class in the Java programming language, for example, provides an indexed data structure, but retains complete control over how it does so. A delivery service promises to convey a package to a destination, but makes its own decisions about mode of transportation and route taken.

Coupling: The extent to which a resource may be modified without adversely affecting another resource. Resources may be tightly– or loosely–coupled. An automobile's fuel system is loosely coupled to the drive train, but tightly coupled to the power plant. Changes to the fuel system, in other words, necessitate changes to the power plant, but not to the drive train. Coupling manifests in the biological realm as symbiosis.

Isolation: The extent to which a resource is aware of other resources. A newly–hired engineer probably does not know much about the employer's accounting system, while an experienced engineer knows which accountant can answer which question. A web spider, by design, learns about other resources available on the Internet. An operating system polls the computer's components to learn about attached resources. The mouse, on the other hand, has no knowledge of the operating system or of other input devices available to a user.

Discoverability: The ease with which a client may learn that a resource exists. A discoverable resource advertises itself to the world or at least does not conceal itself from the world. A resource may choose to advertise or conceal its existence in certain contexts. A company may, for example, tell its suppliers about its supply chain management systems, but conceal this information from the public.

Composition: Whether a resource contains other resources. A component resource, unlike a constituent, can be replaced without changing the fundamental nature of the resource. The tires on a car can be replaced, but the steel belts in a tire cannot be changed without destroying the tire. In service–oriented architectures, a web service may exist as a single process that performs a single business operation, or it may carve up that process into pieces that are delegated to other web services.

Centralization: The extent to which a resource bases itself in a single location or in many locations. A centralized resource, such as a personnel database, may be available from a single location or source. A distributed resource, such as a network, may exist in many locations. Some resources may be distributed in many ways. A company may distribute natural gas by pipeline in densely populated areas, deliver propane by truck in sparsely populated areas, and provide a central site where customers may bring canisters to be filled with propane.

Mobility: Whether a resource can be moved. A warehouse, unlike a rental truck, cannot be moved.

Forgetfulness: A measure of the amount of information a resource retains after providing service to a client. Erl uses the term "statefulness" [11]. A university admissions officer ideally remembers sensitive information for an applicant only long enough to process the application. A hospital and a prison retain information about their "clients" indefinitely.

Preemptibility: Whether a resource allows its service to a client to be interrupted so that it may serve a higher–priority client. A departmental secretary serves an engineer in the department, but sets that work aside when the supervisor needs help. An emergency room doctor interrupts treatment to a flu sufferer to care for a gunshot victim. An operating system pauses its own diagnostics to handle key presses.

Standardization: The extent to which a resource, particularly its interface with the outside world, adheres to a published or widely–acknowledged standard. Drivers take for granted that a service station will provide a pump nozzle that fits the neck of a "standard" fuel tank. A software development company claims that its processes reach the highest levels of the Capability Maturity Model. A web service advertises its compliance with a trusted security protocol, and a compiler purports to enforce ANSI's standard for the C language. A rail company builds a new rail line to an industry standard gauge, while a mining company chooses a non–standard gauge to fit its smaller ore cars.

Risk: A measure of the extent to which a resource imperils its client. In some cases, a client may want to know which specific risk mitigation measures have been taken by the resource provider so that it can evaluate the resource's security for itself. In other cases, a client may simply desire a statement of the risk involved. For example, a delivery service may warrant a shipper up to a certain value against monetary losses caused by shipping damage. A courier service may provide armed escort for high–value shipments, and a web service may provide encryption of all network messages. A client considering a long–term contract with a particular shipper may request statistics on loss rates.

Policy: The mutable preferences or self–imposed constraints of a resource. A lender may deny credit to borrowers below a certain credit rating. A vendor may offer its services only to the private sector or only to the government sector. A worker may be willing to work weekends, midnight shift, or overtime. Policies impact many other properties of a resource, such as location, availability, and cost.

4. Example Profile: M1 Abrams Tank

We now illustrate how the typology can be applied to develop a resource profile. Drawing upon publicly available sources and a bit of conjecture, we profile the US military's main battle tank, the M1 Abrams [19–21], pictured in Figure 1.

Figure 1: The M1 Abrams Main Battle Tank [19]

Existential Properties: Uniquely identifiable, presumably by a serial number assigned by the manufacturer or the military, the Abrams tank represents a material, non–living, and reusable resource. A collection of very many components, its make–up includes the mundane and the exotic, including depleted uranium armor. The model M1A2 SEP tank was manufactured by General Dynamics in Lima, Ohio. It measures 32 ft long by 12 ft wide by 8 ft high and weighs 69.5 tons. The tank carries a 120–mm M256 smooth bore cannon, a .50 M2 BMG machine gun, and two 7.62–mm M240 machine guns.

Availability Properties: The tank may be in service or out of service. If in service, it may be actively engaged in combat or ready for combat. While in combat, it may be firing or maneuvering, or it may be blocked (perhaps by the enemy or the terrain) or starved for fuel or munitions. The tank may be out of service because of mechanical failure, because it lacks a crew, or because of battle damage.

At any given moment, the tank is located on a particular base or maintenance station or at particular coordinates on a battlefield. During combat, the tank serves around the clock, providing a continuous battlefield presence, but firing at discrete targets one by one with its cannon (while simultaneously firing at other targets with its machine guns). While out of action, the tank remains available except during scheduled maintenance intervals.

Like all mechanical systems, the tank and its subsystems experience gradual failure with wear and instantaneous failure with mechanical breakdown. It may experience instantaneous failure under lethal fire.

The tank serves any crew with the requisite skills. It likely contains classified lock–out mechanisms to exclude enemy combatants. It serves only one crew at a time.

Utility Properties: The tank provides many offensive and defensive capabilities, such as mobility, computer–aided firing while in motion, night fighting, protection from enemy fire and contaminated environments, and integration with the Army's common command and control systems. It carries a "payload" of four crew members. It can fire 40 cannon rounds, 1000 .50 rounds, 10,800 7.62–mm rounds, and 24 smoke grenade rounds. The Abrams, at a cost of $4.3 million each, provides a fuel efficiency of 0.6 miles per gallon, a top governed speed of 45 miles per hour, acceleration from 0 to 20 miles per hour in 7.2 seconds, and a demonstrated kill range with its cannon of at least 4,000 meters. It contains many computerized components, possibly artificially intelligent components.

Implementation Properties: To a great extent, an Abrams is fit only for its purpose of taking overwhelming firepower to the enemy. It participates and interacts with its crew members and other combat elements through computerized navigation, command, control, target acquisition, and fire control systems. It can operate autonomously and in isolation from other tanks, but always under the control of its crew and dependent upon support crews for fuel and supplies. The tank is, of course, centralized and fully discoverable by its crew. It may be moved from one theater to another by ship or plane. It forgets one kill while targeting the next one. It is preemptible in the sense that its current crew may be displaced by a better–rested or better–trained crew. It is standardized in that it contains parts that may be interchanged with other tanks of the same model, it uses standard ordnance sizes, it uses standard fuels, and it participates in the Army's common command and control system. The Abrams certainly exposes its client crew to risk—the tank is an important target to the enemy—but it mitigates that risk through its armor, its speed, its lethality, and its environmental controls.

5. Example Profile: NDFD Web Service

Again using public information and a bit of speculation, we develop a resource profile for the National Digital Forecast Database (NDFD) eXtensible Markup Language (XML) Web Service provided by the National Oceanic and Atmospheric Administration (NOAA). The service supplies weather forecast information for a specified latitude and longitude in the continental United States [22, 23]. Figure 2 illustrates the partial results of a request for daily maximum temperature forecasts over a three–day range for a location in northern Mississippi [24].


```
<data>
 <location>
  <location-key>point1</location-key>
  <point latitude="38.99" longitude="-77.99" />
 </location>
 <time-layout time-coordinate="local" summarization="none">
  <layout-key>k-p24h-n3-1</layout-key>
  <start-valid-time>2006-10-17T08:00:00-04:00</start-valid-time>
  <end-valid-time>2006-10-17T20:00:00-04:00</end-valid-time>
  <start-valid-time>2006-10-18T08:00:00-04:00</start-valid-time>
  <end-valid-time>2006-10-18T20:00:00-04:00</end-valid-time>
  <start-valid-time>2006-10-19T08:00:00-04:00</start-valid-time>
  <end-valid-time>2006-10-19T20:00:00-04:00</end-valid-time>
 </time-layout>
 <parameters applicable-location="point1">
  <temperature type="maximum" units="Fahrenheit" time-
layout="k-p24h-n3-1">
   <name>Daily Maximum Temperature</name>
   <value>57</value>
   <value>71</value>
   <value>72</value>
  </temperature>
 </parameters>
</data>
```


Figure 2: Sample Data Provided by the NDFD XML Web Service [22]

Existential Properties: Known to NOAA by the name "ndfdXML," the web service is uniquely identified by its URL: http://www.weather.gov/ forecasts/xml/SOAP_ server/ndfdXMLserver.php. It is an electronic, non–living, and reusable resource provided by NOAA.

Availability Properties: The NDFD web service operates around the clock, subject to failures of the hardware (servers and networks) on which it depends. The service may be idle or busy serving one or more requests. It may perhaps starve while waiting for weather information from its database. NOAA may disable the web service because of error reports, to manage load on the servers, or for reasons of its own.

Any Internet–connected computer may request service by posting a legal request to the URL. (See references [25] and [26] to experiment with the service manually.) Discrete service is provided in response to a request from any client (including other electronic resources, such as a travel web page). It fails if its host server or data sources fail.

Utility Properties: The NDFD web service provides extensive weather information for a latitude and longitude in the continental United States. It responds to inquiries submitted according to SOAP, a protocol for exchanging XML messages, and provides such weather information as temperature, wind speed, and relative humidity. The requestor may specify a time range of interest or a starting date and number of days. The requestor may specify which particular weather variables it desires, or it may request a “glance” containing a predefined set of values.

The performance of the NDFD web service may be characterized in terms of its up–time, by the percentage of requests it fulfills correctly, by the percentage of requests it cannot fill (perhaps because it does not recognize a valid latitude and longitude), and by measures of how quickly it responds to requests. NOAA does not charge for this service.

Implementation Properties: The NDFD web service fulfills a narrowly–defined purpose—report the weather conditions for a specified latitude and longitude—but it employs standards that support modification and expansion of its mission. The web service itself does not seek out clients, nor does it engage its clients in a dialog. Rather, it responds according to a well–defined script to requests for service. While always in control of its own processing logic, the service knows about and depends upon other resources, such as NOAA’s databases and weather forecasters. Whether the service is composed of other web services cannot be inferred from its public interface.

NOAA makes its web service discoverable to human readers. The authors did not find a listing for the service in machine–readable repositories. While the service actually resides on a particular NOAA server, it may be used virtually anywhere with Internet access.

The NDFD web service presumably fulfills every legitimate request without preemption and likely forgets each request immediately after fulfillment. It subjects its clients to the risk that its information may be incorrect.

Finally, the service employs many standards, such as XML, SOAP, the Web Service Definition Language, and its own Digital Weather Markup Language.

6. Example Profile: Oilfield Derrick Hand

As a last example, we apply the typology to profile a fictitious derrick hand, a laborer on an offshore oil well drilling rig.

Existential Properties: Born in the United States, the derrick hand is uniquely identified by his Social Security Number. His employer also assigns him a unique employee number. A biological, living, and reusable resource, the derrick hand is a 38–year–old male with ten years of experience as a “roughneck” and five years of experience as a derrick hand. He gained his experience working offshore in the Gulf of Mexico.

Availability Properties: The derrick hand may be on duty or off duty. If on duty, he may be actively engaged in one of his assigned tasks or on break. While engaged in a task, he may be waiting for supplies or parts. He may be off duty because his shift has ended, because his tour of duty has ended, or because of illness or injury. While off duty, he may be resting on the rig, in transit between the rig and shore, or onshore. While onshore, he may be subject to recall. While he is on the rig and on duty, he may be found at a particular work station (e.g., in the derrick or on the mud tanks). The derrick hand normally works a 12–hour tour and then enjoys a 12–hour rest period. He works 28 consecutive days and then enjoys 28 consecutive days of rest.

The derrick hand attends to one task at a time. He works for a single employer, whom he may have carefully selected. While working for that employer, he does not select which tasks he will perform.

Like all humans, the derrick hand fails gradually because of fatigue or illness and instantaneously because of injury. His failure manifests as reduced effectiveness and speed and as higher error and injury rates.

Utility Properties: The derrick hand skillfully performs several tasks, such as operating the elevators and racking pipe during drilling operations, maintaining the drilling fluid, and repairing mud equipment. His performance may be measured in terms of his speed during drilling operations or his skill at diagnosing and repairing problems with the drilling fluid or equipment. His performance may also be rated according to the reliability with which he appears for his service period (“days on”).

The derrick hand exhibits above average intelligence, as measured by the employer’s job–related intelligence measures. He has worked cheerfully for the same employer for ten years.

Implementation Properties: As one of the most senior skilled laborers on board, the derrick hand adaptively fills the roles of other employees. If one of the floor hands fails to show, for example, he helps fill the gap. During routine drilling operations, furthermore, he relieves his supervisor, the driller, and in the process, gives his supervisor a break and obtains experience in a more responsible position. In addition, while performing his normal duties with the mud system, he trains the less senior roughnecks in his responsibilities. His attention to one task may be pre–empted by another task of higher priority to his supervisor.

Though the driller directs the derrick hand, the derrick hand remains free to exercise—and is rewarded financially for exercising—his own ingenuity and creativity in optimizing operations and in identifying and correcting problems. Interacting heavily with his co–workers, he carefully choreographs his actions in the derrick with those of the driller and roughnecks working 80 feet below him on the drilling floor. Though the hands work closely together, any one of them can be reassigned to another rig and replaced by another with equal skills without disrupting the operation. The other hands on the rig easily discover and communicate with the derrick hand.

The derrick hand serves a single employer at a time. He remembers and learns from past experiences. He undergoes standard training, some of which is mandated by regulatory authorities, and performs his usual tasks in a standard way. He employs standard procedures for repairing and maintaining equipment. He exposes his employer to many risks, ranging from the trivial to the catastrophic, as a result of his negligence or impairment. He prefers to work offshore in the Gulf of Mexico, but would consider onshore or overseas assignments.

7. Conclusion

A cornerstone of many simulation studies is the modeling of resources. Understanding the interactions of clients and resources, especially contention for resources, is a central focus of these studies. Key to a successful model is an accurate representation of relevant characteristics of the resources. A meaningful simulation depends on a valid model.

A survey of domains reflects wide-ranging interest and perspective on what is a resource. The proposed typology considers resources across domains and categorizes them according to their properties. The purpose of the typology is threefold:

(1) to gain a better understanding of the nature of resources;

(2) to facilitate the development of application-specific resource models; and

(3) to inspire the design of general object-oriented resource classes which are applicable across domains.

As illustrated by the examples in this paper, the typology can guide the development of resource profiles. Each profile serves as a "meta-model" from which one or more models can be developed. Some characteristics described by a profile will need to be represented by a model, while others can be ignored.

Resources in different domains share many properties. This suggests that general resource classes can be developed. The object-oriented approach facilitates reuse and permits customization by overriding inherited methods to modify their behavior. The support for resource modeling provided by existing simulation languages is incomplete. The typology will influence the design of comprehensive resource modules for the SIMSCRIPT III object-oriented simulation language.

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