UNARE ERGINATIONNE Requirements and Software Design Universe Comparison of Comparison and Software Origination and Comparison and	OFTWORE END/OREERING. Domain, Requirements and Software Design Voluma 3 Department of course of cou
	The aims are to introduce basic principles and techniques for
Topic 19 / Phenomena and Concepts	 The arms are to introduce basic principles and techniques for * "discovering" phenomena that need conceptualisation,
Theomena and concepts	* discovering <i>phenomena</i> that need <i>conceptualisation</i> , in particular, to introduce those phenomena whose
• The prerequisite for following this part of the lecture is that you	conceptualisation is in terms of
are willing to think, and are able, or at least wish to think abstractly.	\star entities (information, data),
assi asiy.	\star functions (and relations),
	$\star \ events$ (asynchronous and synchronous) and
	\star behaviours, and
	to introduce basic principles and techniques for the description of
	such phenomena and their underlying concepts.
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norma and Concepts Technology April 5, 2006, 00:13 Page 471, Topic: 10, Fol: 3 Read Please Place, Dr. State Places Place, Dr. State Places, Dr. State Places, Place, Dr. State Places, Dr. State	1 honodaction Honodaction Honodaction April 5, 2006, 00:13 Page 472, Topic: 10, Fol: 4 Kind Power Pad, Kri 2010 Honoda Honodaction Pade 472, Topic: 10, Fol: 4 Kind Power Pad, Kri 2010 Honoda
• The objective is to intellectualise the reader, as necessary, but	Introduction
not yet sufficiently enough for the reader to become an effective professional software engineer.	• In the next lecture topics we shall cover a first set of facets of the
 The treatment is from systematic to rigorous. 	concept of description: the problem of identification, that is, of
• The treatment is from systematic to rigorous.	being able to identify or delineate,
	\star phenomena and
	\star concepts,
	of interest; that is
	\star physically manifest things, and
	\star mental constructions.
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• We shall try to wrestle with some abstract ideas.	Phenomena and Concepts
• They impinge upon what can be known, and what can be described.	• In these lectures we shall thread a careful course.
* As such these abstract ideas border on <i>philosophy</i> ,	\bullet We do not wish to establish a brand new theory of phenomena.
* in particular such philosophical disciplines as	• We certainly do not wish to entertain such ideas as
 epistemology, and ontology. 	\star object-orientedness, conceptual schemas, or whatever.
• For this reason we cannot treat these ideas with the kind of	• We simply wish to go as far as very simple mathematics can
certainty usual in a discourse of mathematics or the natural	support us.
sciences,	\star By that we mean: types and values, functions, events and
• but must be prepared for a certain degree of uncertainty!	behaviours.
	• No further!
	• But first we discuss the ideas of phenomena and concepts.
405 1202, Far. + 64 688 8294 © Dimetigence, Fenduri 11, DF-3868 Hilton, Donards E-mail: definen-shouds, lynore@parlices, dameBipmer bit, URL was insteaded, big	+66 625 220, Fax - 16 488 101 🔅 Osm Bjærer, Faskej 11, OK-388 Hilte, Danask 🕹 Kuller, Baransk de Baransk de, Ljoverdynal con, dansk sjører bjører kir (462 vari om den de) * de
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Physically Marfest Phenomena w (do/vall/2ds/2ds2-i April 5, 2006; 00:13 Page 475; Topic: 19, Foil 7 Riod Pheneri Tabu (70.800 (qt.trph); Denau 4 w (do/vall/2ds/2ds2-i April 5, 2006; 00:13 Page 475; Topic: 19, Foil 7 Riod Pheneri Tabu (70.800 (qt.trph; Denau 4	2.2 Mentally Conceived Concepts Table 2, 2006, 00:13 Page 41%, Tapic 10, 2016 and 20
Physically Manifest Phonomena	Montally Conserved Concenter
Physically Manifest Phenomena /	Mentally Conceived Concepts
• In the world there are the physically manifest <i>phenomena</i> .	• We often abstract a phenomenon into a <i>concept</i> .
• in one world oncre are one physically mannest phenomena.	
\star We can sense them: touch, see, hear, feel, smell and taste them.	Example 5.43 Automobile Phenomenon Versus Car Concept:
★ We can sense them: touch, see, hear, feel, smell and taste them.★ Or we can measure them: mechanically,	
 * We can sense them: touch, see, hear, feel, smell and taste them. * Or we can measure them: mechanically, electrically/electronically, chemically, etc. 	Example 5.43 Automobile Phenomenon Versus Car Concept:
 * We can sense them: touch, see, hear, feel, smell and taste them. * Or we can measure them: mechanically, electrically/electronically, chemically, etc. • Thus we can point to them and designate them, in one way or 	Example 5.43 Automobile Phenomenon Versus Car Concept:The specific phenomenon of "that automobile"
 * We can sense them: touch, see, hear, feel, smell and taste them. * Or we can measure them: mechanically, electrically/electronically, chemically, etc. 	 Example 5.43 Automobile Phenomenon Versus Car Concept: The specific phenomenon of "that automobile" is abstracted into the type, the class, the set of all cars,
 * We can sense them: touch, see, hear, feel, smell and taste them. * Or we can measure them: mechanically, electrically/electronically, chemically, etc. • Thus we can point to them and designate them, in one way or 	 Example 5.43 Automobile Phenomenon Versus Car Concept: The specific phenomenon of "that automobile" is abstracted into the type, the class, the set of all cars, i.e., the concept car.
 * We can sense them: touch, see, hear, feel, smell and taste them. * Or we can measure them: mechanically, electrically/electronically, chemically, etc. • Thus we can point to them and designate them, in one way or 	 Example 5.43 Automobile Phenomenon Versus Car Concept: The specific phenomenon of "that automobile" is abstracted into the type, the class, the set of all cars, i.e., the concept car.
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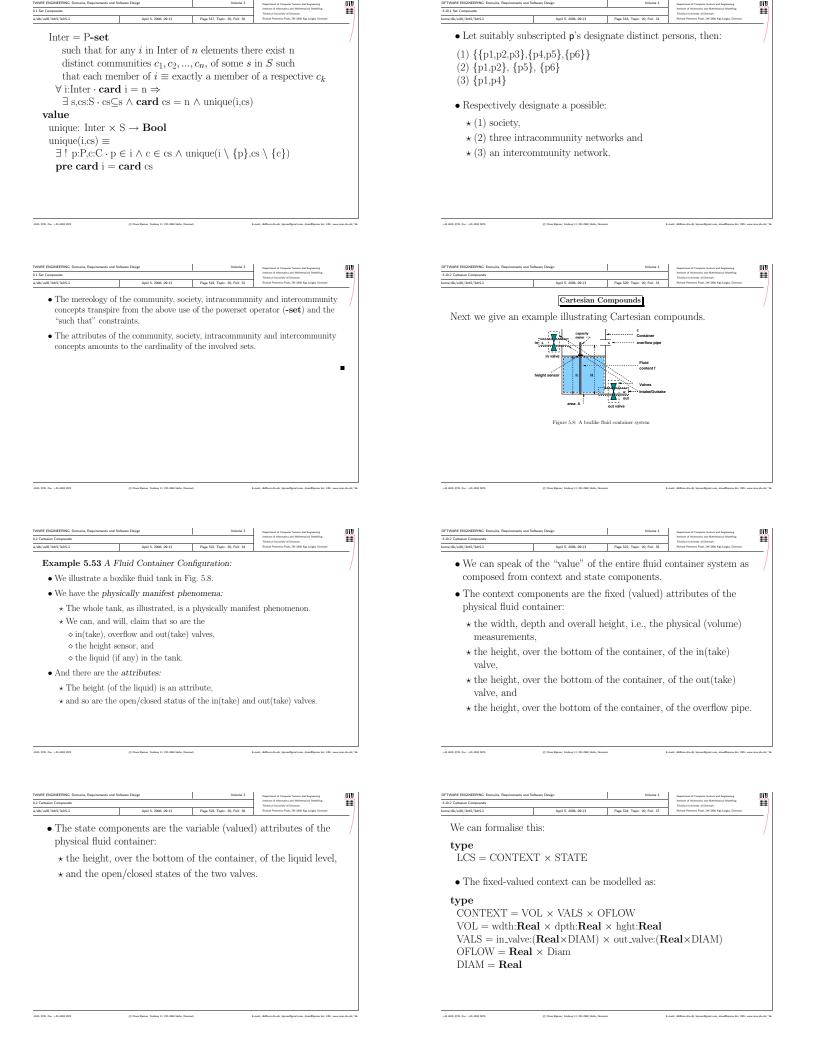
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and Concepts / Characterisation 5.94 By a phenomenon we shall loosely understand
• some physical thing
into four categories: • that humans can sense or
• which natural science based technology can measure,
and where a phenomenon is typically
unction applications, i.e., • a natural thing or • a human-made artifact
• a numan-made artifact
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ve shall loosely understand / Concrete and Abstract Concepts
• Phenomena can be pointed to or measured. They are physical.
• Concepts are mental constructions.
• When we "lift" our consideration, for example, from <i>that specific car</i> over there is a fix physicar to a concentrative of the set of some then we have
s of phenomena there, i.e., of a phenomenon, to a representative of the set of cars, then we have abstracted "away" from a specific phenomenon to the concrete concept of car.
• When we "lift" our considerations, for example, from those of dealing with cars,
 trains, airplanes or ships, that is from a set of concrete concepts, to consider
specimens (i.e., instances) of these as vehicles (or conveyors), then we consider vehicles (conveyors) as abstract concepts.
And so on.
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Volume 3 Dependent of Carepoon Science of Care
24 Concrete and Abstract Concepts to 10 Minutes/a Mading Technology and Abstract Concepts to 10 Minutes/a
concept we mean an Characterisation 5.97 By an abstract concept we mean an
into one concept. abstraction of a set of similar concepts into one concept.
• Given a description of an abstract concept we can speak of its concretisation
relation between the • as an identification which establishes a relation between the omenon which is intended • abstract concept and at least one concrete concept which is
intended covered by the abstract concept.
Enable ditendende, hjorefigner hit (H. von inn die de/ da 🕴 enderdigen hit (H. von inn die de/ da 🗤 enderdigen hit (H. von inn die de/ da 🗤 enderdigen hit (H. von inn die de/
Volume 3 Depense of Compare Science of Compare Scie
E 1D, Fab 15 - Bauly Found Toulogie and Description
• Usually we shall be formulating our descriptions in terms of concepts, not in
terms of phenomena.
• But occasionally it is required that a description in terms of phenomena is developed and presented.
-
entities, functions, events and behaviours are of phenomena.
ll of which are of some type Characterisation 5.99 A description is said to be conceptual if all of its
A-set. Characterisation 5.100 A description is said to be specific problem-oriented if all of its entities, functions, events and behaviours are of some mixture of both phenomena (one or more) and concepts (one or more).
2 5 Competence of the second secon

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• The South Coast Rail Line regional railway net consists of * a single linear route, r,	homn/db/vdll/2db5/2db5/i April 5, 2006, 09:13 Page 466, Topic: 10, Folt: 18 Robard Process Flad, DK-300 KgaLygdg, Deseak
\star a single linear route, r ,	What Is a Description?
	• Finally we are ready to address the crucial issue of what a description is.
* made up noin six stations, $s_1, s_2, s_3, s_4, s_5, s_6$, and * five consecutive lines, $\ell_{12}, \ell_{23}, \ell_{34}, \ell_{45}, \ell_{56}$,	description is.
★ such that route r can be thought of as a sequence of alternating stations and lines: $\langle s_1, \ell_{12}, s_2, \ell_{23}, s_3, \ell_{34}, s_4, \ell_{45}, s_5, \ell_{56}, s_6 \rangle$ or the other way around:	Characterisation 5.101 By a <i>description</i> we mean
$\langle s_1, \epsilon_{12}, s_2, \epsilon_{23}, s_3, \epsilon_{24}, s_4, \epsilon_{45}, s_5, \epsilon_{56}, s_6 \rangle$ of the other way around. $\langle s_6, \ell_{56}, s_5, \ell_{45}, s_4, \ell_{44}, s_3, \ell_{23}, s_2, \ell_{12}, s_1 \rangle$.	• some text which either designates
* More specifically line ℓ_{12} is 17 km long, line ℓ_{23} is 19 km long,, and line ℓ_{56} is 23 km long.	\star a set of phenomena in such a way
 ★ Topologically and geodetically line ℓ₁₂ runs as follows: (etcetera). ★ Stations s₁ is named Arlington, s₂ Burlington,, and station s₆ is named Georgetown. 	\star that the reader of the description
\star Topologically and geodetically station s_1 is organised as follows: (etcetera).	\star can recognise these phenomena from the description
* Etcetera.	
25 125 Far + 66 60 801 © Dom Egren, Findey 11, 165-30 Main, Danest Eraik & Benefard, SportSpalan, Amblyon 12, UK, was ins dard/ 6	-16 653 220, For +16 683 837 (2) Ottom Tigens Finding 11, 06 2018 Mars, Danask (5 and the distancial de Spandingens Des URS, sension date
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• or a description designates	• A later lecture covers
\star a set of concepts in such a way	\star (i) recognisability of descriptions,
\star that the reader of the description	\star (ii) the issue of providing as few phenomena (or actually
\star can concretise these into recognisable phenomena,	concrete concept) descriptions as possible (i.e., the so-called "narrow bridge"),
\bullet or a description is a text which designates both	\star (iii) the issue of instead relying on definitions and
\star recognisable phenomena and	\star (iii) the issue of instead toying on dominations and \star (iv) the issue of risking refutable descriptions.
\star recognisable concepts	(1) the hole of tisking relation descriptions.
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Topic 20	• Similar remarks can be made for the possible relations between entities and
Entities	behaviours.
• One man's entity is another man's function!	Characterisation 5.102 By an <i>entity</i> we shall loosely understand
• We hedge the opening of this part of the lecture by a caveat, and a veiled	• something fixed, immobile or static.
warning.	Although that thing may move,
• When we now shall try to characterise what an entity is,	• after it has moved it is essentially the same thing,
• it must be understood as a choice that the developer has to make	• an entity
· · · · · · · · · · · · · · · · · · ·	
\star of whether to consider a phenomenon or a concept as an entity or as a	
\star of whether to consider a phenomenon or a concept as an entity or as a function.	• From a pragmatic point of view,
 * of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. 	From a pragmatic point of view,entities are the "things" that, if implemented inside computers,
 * of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. * Colloquially speaking: if you think of the phenomena or concepts as information typically computerisable as data, then the phenomena or 	
 * of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. * Colloquially speaking: if you think of the phenomena or concepts as 	• entities are the "things" that, if implemented inside computers,
 * of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. * Colloquially speaking: if you think of the phenomena or concepts as information typically computerisable as data, then the phenomena or concepts are entities. 	entities are the "things" that, if implemented inside computers,could typically be represented as data.
* of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. * Colloquially speaking: if you think of the phenomena or concepts as information typically computerisable as data, then the phenomena or concepts are entities.	entities are the "things" that, if implemented inside computers, e could typically be represented as data.
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 * of whether to consider a phenomenon or a concept as an entity or as a function. * Usually that choice is an easy one to make. * Colloquially speaking: if you think of the phenomena or concepts as information typically computerisable as data, then the phenomena or concepts as information typically computerisable as data, then the phenomena or concepts as entities. 	 entities are the "things" that, if implemented inside computers, could typically be represented as data. THE DESCRETE DESCRETE Descine, Represented as follows: OPTIMALE DESCRETE Descine, Represented as follows: April 1 Amage Testing 1 Amage Testing April 1 Amage Testing We make the distinction between * atomic entities and * composed (i.e., composite) entities. Atomic Entities Characterisation 5.103 By an atomic entity we shall understand an entity

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bl/vell1/3ch5/3ch5-ii April 5, 2006, 02:13 Prage 402, Tepic: 20, Foil: 5 Richard Present Plate, 50:500 KpcLappt; Donnak	hommy dby/vall/2xb5/2xb5-ii April 5, 2006, 00:13 Page 404, Tapic: 20, Fail: 6 Robard Prevene Plant, 05:300 Kg1.paple; Desnak
Example 5.46 Atomic Entities: We give a few examples:	Composite Entities
• a (specific) pencil,	Characterisation 5.104 By a composite entity e we shall
• a (specific) chocolate bar,	understand an entity
• a (specific) person or	\bullet which can best be understood as composed from
• a (specific) timetable.	• other entities, called the subentities, e_1, e_2, \ldots, e_n , of entity e
Lecturer:	•
• Discuss parts of pencil, parts of person:	
• whether entities or not — depending on viewpoint.	
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Example 5.47 Composed Entities: We give a few examples:	Subentities
\bullet a (specific) railway net (as composed from lines and stations),	Characterisation 5.105 By a <i>subentity</i> we shall understand an
• a (specific, say passenger) train (as composed from passenger cars	entity
and engines (locomotives)) or	\bullet which is a component of another entity
• a (specific) transport industry (as composed from the transport net, the transport vehicles, and so on).	
	Example 5.48 Subentities: We give a few examples:
•	• the lines and stations of a (specific) railway net,
	• the locomotive(s) and cars of a (specific) train,
	• the railway net of a (specific) railway system.
	•
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Maralagy and Atchbana all (Jab/(Jab5-i April 5, 2006, 00.13 Page 497, Topic: 20, Foil: 10 Biole Present Pade (Joile) (Pade (Joseph Densis	3.4 Valem, Menology and Atchoten https://www.accentres.com/accentres/accent
Values, Mereology and Attributes	Characterisation 5.106 By a value v_e of an entity we shall loosely understand
	the following:
• Examples 5.46–5.48 designated certain entities.	 If the entity is an atomic entity, then the entire set of identified attributes.
• For each of them we can speak of a <i>value</i> of that entity.	* then the entire set of identified attributes, $a_{1_e}, a_{2_e}, \ldots, a_{n_e}$, of the entity.
• And for each of them we can speak of zero, one or more <i>attributes</i> of that entity.	• If the entity is a composite entity (thus consisting, say, of subentities, e_1, e_2, \ldots, e_m) then there are three parts to the entity value:
• A concept of <i>mereology</i> is associated only with composite entities	* how it is composed — its mereology m ,
\star and then expresses	* the entire set of identified attributes, $a_{1_e}, a_{2_e}, \ldots, a_{n_e}$, of the entity, and
\star how the entity is composed from subentities.	* (inductively) the identified values, $v_{e_1}, v_{e_2}, \ldots, v_{e_m}$, of respective subentities
· ·	(e_1, e_2, \ldots, e_m) .
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Characterisation 5.107 By an <i>attribute</i> of an entity we shall	Example 5.49 Attributes and Values:
Characterisation 5.107 By an <i>attribute</i> of an entity we shall / oosely understand	Example 5.49 Attributes and Values:The following are some of the attributes of an atomic pencil entity:
Characterisation 5.107 By an <i>attribute</i> of an entity we shall	-
Characterisation 5.107 By an <i>attribute</i> of an entity we shall loosely understand	• The following are some of the attributes of an atomic pencil entity:
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Characterisation 5.107 By an <i>attribute</i> of an entity we shall / oosely understand	 The following are some of the attributes of an atomic pencil entity: the physical length of the pencil, the materials from which it is made, the colour of the (lead) pen in the pencil, all the other attributes associated with the appearance of the
Characterisation 5.107 By an <i>attribute</i> of an entity we shall oosely understand	 The following are some of the attributes of an atomic pencil entity: the physical length of the pencil, the materials from which it is made, the colour of the (lead) pen in the pencil, all the other attributes associated with the appearance of the pen (wear and tear),
Characterisation 5.107 By an <i>attribute</i> of an entity we shall / oosely understand	 The following are some of the attributes of an atomic pencil entity: the physical length of the pencil, the materials from which it is made, the colour of the (lead) pen in the pencil, all the other attributes associated with the appearance of the pen (wear and tear), tis purchase price, etc.
Characterisation 5.107 By an <i>attribute</i> of an entity we shall / oosely understand	 The following are some of the attributes of an atomic pencil entity: the physical length of the pencil, the materials from which it is made, the colour of the (lead) pen in the pencil, all the other attributes associated with the appearance of the pen (wear and tear), tis purchase price, etc. The value of the atomic pencil is thus
Characterisation 5.107 By an <i>attribute</i> of an entity we shall / oosely understand	 The following are some of the attributes of an atomic pencil entity: the physical length of the pencil, the materials from which it is made, the colour of the (lead) pen in the pencil, all the other attributes associated with the appearance of the pen (wear and tear), tis purchase price, etc.

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Entity Mereology	• Please note our attempt to distinguish between
By mereology we understand a theory of part-hood relations. That is,	\star entities,
of the relations of part to whole and the relations of part to part	\star entity values,
within a whole.	\star entity attributes and
Characterisation 5.108 By the mereology of an entity we shall	\star entity mereologies.
loosely understand	\bullet Note that we use the term attempt.
• whether it is atomic,	
\bullet or, when it is composite, then how it is made composite	
\bullet (i.e., from which kind of subentities it is composed)	
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Menelogy Techcia University and Anti-Anti-Anti-Anti-Anti-Anti-Anti-Anti-	3.5 Entity Mereology Techical University of Demark
Vall/145/335-ii April 5, 2006, 00:11 Page 500, Topic 20, Fail: 16 Richar Premus Plat, DC/380 HpL rayle, Downak	Journa (db/vdll/dbf/db5-ii) April 5, 2006, 00:13 Page 504, Topic: 22, Foli: 17 Ristor Province Total: 06:200 Pag Longia; Danask
Example 5.50 Mereology Facets of a Railway Net:	 There is no end to the kind of attributes and the form of mereology one may eventually associate with an entity.
• The mereology of a railway net transpires from the <i>italicized</i> terms.	• And for that matter, one can also associate attributes and mereologies with
\star A net is composed from, and hence decomposable into a	functions and behaviours, as we shall see.
collection of lines and a collection of stations.	• It is not productive, we strongly believe, to try enumerate all the possible
* Any line links exactly two distinct stations.	categories of
* Any station is linked to one or more distinct lines.	* mereologies and * attributes —
* A rail line is composed from linear rail units.	\star attributes — \star and hence information —
* The connectors of a rail unit are (here considered) <i>inseparable</i> from the pairs of rails (and the ties and their nails, etc.)	• that one may associate with entities (functions and behaviours).
making up the main part of rail units.	• One easily becomes lost in philosophical discourse.
• We have not said anything above about how the collections form	• Our job is mainly constrained by putting whatever we domain-analyse inside the
• We have not said anything above about now the conections form nets. But such formation rules are part of the mereology.	computer.
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vall/(hd5/3a55-ii April 5, 2006, 00:13 Page 565, Topic 20, Fail: 13 Richar Parenas Paul, DC380786-Longle, Donard	home;(db)roll/)dd5/3d55i Apil 5, 2006; 00:13 Page 506; Topic: 20; Foli: 19 School Proves Flak; 06:508 VpLingle; Danak
• Hence, in the final analysis we need just resort to what can be described in terms of abstractions of	Mereologies and Attributes
	• So an entity e value v_e is made up, in a loose sense, of
* computer data, i.e., values and types,	\star (i) its mereology —
\star computing routines (algorithms) and	\diamond (i.a) whether atomic or
* computing processes.	\diamond (i.b) composed from subentities, and then how —
• Thus we shall mainly focus on such mereologies	* (ii) entity attributes, $a_{1_e}, a_{2_e}, \ldots, a_{n_e}$, * and (iii), when the entity, e , is composite, then (inductively) the values,
\star which can be informally, but precisely described, in natural	$v_{e1}, v_{e2}, \ldots, v_{em}$, of these entities (e_1, e_2, \ldots, e_m) .
English	
* and which can be mathematically described,	• We shall model
\star or, further constraining the issue of mereologies, which can be represented inside the computer.	\star all this information as values of appropriate types.
represented histic on puter.	
1, Fac: +6 683 8014 💿 Diese Rjener, Fredorij 11, Dir 3489 Helze, Domask Ernsle derflowerdtunde, lijerwertgesaltom, dierethijsere lai; URL: was innet die die "die	+6 605 120, Fac +6 683 604 🛞 Cone Rjenne, Fendroj II, DK-206 Helto, Danak E-mile: defininguation, denthjone bij (SE: som investigant bij (SE: som
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Model-Oriented Mereologies	Model-Oriented Attributes — An Aside
• Volumes 1 and 2 of this series of volumes focused on property- and	Atomic Types and Values
model-oriented ways of specifying mereologies and attributes.	• We could consider the constraints that might be put on a
• In those volumes, except in Chap. 2 in Vol. 2 (<i>hierarchies and composition</i>), we	model-oriented mereology for some entity either as a property of
did not single out the concept of mereology.	the mereology or as an attribute of the entity.
• But the model-oriented means of modelling composite entities as	\bullet In addition to this, there are the end types of the atomic entities
* sets Cartesians *	that eventually make up any entity.
	• The actual values of these atomic types, in our view, constitute the
* lists maps *	
* functions	attributes of the entity.
	attributes of the entity.
* functions	attributes of the entity.
* functions	attributes of the entity.

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<form> 9. But, as amply shown in, for example, Vol. 2, 9. Chere are seemingly composite types that model what we should like to classify as attributes rather than as mereologies: * functions that model temporal progression, e.g., traffic, * functions that model denotations, * and so m. 9. We shall therefore have to resign, for this volume, and say: * for a treatment of the proper modelling facets of entities * we must refer to the entirety of both Vols. 1 and 2 of this series. * The treatment of the proper modelling facets of entities * we must refer to the entirety of both Vols. 1 and 2 of this series. * The treatment of the proper modelling facets of entities * we must refer to the entirety of both Vols. 1 and 2 of this series. * The treatment of the proper modelling facets of entities * we must refer to the entirety of both Vols. 1 and 2 of this series. * The treatment of the proper modelling facets of entities * we must refer to the entirety of both Vols. 1 and 2 of this series. * Our entite the entirety of both Vols. 1 and 2 of this series. * Our entite things have values. * Physically manifest things have values. * Physically manifest things, in addition, have mereologies: * Properties (mereology and attributes), like values (in general), enerology and all its attributes), like values (in general), enerology and all its attributes). * Properties (mereology and attributes), like values (in general), enerology and all its attributes). * Properties (mereology and attributes), like values (in general). * en expressed in terms of (usually nonthing) values. * More mathematic treface the treface the treface the treface the treface the</form>	 So an entity value is made up, roughly speaking, * of its mereology, * its attributes * and (if composite) the values of all subentities. We shall, for convenience, lump the two facets, * mereologies and * attributes, into one concept: properties. TOTAL CONCENTRY OF A CONCENTRY O
	 * of its mereology, * its attributes * and (if composite) the values of all subentities. We shall, for convenience, lump the two facets, * mereologies and * attributes, into one concept: properties.
<form> ehrer are seeningly composite types that model what we should like to classify as attributes rather than as mereologies: # functions that model temporal progression, e.g., traffic, # functions that model denotations, # and so on: We shall therefore have to resign, for this volume, and say: # for a treatment of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # we must refer to the entirety of both Vols. 1 and 2 of this series. Method mathematication of the proper modelling facets of entities # Physically manifest things have values. Physically manifest things, in addition, have mereologies: Physically manifest things, in addition, have mereologies: Physically manifest futures. Physically manifest futures. Physically manifest futures of (usually nonthing) values. Method a physically manifest phenomenon: a e expressed in terms of (usually nonthing) values. </form>	 * of its mereology, * its attributes * and (if composite) the values of all subentities. We shall, for convenience, lump the two facets, * mereologies and * attributes, into one concept: properties.
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	 * and (if composite) the values of all subentities. We shall, for convenience, lump the two facets, * mereologies and * attributes, into one concept: properties. TOTUME ENGREENCE Commen, Represented to Solve Dage Yes 20 Yes 20
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	 * mereologies and * attributes, into one concept: properties. TOTMET EXERCENCE Concern Represente at later Days Area 2 and 2 a
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manifest things. * Physically manifest things, in addition, have mereologies:	 a property of a usually composite manifest phenomenon, that it is a manifest atomic or composite phenomenon itself; and <i>* attributes:</i> a property of a manifest phenomenon, which is not a manifest phenomenon. It is more like a property. * Both kinds of properties are represented by a type and a value.
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 A particular railway net is a manifest phenomenon. Any k line or k station, and, for that matter, 	• The curvature of a rail unit, we may claim, is an attribute (i.e., also
 Any * line or * station, and, for that matter, 	• The curvature of a ran unit, we may crain, is an attribute (i.e., also 7) a property, a concept) of that rail unit.
★ line or★ station, and, for that matter,	\star The curvature itself cannot be taken apart from the rail unit and
\star station, and, for that matter,	manifested as such.
	• Other examples of railway net <i>attributes</i> are:
★ any smallest rail unit	\star the length of a line;
	* that a unit of a line is closed for traffic; and
and many things in between,	* that a line, when open, can ever only be open in one direction
\star like platform or siding tracks,	(an up line, as opposed to a down line, for lines connected to a
are also manifest phenomena,	station [into, respectively out from]).
• and are thus <i>thing properties</i> of the net phenomenon.	•
221, far + 64 60 80 C	-16 655 221, Far -16 681 12N © Dave Gener, Packoq I, 10 548 MAD, Davent Evals dellava duch, hjerenkynstan, davekjeren ku, 561, sewa inn duch
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Real Examples and Our Type System	Then, we give a formal description.
Set Compounds	type P
Example 5.52 Communities and Community Networks: Intra and Inter:	C = P-set
• An informal description:	S = C-set
\star A community, C, consists of a finite set of one or more people, P.	such that for any two distinct elements c_i, c_j of some s in S they share no people in common
\star A society, ${\sf S},$ consists of a finite set of one or more disjoint communities.	$\forall s: S \cdot \forall ci, cj: C \cdot \{ci, cj\} \subseteq s \land ci \neq cj \Rightarrow ci \land cj = \{\}$
* An intracommunity network, Intra, consists of a finite set of one or more	Intra = P -set
people within a community. * An intercommunity network, Inter, consists of a finite set of one or more	
* An intercommunity network, mer, consists of a mine set of one of more people, exactly one from each of a subset of communities of a society.	such that for any i in Intra there exists a com-
	munity c of some s in S of which i is a subset



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• The variable-valued state can be modelled as:	* Let the various numerals below designate reals (of unit centimeters), then:
type	
$STATE = liquid:LEVEL \times input_valve:OC \times output_valve:OC$ LEVEL = Real	lcs: (ctx,sta)
DEVEL = Real OC == open closed	ctx: (vol,vvs,ofw)
OC == open closed	vol: (100.0,100.0,300.0)
• OC stands for the open/close state of a valve.	vvs: $((250.0,5.0),(10.0,5.0))$
	ofw: (255.0,5.0) sta: (221.0,(open,closed))
• open and closed are atomic tokens, i.e., identifiers.	sta. (221.0,(0pen,closed))
• By being different they denote different "values".	i.e., (((100.0,100.0,300.0),((250.0,5.0),(10.0,5.0)),(255.0,5.0)),(221.0,(open,close \star exemplifies a configuration.
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• We thus consider the fluid container system to be an atomic entity.	Tist Communication
	List Compounds
• The attributes of the fluid container system amount to container	The next example illustrates the list compound.
* width,	Example 5.54 Train Journeys:
\star depth and \star height,	• A train journey is an ordered list of two or more station visits.
	* *
• to valve	• A station visit is a grouping of arrival time, station and platform names, and departure time.
* height positions	names, and departure time.
\star and diameters,	type
 to the open or closed state of the input and output valves, 	Time, Sn, Pn
• and to the height of the fluid.	$Journey = Sta_Visit^*$
-	$Sta_Visit = arrival:Time \times sta_name:Sn \times pla_name:Pn \times dept:Time$
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NRARE EXCREENDED Commins, Requirements and Suffuser Design Volume 3 D3 List Compands Discussion Volume 3 Discussion Discus	OFTWARE ENGINEERING. Duration, Requirements and Software Design 3.13.3 Line Compounds homos, bound (126); (136); (137); (138);
• The list (and Cartesian) expression:	• The mereology of the train journey concept transpires from the
$<(a_1,s_1,p_1,d_1),(a_2,s_2,p_2,d_2),(a_3,s_3,p_3,d_3),(a_4,s_4,p_4,d_4)>$	above use of the list and Cartesian type constructors $(^*, \times)$.
• where suitably subscripted a , s , p and d stand for, respectively,	• We thus consider the train journey concept to be a composite entity
arrival times, station names, platform numbers (or names), and	• whose atomic subentities are station visits.
arrival times,	• We consider only one attribute of a train journey,
\bullet designate a journey starting at time $d1,$ ending at time $a4,$	\star namely its number of station visits.
\bullet from station $s1$ via station $s2$ and $s3,$ in that order, and ending at	• The attributes of atomic station visits are
station s4.	\star arrival time,
	* station name,
	\star platform number and
	\star departure time.
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0.4 Map Compounds Intribut Vision Compounds The Compound State Sta	3.30.4 Map Compounds texture of Neurosci Mading Tickial University of
Map Compounds	We can formalise this:
We give an example illustrating map compounds.	type
	File, Fn, Dn
Example 5.55 Computer File Directories: This example is a "classic".	$DIR = (Fn _{\overrightarrow{m}} File) \times (Dn _{\overrightarrow{m}} DIR)$
• A directory consists of	
\star zero, one or more uniquely named files,	• Here $A_{\overrightarrow{m}}B$ denotes a map from unique A's to not necessarily unique B's.
\star and zero, one or more uniquely named directories.	• A map is like a function:
• So directories map	★ Given a map m (say in $A_{\overline{m}}B$)
\star file names into files and	\star and an a in $A,$ such that
* directory names into directories.	\star a is in the definition set of $m,$
• Files, file names and directory names are further unexplained entities.	\star then $m(a)$ (m applied to a) is some b.
he, he hands and directory hands are further unexplained enduces.	
405 320, Far. + 64 688 804 💿 Direc Egener, Feshing 11, DF 3469 Halo, Donast Evado, abdition datu de, lipsendiguest com, doneBjornet bit, URL www.inn.do.de, "de	- +6 455 120; Fac +6 488 1804 () Dane Bjenn, frakted 11, DK-306 Halts, Danask Senark & Senark delfere als de lijsen-Bjenn 20; URL some inn als de/"da

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• Example directories are:	• The mereology of the directory concept transpires from the above use of the map and Cartesian type constructors $(\pi t, \times)$.
([],[]) ([fn→file],[])	
$([n \mapsto ne_{j,[]})$ $([n \mapsto file], [dn \mapsto ([], [])])$	• The attributes of a directory is
$([fn1 \mapsto file1, fn1 \mapsto file1], [dn1 \mapsto ([], []), dn2 \mapsto ([fn \mapsto file1, [])))$	\star the number and name of files
$[\operatorname{fn1} \mapsto \operatorname{file1}, \operatorname{fn1} \mapsto \operatorname{file1}], [\operatorname{dn1} \mapsto ([], []), \operatorname{dn2} \mapsto ([\operatorname{fn} \mapsto \operatorname{file}], [\operatorname{dn} \mapsto ([], [])])])$	\star and the number and names of subdirectories.
• Here fn, fn1 and fn2 are file names; file, file1 and file2 are files and dn, dn1 and	
dn2 are directory names.	
The general map expression $[a1 \mapsto b1, a2 \mapsto b2,, an \mapsto bn]$,	
where all a1 , a2 , and an are distinct,	
• denotes a map from ai to bi.	
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ma Techsical biological and a second	J. 11. type Contrations Technical University of Dimension in Technical University of Dimension International University of Dimension Internationa
Type Constraints	Example 5.56 Type Constraints:
1, pe constraints	We will illustrate some type constraints that should have been expressed in
n Example 5.52 the informal text lines between the formula lines	earlier examples:
llustrate the idea of a type constraint.	* Liquid container system:
These type constraints can be considered part of the mereology of	♦ The in(take) valve must be placed higher than the out(take) valve.
the entities modelled.	♦ The liquid height cannot be lower than the level of the out(take) valve minute the dispersion of the taylor.
haracterisation 5.109 By a type constraint we shall loosely	minus the diameter of that valve. ♦ The liquid height cannot be higher than the level of the overflow pipe
derstand	plus/minus the diameter of that pipe.
some text which delimits a prior type description	\diamond The diameter of the out(take) value should stand in the following relation
to not contain all the values	to the diameter of the $in(take)$ value: (etc.!).
otherwise allowed just by that prior type description	
•	
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	OFTWARE ENGINEERING, Donaim, Requirements and Software Design Volume 3 Opposter of Compare Ortification of Optimized Software (Software Optimized Software Optimized
	Bit Inpre Constraints Mathematical Mathemat
1	* Train journeys:
capacity meter Container	 A rival times should be before departure times at any one station,
in s / / · · · · · · · · · · · · · · · · ·	\diamond and their difference should be a minimum of t_{lo} minutes and a maximum of
in valve	t_{hi} minutes, possibly depending on which station these times relate to.
Fluid content f	♦ Departure times at one station should be before arrival times at any next station,
height sensor h H	\diamond and their difference should be commensurate with the normal travel time
Valves	between such stations.
w with the second secon	♦ The sequence of station names must be commensurate with a route through the railway net. ⁴
area: A out valve	♦ No station name can occur more than once. (That is, no cycles.)
Figure 5.9: A Liquid Container System: The Physics	
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ICHEEEBNIC Densides, Requirements and Submer Design Volume 3 Properties 3 atching Mark Subscript Instrument of Markan Subscript Table Subscript April 5 2006, 60:13 Page 530, Taple, 20, Table 22 * Computer directories: One might envisage some strictly not necessary constraints on directories:	OFTINEE EVENEEENC Domain, Reprimerent and Schwar Daigs Views 3 Single Contraction, Reprimerent and Schwar Daigs April 5, 2006, 0013 Page 540, Tigtic 20, Fail 5 April 5, 2006, 0013 Page 540, Tigtic 20, Fail 5
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NEXEEENING: Domains, Regularisation and Software Darige Values 3 monodim 1 (2mk7/ab5.2 April 5.2006, 00.13 Page 500, Topic 20, Table 2 Non-order Software Topic 20 Table 2 * Computer directories: One might envisage some strictly not necessary constraints on directories: At any level of a directory, file names (at that level) must be distinct from directory names (at that level). 	OTTWARE ENCIDEERING. Domain. Requirements and Software Design April 5, 2006, 09.13 Page 548, Taple: 20, Fail: 3 April 5, 2006, 09.13 Page 548, Taple: 20, Fail: 3 Multiplication of distance of the state
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$\begin{array}{c c c c c c c c c c c c c c c c c c c $	OTTWARE ENCIDENTIAL Duration, Requirements and Software During. Wilew 3 April 5, 2006, 00.13 Page 540. Topic 20, 761 Constraints Manual April 5, 2006, 00.13 Page 540. Topic 20, 761 Constraints April 5, 2006, 00.13 Page 540. Topic 20, 761 Constraints Constraints by a bit of set, Cartesian, list, map, and, as we shall soon see, function notation. Hence we presented some of that set, Cartesian, list and map
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$\begin{array}{c c c c c c c c c c c c c c c c c c c $	OFTWARE ENCIDENCE: Domain, Requirements and Software Datage Videou 3 Site Type Constraints Manual Market Software Datage Videou 3 Software of Encode Videous 4 Software of Encode Videous 4 Software Videous

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Summary: Principles, Techniques and Tools	Recall that the attributes of a composite entity have two facets: • there are the attributes which indicate how the composite entity is composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity is composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity is composite entity in the composite entity in the composite entity in the composite entity in the composite entity is composite entity in the composite entits entity i	/
Principles 5.27 The principle of analysing and modelling entities is		,cu,
as follows:	• The compositional attributes are expressed by saying that the composite en	entity
• First decide whether an entity, that is, whether values of a class,	\star consists of a set	
i.e., type, of entities are atomic or composite.	\star or a Cartesian	
• Then, for atomic entities decide on which one or more attributes these atomic entities have.	\star or a list \star or a set of uniquely identified, that is, a map	
• And, for composite entities, decide on which of the following two	of subentities.	
aspects these composite entities have:	• The auxiliary attributes of a composite entity are very much like the attrib	outes
\star their mereology, i.e., their compositional attributes	of atomic entities:	
\star and their subentities	\star they characterise the values of the entities as such, less their possible subentities.	
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y: Principles, Techniques and Tools Techniques and Tools Techniques and	### A Forcions Institutional Valuational Valu	by Desmark
echniques 20 Entities are modelled as follows:	Topic 21	/
Atomic entities by stating an arbitrary aggregation of possibly	Functions	· · · · ·
constrained types (say sorts),	Characterisation 5.110 By a function we shall loosely understand	
and composite entities by stating two things:	• something, a mathematical quantity (that no one has ever seen), which	
\star an arbitrary aggregation of possibly constrained types (the	• when applied to something (else),	
auxiliary attributes, e.g., sorts), and	• called an <i>argument</i> of the function,	
* a specific set, Cartesian, list, map (or function) composition of	• <i>yields</i> something (yet else),	
types (the compositional attributes)	\bullet called a $result$ of the function for that argument.	
	 If the function is applied to something which is not a proper argument of the function 	the
bols 5.10 Models of <i>entities</i> are, for example, expressed using the	 function, then the totally undefined result, called chaos, is yielded 	
3L abstract type (sort) or concrete type concept.	• then the totany undernied result, caned chaos , is yielded	-
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The question, for us, when confronted, as we are,	Example 5.57 Functions: We give some rough sketches of	/
with phenomena of one kind or another, is	examples:	
• to decide which phenomena we should model as functions, and	\bullet To deposit savings in a savings account can be viewed as a func	ction:
which we should not.	\star the <i>deposit</i> function is applied to two arguments,	
	\diamond the deposit <i>amount</i>	
	\diamond and the account balance.	
	\star The function yields a new balance.	
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The above is an appropriate choice of argument and result types if		
I he above is an appropriate choice of argument and result types if we consider only the account balance (and the amount deposited).		/
\star If, however, we consider the entire bank (and the amount	 * some response to the client, \$ for example that the deposit transaction succeeded, or did 	d net
deposited),	s for example that the deposit transaction succeeded, or did succeed,	1 1106
\star then the <i>deposit</i> function is more appropriately applied to the		d
following arguments,	account number,	
◊ the bank,	\star then you may wish to add a further, the response, component	ent to
the client name, the client account number (hence the account helence) and	the result, for example,	
 ♦ the client account number (hence the account balance) and ♦ the deposit amount, 	d	
* and yields a new bank.		
122, Far + 6 493 801 © Dien Egens, Felderj II, DC 366 Mitz, Denast Geben drudt, SporeGparline, Anellynes M, UR, was	na inn da Af / da 📧 122, Fac + 64 683 123, Fac + 64 683 123 (jomer.biz; URL: v

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Another example:	Another example:
• Inquiring about and actually buying an airplane ticket is abstracted	• To unload a ship in harbour at a quay can be considered a
as a function. For example, this can be viewed as:	function. For example, viewed as:
* The purchase function	* The unload function
★ is applied to three arguments,	* is applied to two (composite) arguments,
♦ travel information about from where to where, on which flight ata	\diamond a <i>ship</i> (loaded with cargo destined for)
flight, etc., \diamond the airline flight reservations register,	\diamond the quay of a harbour.
 ♦ and the price (in terms of monies). 	* This function yields a "paired" result:
* This function yields a "paired" result:	 ♦ the ship less its unloaded cargo, and ♦ the quay "plus" the unloaded cargo.
\diamond the <i>ticket</i> ,	v ene que, plue ene amouade earge.
\diamond and an updated flight reservations register.	
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Yet another example:	A final example:
• To admit a patient at a hospital can be viewed as a function. For example, viewed as,	• To land an aircraft can be viewed as a function. For example, viewed as,
\star the admission function	\star the <i>touchdown</i> function
* is applied to a number of arguments,	* is applied to two arguments,
\diamond the <i>patient</i> ,	\diamond the <i>aircraft</i> (which is in a state of flying),
♦ the hospital (not registering that patient),	\diamond and the <i>runway</i> (which is assumed free for landing, i.e.,
\diamond the receiving medical doctor, nurse, etc.	reserved for "that" aircraft).
\star This function yields a "composite" result:	* This function yields a "composite" result:
\diamond an updated <i>hospital</i> (now registering that patient).	♦ the aircraft (which is now in a state of running along the runway),
	\diamond and the <i>runway</i> (which is occupied by "that" aircraft).
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istons	A.1. Function Signatures Television Multiple Constraints and Multiple C
• An important task in describing, prescribing or specifying	Function Signatures
(domains, requirements, respectively software design)	
\bullet is that of identifying all relevant functions,	Characterisation 5.111 By a <i>function signature</i> we shall understand the following composite information:
• of (i) naming them, their (ii) arguments and (iii) results,	· ·
• and of (iv) defining what they "compute".	• The name of the function,
• In the above example we have covered (i–iii) but not (iv).	• a sequence of names of the types of the arguments and
	• a sequence of names of the types of the yielded results
	• A function signature is not a definition of the function.
	• But it is a significant indication of what the function "appears to
	be about".
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Example 5.58 Function Signatures: The signatures corresponding to the	We formalise the above:
functions mentioned in Example 5.57, are:	type
• Function name: deposit; argument types: amount and balance; and result type: balance.	Amount, Balance TravInfo, ReservReg, Price, Ticket
• Function name: ticket_purchase; argument types: travel information,	Ship, Quay
reservation register and price; and result types: reservation register and	Patient, Hospital, MedicalStaff Aircraft, RunWay
ticket.	value
• Function name: unload; argument types: ship and quay; and result type: ship, and quay.	deposit: Amount×Balance \rightarrow Balance ticket_purch: TravInfo×ReservReg×Price \rightarrow ReservReg×Ticket
Function name: admission; argument types: patient, hospital and medical	unload: Ship×Quay \rightarrow Quay×Ship
staff; and result type: hospital.	admission: Patient×Hospital×MedicalStaff \rightarrow Hospital touch_down: Aircraft×RunWay \rightarrow Aircraft×RunWay
 Function name: touchdown; argument types: aircraft and runway, and result types: aircraft and runway. 	
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• Once a function is rough-sketch identified	Function Definition
• the developer can determine, at least tentatively,	
• the function signatures.	• We have not spent much time or space, above, but we have indeed mentioned the concept of function definition.
• To do so does indeed often require detailed considerations.	Characterisation 5.112 By a function definition we shall
• Delineating the function signatures focuses the developer's mind.	understand
Many issues surface during this preliminary rough-sketch step.	• a description, a prescription, or a specification
• Writing down, systematically, whether informally only, or also formally, tends to further focus the development:	• which defines the relationship between
	\star arguments and
• step-by-step "achievements" can be recorded!	* results
	• of a function
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Example 5.59 Function Definition: We exemplify function	• The air ticket purchase function,
efinitions for some of the functions of Examples 5.57 and 5.58.	* when applied to
• The deposit function,	 ♦ some (relevant) travel information, ♦ an airline reservations register,
\star when applied to an amount (to be deposited) and a (n account)	\diamond and a(n assumed ticket) price,
balance,	* yields
\star yields a new balance (of that account)	\diamond a new airline reservations register
\star which is the sum of the original balance and the deposited	\diamond and a ticket \diamond such that the ticket satisfies the travel information
amount.	\diamond such that the ticket satisfies the travel information \diamond and the ticket (i.e., the reservation that it designates) is properly reflected
	in the yielded, i.e., new airline reservations register.
	More information must be given about the three entities: travel information,
	airline reservations register and ticket, in order to define what is meant by "satisfaction" and "proper reflection".
	Subside bon and proper released .
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Characterisation 5.113 By an <i>algorithm</i> we shall understand	Example 5.60 Algorithm: We finally indicate rough sketches f
• a step-by-step specification	algorithms for computing the deposit function (item (i)), respecti
• which can serve as prescription for computation by a mechanical	the ship unload function (item (iii)), of Example 5.59.
device, i.e., a computer,	• A deposit algorithm:
• such that that computer computes what a function definition otherwise has defined	* Let the amount to be deposited be held in a variable v_d , and the initial contents of v_d be d .
	\star Let the balance of the account into which a deposit is to tak
•	place be held in a variable v_b , and let the initial contents of b .
	* Now add the contents d of v_d to the contents b of v_b , yielding
	$d+b$ as the new contents of variable v_b .
	* Nothing is said about the final contents of v_d .
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• An unload algorithm:	type
* Let the cargo area of ship s be represented by a variable s_c . The	Sn, Qn /* Ship and Quay Designators */ C /* Container */
contents of s_c is assumed to be a set of containers	variable
$\{s_{c_1}, s_{c_2}, \dots, s_{c_n}\}.$	s_c:C-set
* Let the cargo area of the quay, q, at which the ship is docked be	q_c:C-set
represented by a variable q_c . The contents of q_c is assumed to be	value q:Qn
a set of containers $\{q_{c_1}, q_{c_2}, \ldots, q_{c_m}\}$.	is destined: $Qn \times C \rightarrow \mathbf{Bool}$
\star Let an auxiliary predicate function is destined apply to a quay	unload: C-set \times C-set \rightarrow C-set \times C-set
designator q and ship container s_{c_i} , and let it yield true if that	$unload(s.c,q.c) \equiv$
container is destined for quay q , false otherwise.	while \exists c:C·c \in s.c \land is destined(qn,c) do let c:C·c \in s.c \land is destined(qn,c) in
* Now, for every ship s container s_{c_i} of s_c for which $q(q, s_{c_i})$	s.c := s.c \ {c} \parallel q.c := q.c \cup {c}
holds, remove s_{c_i} from s_c and add s_{c_i} to q_c .	end end
y y y	
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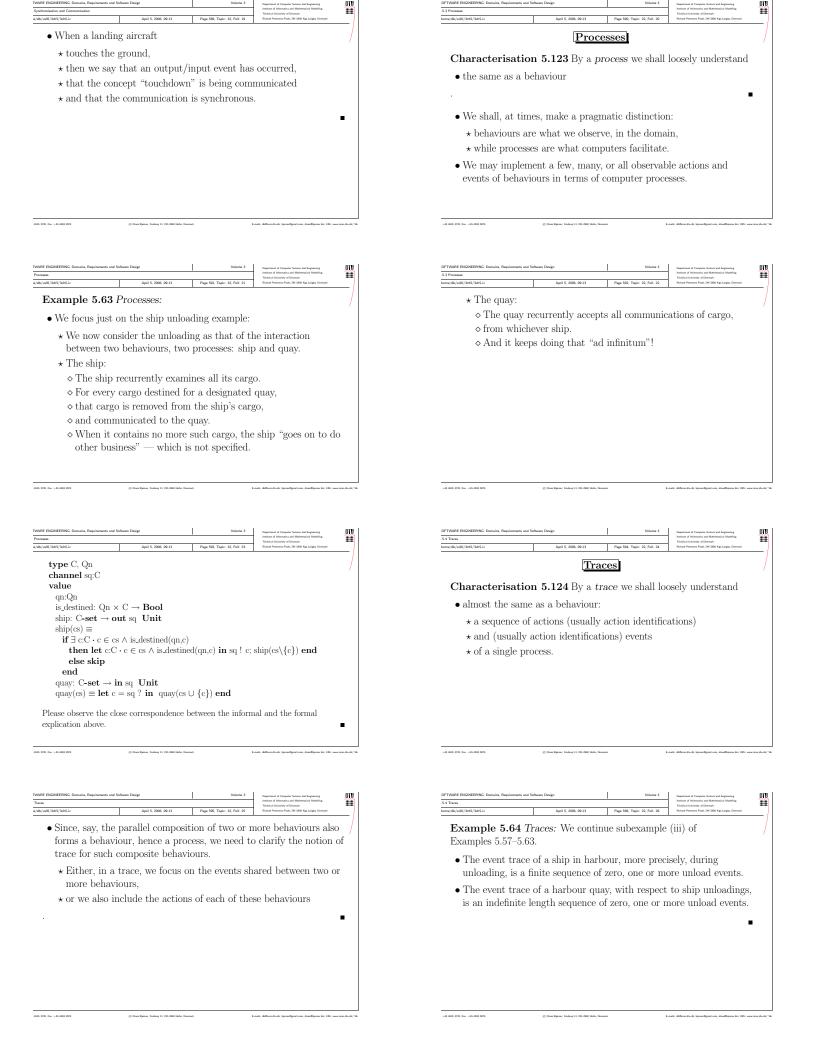
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q:Qn				
is_destined: $Qn \times Qn$	$D \rightarrow Bool$			
•	$-set \rightarrow C-set \times C-$	set		
$unload(s_c,q_c) \equiv$				
(/ 1 /	$s_c \land is_destined(qn, qn)$	ob (e		
	\wedge is_destined(qn,c) in	/		
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end end	q_c := q_c o (c)			
end end				
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n 1/3ch5/3ch5-iii	April 5, 2006, 09:13	Page 570, Topic: 21, Foil: 28	Technical University of Denmark Richard Petersens Plads, DK-2000 Kgs.Lyngby, Denmark	Ħ
,				—/
We leave it to th	e course student	to examine the	e three definitions,	
.1				· · · ·
\star that of the un	load function,			
$\star{\rm that}$ of the un	load algorithm an	nd		
$\star{\rm that}$ of the un	load pseudo-prog	ram.		
We believe that the difference between those definitions				
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 Example 5.61 States, Actions, Events and Behaviours: We show some examples where the four concepts "intermingle". The below examples relate to subexamples (i, ii, iii) of Examples 5.57–5.60. Clients and bank accounts: The balance of some client's bank account forms a state. Carrying out the functions of depositing (and withdrawing) monies into (respectively from) the account amounts to actions. The decisions by a client to make deposits and withdrawals amount to events that trigger respective actions. 	 Assuming that there is a lower credit limit, the situation where a withdrawal action results in a bank account balance that exceeds the credit limit amounts to an event. That event may or may not trigger an action, or may do so in a delayed fashion. The sequence of a specific series of deposit and withdrawal events and actions forms a behaviour. For any given client and bank account many such behaviours are possible.
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 Airline ticket purchase: * The airline seat reservation register forms a state. * Carrying out the functions of actually buying a (or cancelling an already bought) ticket amounts to actions. * The decisions to buy (reserve without paying, or actually reserve and pay), respectively cancel, a ticket are events that trigger respective actions. > Having reserved, without actually paying for a ticket, and then not paying for the ticket before a certain date, amounts to an event, which may, or may not trigger an action. * The sequence of a specific series of one or more ticket purchases and zero, one or more ticket cancellation events and actions forms a behaviour. For any given airline reservation system and potential passengers many such interleave and/or concurrent behaviours are possible. 	 Ship unloading and quay loadings: The ship cargo and the quay cargo storage can be considered either as a combined state, or, respectively, as the states, of a ship and a quay. Carrying out the function of unloading a ship amounts to an action. The decision to start unloading amounts to an event that triggers the unload action. The phenomenon that there is no more cargo to unload amounts to an event, which may or may not trigger an action.
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 * Behaviours: • The quay behaviour: • Seen from the point of view of a quay, the sequence of a specific series of unload events and actions, with respect to possibly different ships, forms a behaviour. • For any given quay many such behaviours are possible. • The ship behaviour: • Seen from the point of view of a ship, the sequence of a specific series of unload events and actions, with respect to possibly different quays, forms a behaviour. • For any given ship many such behaviours are possible. • The combined quay/ship behaviour: • Any set of pairs of commensurate quay and ship behaviours forms a behaviour. 	 Synchronisation and Communication From the above we observe two closely related phenomena: That behaviours may communicate, and that the communications may take place synchronously, or asynchronously.
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E BIGHEERING: Duration, Responsements and Software Design Values 3 Business of Graphics Using and Responsements and Software Design Diff transmission And S. 2006, 00:13 Page 59%, Tapic 20, Table 3 Business of Graphics Using and Response Diff Characterisation 5.1118 By communication we loossely mean • the exchange of entities between behaviours, • from one to the other, or both ways	OFTIWEE EXCRIMENTAL Communication Volume 3
A communication may involve one "sender", i.e., output,and one or more "receivers", i.e., inputs.	\bullet of one entity from one sender to one or more receivers . \blacksquare

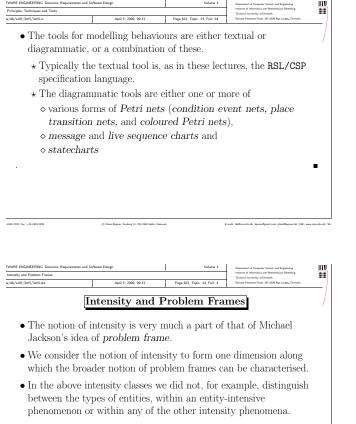
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Characterisation 5.120 By a shared event we mean the simultaneous occurrence of one output event in one sender	• Thus synchronous communication can be said to be via a zero-capacity buffer between the sending and the receiving behaviours.
behaviourwith its one or more synchronously communicating input events in	• Whether the synchronous communication is between one sender
one or more receiver behaviours	 and one receiver, or several receivers is not stated here — but any description (prescription, specification) must state that,
•	• as it must state how the identification of the sending and receiving
	behaviours is accomplished.
	• The sender behaviour is thus expected to be "held up" from the moment it wishes to synchronously communicate till the moment all communications have been accomplished.
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Characterisation 5.121 By asynchronous communication we shall loosely understand	• Thus asynchronous communication can be said to be via a non-zero-capacity buffer between the sending and the receiving behaviours.
 the possibly delayed, e.g., buffered, communication between behaviours	 Whether the buffer acts like a queue or like a heap we do not specify here —
\bullet of one entity from one sender to one or more receivers	• but any description (prescription, specification) must state that,
•	• as it must state how the identification of the sending and receiving behaviours is accomplished.
	• The sender behaviour is thus expected to be able to proceed with its "own" actions once it has placed its asynchronous communication.
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Characterisation 5.122 By synchronisation we shall loosely / understand	• Thus we consider the output communication in (i.e., from) one sender behaviour
• the explicitly expressed (i.e., controlled)	• to designate the same event
simultaneous occurrence of an	• as the simultaneous input communication(s) in one (or more)
• event in two or more behaviours	receiver behaviour(s).
	• We say that synchronisation reflects shared events.
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Example 5.62 Communications: We continue our line of examples /	• When a ship
with subexamples (i, iii, v) of Examples 5.57–5.61.	\star unloads a (piece of) cargo (i.e., a container) onto a quay,
• When the bank account holder, i.e., the client,	* then we say that an output/input event has occurred,
 * hands over the monies to be deposited to the bank teller, * then we say that an output/input event has occurred, 	\star that the cargo is being communicated \star and that the communication is synchronous.
* then we say that an output/input event has occurred, * that the monies are being communicated	and that the communication is synchronous.
* and that the communication is synchronous.	



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Process Definition Languages	Topic 23
• The formal part of Example 5.63 illustrated textual definitions of	Choice on Modelling Phenomena and Concepts
processes.	\bullet On one hand, we have a universe of discourse conceived of in terms
• There are also a number of two-dimensional, diagrammatic ways of	of phenomena and concepts.
"rendering" the progress and interaction of two or more processes.	• On the other hand, we have some principles, techniques and tools for modelling phenomena and concepts.
• These were covered extensively in Vol. 2's Chaps. 12–14:	 Previous lectures have covered the model concepts of
* Various forms of Petri nets (condition event nets, place transition nets, and coloured Petri nets).	 revious rectines have covered the model concepts of * entities,
* message and live sequence charts (MSCs and LCSs) and	* functions,
\star statecharts.	\star events, and
• Variations of these diagrammatic forms are currently embodied in	\star behaviours.
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• Confronted with a description (prescription, specification) task there are a number of modelling questions.	Qualitative Characteristics
• Some we covered in other lecture series.	 In which order do we describe (prescribe, specify) phenomena and concepts?
• Some of these will be covered in this lecture.	• Do we model them according to whether they are modelled as
• Others will be covered in several of the remaining lectures.	* entities, or functions, or events or behaviours?
	• The answer to these questions is relatively simple:
	* It depends on which phenomena and concepts that
	* best "characterise" the universe of discourse being described
	(prescribed, specified)!
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AllE BLOREERING Domain, Requirements and Software Design Working All Design A	OFTWARE ENGINEEPING. Domains, Repriments and Software Design Volum 3 Operator (Logarceal (Logarce
Quantitative Characteristics	• To do so we introduce a notion of universe of discourse "intensity".
	• The background for our "intensity" notion is the qualitative
• Thus the describer (prescriber, specifier) is confronted with another	characterisation of a phenomena or a concept as being (modelled
question:	as):
* What does it mean that	\star an entity
 ◊ a phenomenon or concept ◊ characterises a universe of discourse 	\star a function
 ◇ characterises a universe of discourse ◇ "better" than another phenomenon or concept? 	\star an event
• The answer is, basically, a matter of style and of taste.	\star a behaviour
• But we shall try formulate some guidelines.	
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• Company and angles we negtulate that one can quantitatively	Information-Intensive Universe of Discourse
Correspondingly we postulate that one can quantitatively characterise a phenomenon or a concept as one or more of:	
characterise a phenomenon or a concept as one or more of:	Characterisation 5.125 By a universe of discourse being said to
characterise a phenomenon or a concept as one or more of: * information-intensive	be information-intensive we roughly mean that
characterise a phenomenon or a concept as one or more of:	be information-intensive we roughly mean thatentities, their number and type
characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive	be information-intensive we roughly mean that
characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive * event-intensive	be information-intensive we roughly mean thatentities, their number and type
 characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive * event-intensive * process-intensive • Usually it only makes sense to speak of intensity if a phenomenon or a concept is predominantly one of the above, or, at the very 	be information-intensive we roughly mean thatentities, their number and type
 characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive * event-intensive * process-intensive • Usually it only makes sense to speak of intensity if a phenomenon or a concept is predominantly one of the above, or, at the very most, two. 	be information-intensive we roughly mean thatentities, their number and type
 characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive * event-intensive * process-intensive • Usually it only makes sense to speak of intensity if a phenomenon or a concept is predominantly one of the above, or, at the very 	be information-intensive we roughly mean thatentities, their number and type
 characterise a phenomenon or a concept as one or more of: * information-intensive * function-intensive * event-intensive * process-intensive • Usually it only makes sense to speak of intensity if a phenomenon or a concept is predominantly one of the above, or, at the very most, two. 	be information-intensive we roughly mean thatentities, their number and type

.6.2.2 Function-Intensive Universe of Discourse buttless of Material Malating Technical Malating
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Characterisation 5.126 By a universe of discourse being said to
be <i>function-intensive</i> we roughly mean
• that functions, their definition, their application and their
composition, • play a central role in understanding that universe of discourse
• play a central fore in understanding that universe of discourse
Example 5.66 Function-Intensive Phenomena:
• Most resource planning, scheduling and allocation, and
rescheduling systems (say, for production and for transport) can be said to be function-intensive.
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• A railway train traffic system with its movement of trains, their
arrival and departure from stations, their reaching intermediate positions along a line, and the attendant rail-point interlocking and signal settings, can be said to be an event-intensive system.
• Similarly for air traffic systems: The arrival and departure of
aircraft, in and out of ground, approach and regional monitoring and control zones, can be said to be event-intensive systems.
• Telephone exchange systems, with the handling of single- and
multiple-party telephone calls, hang-ups, simple service-oriented inquiries, etc., can be said to be event-intensive systems.
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Example 5.68 Behaviour-Intensive Phenomena:
• Freight logistics systems with their handling and actual flow of freight by senders and logistics firms, and from senders via logistics
firms, transport hubs, and transport conveyors to receivers, can be said to be behaviour-intensive systems.
• Healthcare systems, with their flow of people (patients and staff),
material (medicine, etc.), information (patient medical records),
and control, can be said to be behaviour-intensive systems.
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OFTWORE EVAILABLESING, Denation Requirements and Software Design Volume 3 <u>6.1 Principles</u> , Techniques and Tools Instead Undersyl (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 23, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15 Neurol Month (JASS-1): <u>April 5, 2006, 09-11</u> Page 622, Tapic 24, Fail: 15
Principles, Techniques and Tools
Principles 5.28 • When describing a universe of discourse focus on identifying and describing <i>phenomena</i> and <i>concepts</i>
•

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Techniques 21 • Analyse the identified phenomenon or concept / and	Discussion 5.19 • There are some dualities.
• decide whether to model as an	\star An entity can possibly be modelled as a function,
	\star or an entity can possibly be modelled as a behaviour,
 ★ entity, including as a set (i.e., type) of entities, ★ or as a function, 	* etc.
* or as an event,	• We can hint at this as follows.
* or as a behaviour.	* Entity as function: you may consider the phenomenon, p ,
• Then use the elsewhere given techniques (and tools) for	\diamond for example, modelled as an integer, as an entity, i_p ,
respectively modelling entities, functions, events and behaviours	\diamond or as the function, f_p . \diamond As an entity i_p denotes a value.
	\diamond As a function f_p is to be applied to an empty argument, $f_p()$,
	and then yields the value.
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• Entity as behaviour: you may consider the phenomenon, p ,	\diamond There are two behaviours,
\star for example, modelled as an integer, as an entity, i_p ,	\circ the inquiring behaviour q_p ,
\star or as the behaviour, b_p .	\circ and the integer behaviour b_p .
\star As an entity i_p denotes a value.	\diamond To ascertain the value of p behaviour q_p synchronises and communicates with b_p
\star As a behaviour b_p is a behaviour composed, in parallel, with that	\diamond by requesting the value of the integer phenomenon and
of the phenomenon, i.e., an inquiring behaviour, q_p , which wishes to know, to use, the value of the integer phenomenon.	♦ obtaining, in return, that value.
* This is modelled as follows:	
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• Thus, whether we model a phenomenon, that appears to be an	Example 5.69 Shared Documents:
entity, as an entity, or as a function, or as a behaviour, is not always that straightforward.	 A (perhaps even information-intensive) phenomenon can be thought of as a large collection of uniquely identified documents.
\star If the phenomenon is otherwise simple, i.e., is not subject to the constraints listed for the next two alternatives, then model it as	• Users of these documents may wish to read, copy or edit some document(s).
an entity.	• We consider these users as a set of many behavioural phenomena,
★ If instead the phenomenon is shared among many behavioural phenomena then model it as a behaviour	 hence we model the document collection as a behaviour.
	 This document collection behaviour is centred around an internal entity: the document storage.
	• User behaviours now communicate with the document collection
	behaviour,
Far + 66 688 861 © Dan Egnes, Fashaj 11, DC 388 884, Denark E-maile differenties, Equivalgueilan, dantifipere ita (UK, wasien die de/"de	+66 625 222 for +16 458 62M © Direct Grands (L) 06 506 Note, Ganarda & Enach de Banacha de Spannlippen ber URs war winder de A
DERORDER/DRG Chaminks, Requirements and Software Davigs Volume 3 Opportune of Carpens Column of Carping Instruction of Instruction and Table Opportune Table Opportune Table<	OFTWORE ENVIRCENTING Chronicin, Requirements and Schwars Davigs Values 3 Optimized Croups- Gioso on Generation (a.1.2) Principlen, Technologien and Touls Difference on the Company of Company Company Technologien (a.1.2) Principlen, Technologien (a.1.2) Pri
★ by requesting copies of documents for reading, and hence no	Tools 5.11 • The tools for <i>modelling entities</i> are those of sorts and
return,	concrete types, as well as axioms, i.e., constraints over these.
* by requesting copies of documents for copying, and hence no	• The tools for modelling functions are those of function signatures
	and function definitions, whether by explicit (i.e., function body)
return, or	
	definition, or by pre/postconditions, or by axioms.
return, or * by requesting original documents for editing, and hence for	definition, or by pre/postconditions, or by axioms.
 return, or * by requesting original documents for editing, and hence for subsequent return. Requests are communicated from a user behaviour to the document 	definition, or by pre/postconditions, or by axioms.
 return, or * by requesting original documents for editing, and hence for subsequent return. Requests are communicated from a user behaviour to the document collection behaviour. Responses are communicated from the document behaviour to the 	definition, or by pre/postconditions, or by axioms.
 return, or * by requesting original documents for editing, and hence for subsequent return. Requests are communicated from a user behaviour to the document collection behaviour. Responses are communicated from the document behaviour to the requesting user behaviour. 	definition, or by pre/postconditions, or by axioms.



- Once we add that dimension to our categorisation, then we start moving closer to Michael Jackson's notion of problem frames.
- We shall take a deeper look at problem frames in a later lecture.

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OFTWARE ENGINEERING: Domains, Requirements and So	ftware Design	Volume 3	Department of Computer Science and Engineering	DTU
7.1 Entities, Functions, Events and Behaviours			Institute of Informatics and Mathematical Modelling Technical University of Denmark	Ħ
ome/db/voll1/3ch5/3ch5-dis	April 5, 2006, 09:13	Page 622, Topic: 24, Foil: 1	Richard Petersens Plads, DK-2000 Kgs.Lyngby, Denmark	
	Toni	ic 24		/
		ission	<u> </u>	
Entities,	Functions, E	vents and B	ehaviours	
• We have postulated	that the concepts	of		
• entities, functions, e	vents and behavio	urs		
\bullet offer a suitable com	plement of choices			
\bullet when modelling phe	nomena and conce	pts.		
\bullet How do we know the	at?			
\bullet From where do we l	mow that?			
• Well, pragmatics, i.e	e., experience, has	shown that they s	uffice, to a large extent.	
• And the four notion	s each fit into nice	ly complementing	theories:	
\star of data types, of	recursive function	theory and of proc	cess algebras.	
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