Charting Java

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Preface

First are presented some questions and some attempts to answer them:

What is a computer? A machine that can be ordered to process data. The machine gets data and commands from keyboard, mouse, storage-disks, network-connections (like the Internet). The machine stores the processed data (a fax sent, an email received) on storage-disks and can show it on output devices like screen or printer. For more see the text beginning with page 28.

What is a program? A program is given by a sequence of commands which tell the computer what to do. Programmers store programs by writing those sequences of commands into text-files, as if writing a letter or an email. First examples of a program are given on page 37 and on page 71.

What is an operating-system? A program that organizes technical-related tasks of hardware-management (allocating storage-space, accessing hard-drives (also called hard-disks), disk-drives establishing fully-functional network-connections ...). For more see page 43.

What is a platform? The computer hardware together with the working software of an operating-system is called a computer-platform (this is considered more extensively in the context of operating-systems).

What is Java? The term Java may be heard to be describing the entire **virtual platform**[1] given by the Java Runtime Environment (JRE, past page 51). Or the name Java may be used for the entire Java Development Kit, a **software-kit** that enables a programmer to write programs in the Java programming-language. But the term Java may also denote the Java **programming-language**. (For more information on programming-languages see pages around page 37.)

There are several overlapping, sometimes also rather fragmented, approaches to a multi-faceted piece of knowledge like the Java programming-language:

Handbook view: Notions are presented as far as possible in their strict logical dependence, assuming that the reader furnishes some familiarity with the concepts. The topics are usually covered extensively in an analytic, often rigid way. The ➡▤ ➡▤ Java Language Specification [JLS2] may be an example of a publication with such a view.

Reference view: References collect notions, more or less commented, in a dictionary-like presentation, sometimes in the form of an index or a glossary. Examples are the ➡▤ ➡▤ Java Platform API Specification [JPAPIS] or the Java Developers Almanac [JDA].

Practical/Textbook view: Learning with examples that introduce and illustrate concepts. Synthetic experiences and experimenting becomes possible as part of homework problems. The Online Tutorials on *Sun*'s Java-related Internet-site (`http://java.sun.com`) can be seen as examples for this kind of approach.

Programmed Learning (of practical skills): Learning in a textbook way by predominantly solving tasks under written guidance. Some certification books may represent examples for this approach. Search for "Java certification" in the Internet.

Theory-Oriented This means predominantly learning concepts of programming. In this context practical applications would distract from the central idea. Example: Algorithms (sorting, cryptography, routing packages of bytes through networks) can be formulated in many different programming-languages, their ideas remains the same. Many books with the notion "Algorithms" in their title may fit into this category.

This classification could make a reader aware of the choices and possibilities when searching for information. This present text could be classified as a textbook, although within the sections titled "Concept: ... " this text attempts a theory-related introduction to the notions.

[1]A computer-platform runs a program, called the Java Runtime System (JRS) that makes the computer mimic another platform: the so-called Java Runtime Environment (**JRE**).

This Book

This book tries to present a reasonable broad approach to computers, networks and Java programming (Java 2 Standard Edition, Version 1.4. The Java 2 Micro Edition (J2ME) and the Java 2 Enterprise Edition (J2EE) haven't been covered here.). As a result of some reading of this book, a beginner should be able to categorize notions of that field and be ready for learning advanced programming techniques. The text works as a collection of concepts and their transformation into the Java language. Marginal or advanced topics have been deliberately omitted. The Java programs presented are prototypes, maybe inviting to be changed and to be extended by the reader. All in all, the text should give a fast practical access to the Java language and its basic concepts. This book represents no atlas, rather a collection of charts.

Structure

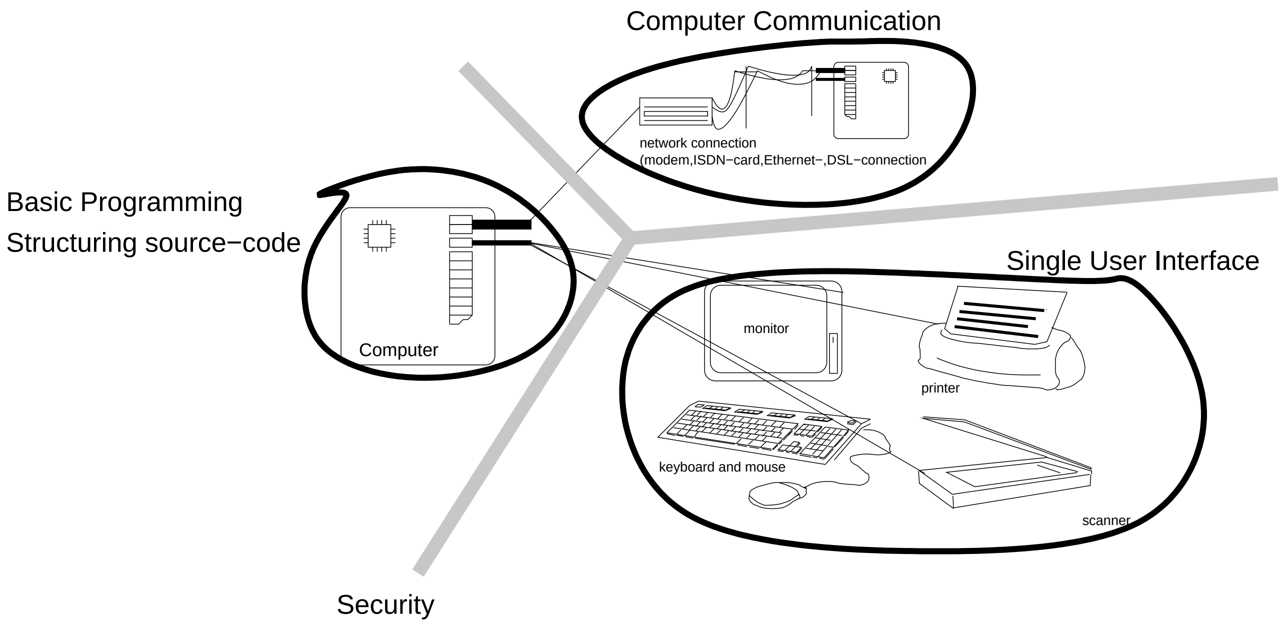
The text has been structured into *conceptual sections and Java-specific sections*. Conceptual sections describe general notions and give an overall idea of the content. The knowledge of these sections may be also applicable in non-Java contexts. The *Java-specific sections* demonstrate the realization of those concepts in the case of the Java programming-environment. — Headers of the parts and sections of the book denote the main view-point of these passages. Nevertheless *some* extensions of those main ideas can be found in *other* parts of the book. But these extensions are bound to their respective main passage by cross-references, so that they should be easily relatable. — Many programs have their descriptions added to the program's (source-)code as comments. This may better integrate the programs into the text and may make it straightforward to identify program-specific information. — Concepts and principles are introduced predominantly without referring to any special programming-language. Those paragraphs should furnish the theory that makes much of the ➡▤ ➡▤ Java Platform API Specification self-explaining. (See the concept of color on page 522 which gives some of the basic information used in the Java-class `java.awt.Color`) — The text presents simple procedural programs first; the structuring of code with methods, classes and threads comes later. — To keep the ideas above in a good order, some notions of the Java language are anticipated at times (especially the construct of a `main()`-method inside a class-declaration, being indispensable when writing regular programs.). — All the examples can be refined and extended and to get practice in Java; the reader may benefit from doing some creative work with them. — The text allows the reader several lines of access to spot specific information:

- Table of Content
- Index
- Chapter and Section Introductions/Summaries should make a small text-booklet of an overview
- Images as a picture book of ideas
- Most of the gray frames are part of a glossary. Related details can be found in the context of these gray frames.
- List of classes or interfaces introduced (in the Appendix)
- List of Programs (in the Appendix)
- List of Syntax-diagrams (in the Appendix)

Another approach may be taken by browsing through the text, then checking and maybe even extending the programs, thereby referencing the text if necessary. A text on the Java Application Programming Interface (API) available for parallel reading may give details which have been deliberately omitted in this text. Some of those details also may have been changed at the time this text has been published.

Content

The central parts of that book are basic programming, structuring source-code, communication between computers, security and single user interfaces:



The first chapters describe the building elements of the Java language-expressions and statements. These building elements do not differ very much from the basic structures in languages like C/C++, Pascal or COBOL. — Then chapters titled Proceduralization, Object-Orientation, Multithreading, Packaging and to a certain extent the chapter about communication (messaging, streaming, component-programming) consider the structuring of code.

A computer-model is introduced to envision the hardware- and software-context in which Java is running. Basic programming introduces to basic programming notions (variables and their creation, expressions like assignment) and their realization in Java. Control structures essentially constitute the acting source-code (if-then- and loop-statements), the rest of the items describe methods to structure and organize the code:

Proceduralization means sorting out a relatively independent sub-task and giving that sub-task a name of its own. This introduces the notion of a Java-method (in Pascal or C/C++ a function or a procedure). The idea is to **give reusable chunks of code a name**, and to call that piece of code again as needed (page 115).
Object-Orientation (page 131) develops the idea of code-reuse in different directions: One aspect means furnishing **data together with the methods to manipulate the data**; this also means extending the notion of a type of a variable. Another aspect means **designing code for extensibility as another way to organize code for reuse**. A third aspect means organizing or **indexing code in a hierarchy** for easier reference. If larger programming tasks have to be solved in a collaborative approach by several persons, then object-oriented structuring of code may prove to be an advantageous approach.
Multithreading (page 197) means running **independent sub-tasks parallel** on multiple processors; and letting them communicate with each other: This means, for example, that some threads wait for information another thread generates.
Packaging (page 239) describes collecting code in a software-library, this just means collecting several meaningfully-related entities of code (Java-classes) and giving them a common surname for easier reference.

Leaving the elements of the core language-functionalities opens a field of selected issues: The part about Communication (page 271) includes a description of how to realize a delegation event-model consisting of source, message and drain. Throwing objects, especially so-called exceptions or errors, happens within a Java-internal communication-infrastructure. The concept of a stream may describe a one-way buffer of incoming- or outgoing data. Wrapping streams includes the idea of “on-the-fly” processing of stream-data (after reading in-, before writing out the data).
Basics of the CPU-to-CPU communication (computer-networks, page 337) stress TCP/IP-communication. Java-specifics like Remote Method Invocation (RMI) are introduced.

Part of the text also considers how to turn a file on the hard-drive, maybe downloaded from a network, into a program ready to be run. This part of activation of program-code is also called “class-loading” (page 431). The area of computer-related security (page 447) is considered by trying to answer questions like the following: How to control a user’s access or a fellow program’s access to hardware and software on a computer-platform, especially in the Java Runtime Environment (JRE), the Java virtual platform.
Finally, single user interfacing (page 507) introduces concepts and examples of how monitor, keyboard,

mouse interact with Java and the end-user. There, the Model-View-Controller (MVC)-concept describes another way of structuring Java source-code. The Appendix may be seen as collecting the remainder.

Limitations

This book tries to get the concepts clear and give a basic introduction that helps the reader to get own programming experiences. The book does not provide exhaustive information on the Java language like any handbook or reference book. For in-depth systematics see the ➡▤ ➡▤ Java Language Specification [JLS2] or other Java Language References. Thus, ramifications of the Java language and Application Programming Interfaces (APIs) are left to be found in the ➡▤ ➡▤ Java Platform API Specification [JPAPIS] and inside handbooks on this subject as mentioned in the Appendix. This especially concerns information which Java version (1.0.1, 1.1, 1.2, 1.3, 1.4) offers which options.

This text presents no in-depth description of standard software-libraries of Java (Application Programming Interfaces (APIs) of Java). For exhaustive information see the books from Addison-Wesley or O'Reilly. For an index-like compilation of the software-libraries see the online-documentations from *Sun Microsystems Inc.* or the Java Developer's Almanac [JDA].

The book is based on the **second edition of the ➡▤ ➡▤ Java Language Specification** [JLS2] and covers the **Java 2 Standard Edition (J2SE)** (not the Java 2 Micro Edition or the Java 2 Enterprise Edition). Only the Java 2 Standard Edition (J2SE) has been considered in this book, aspects of the Java 2 Micro Edition (J2ME) and the Java 2 Enterprise Edition (J2EE) have been omitted. The implementation and some aspects of the Java design may be subject to criticism; this book has been written in the belief that the drawbacks are well outweighed by the advantages when comparing Java to other existent programming-environments.

Algorithms (roughly identifiable as the language-independent version of a program), such as sorting algorithms or cryptographic algorithms, are not described in this text. See the Appendix for hints on sources of algorithms.

The writing of source-code as presented here, does not show how to organize the writing of a **large software-project**. This field is usually treated in books about Object Oriented Design of programming tasks. No extended discussion of component-software is to be found; neither are mentioned other means of structuring code independently of a programming-language, for example the UML (Unified Modeling Language).

Documents, **database**s, their formats, production and handling, and **image-manipulation** are not covered in this text. This means NO DOCUMENT PROCESSING, NO DATABASES, NO IMAGE-PROCESSING. This text provides no information on how to program text-editors and related tasks (character encodings surpassing the ASCII[2]-format, the Unicode-format or a Unicode Transformation Format (UTF) for Unicode-characters, font-management, document-types like the Portable Document Format (PDF), Extended Markup Language (XML), drag and drop implementation). — Relational- or object-databases are not mentioned, neither has been introduced the Java DataBase Connection (JDBC), a Java software-library for accessing data in relational databases with the Structured Query Language (SQL).

References to hard- and software are limited to those products that are likely to be used in a more or less average home-environment: Mouse, keyboard, monitor. The text assumes that the reader has comfortable access to a computer, an installed operating-system, at least a dial-up Internet-connection and maybe two computers connected with each other over, for example, an Ethernet connection. The additional Java software should be downloadable for free from the Internet. Differences between platforms (Unix-type like Linux, WindowsNT/95/98, Mac OS) are not treated exhaustively.

Many of the introduced programs have been tested on 233MHz G3-Mac and Intel-type machines. Generally the programs are written reduced to the essentialities, so that they should present the gist of the functionality they intend to demonstrate.

The Reader

A reader might have the following interests or goals: Know what the Java language means and to be introduced to some of its central capabilities. Wants to get an overview and a short introduction. Wants to check the prototype programs and use them as a basis for own programming efforts. Know how to install a working, cost-free Java Runtime System (JRS) and development-environment on Apple, Linux and Windows platforms. Use another book for learning programming algorithms and other advanced programming-techniques (for example text- and image-processing or database-programming).

[2]American Standard Code for Information Interchange

The Authors

Almost every view on a subject cannot be complete or ignore the descriptor's point of view. The non-completeness aspect clearly can be seen by the limited size of the book. The authors point-of-view clearly sets its limits and preferences. The goal was to establish a foundation from which the wealth of the Java programming system can be explored without getting lost in too many details.

Conventions

The names of subjects are chosen to avoid unnecessarily specialized jargon. Nevertheless in some contexts the usage of notions may vary from that chosen in this book. The index and the explanations in the gray rectangles try to take account of that. The symbol ➡▤ means, there exists an online-source for further information and ➡▤ ➡▤ indicates that this online-source can be considered as highly recommendable for further reading.

Source-code of the (Java) programming language and the content of text-files are presented in `typewriter-font`.

Parts of the text, that represent commands or programs (in `typewriter-font`), may contain passages written in *`italics`* or passages parenthesized by "smaller than" (<) and "larger than" (>) symbols. This indicates that these passages are placeholders for values and have to take a concrete value to give a valid expression. Often these placeholder-passages indicate what values they expect. For an example see the graphic past the program-code on page 71. And see the code fragments at the beginning of the section on the switch-statement on page 107. In the part of the text about networking and HTML-formats, the "smaller than" (<) and "larger than" (>) symbols are also used as so-called HTML-tags (page 370). In Bachus-Naur expressions, which should be clearly discernable from HTML-text or terminal-commands or programs, the "smaller than" (<) and "larger than" (>) symbols indicate that the enclosed entity occurs one or multiple times (page 655).

Arrows ($\rightarrow$), within the text of the gray boxes, denote notions which have been referenced by the index with a capital letter. In other context, arrows within the text can be substituted by the words "is super-class of" (see page 615, following the graphic).

Part I.

Computer-Models

Computer-Models — Wanting to know all about a computer may resemble wanting to know all about a car. Most people want to use the car for driving, not as an object of study to become a car-mechanic. So, the average user of a car has limited skills for repairing or servicing the car. To the average user the car represents just an object that helps to accomplish personal purposes. Therefore, every motorist has a well-developed set of ideas about a car's behavior, maybe not as refined as that of a test-driver, but enough to serve the daily needs well.

The relation between a user of a computer-system and the computer exhibits aspects of the same kind. The user of a computer-system confines her- or himself to those few skills which are necessary to get the computer-system's support in accomplishing the daily real-world tasks. The notion of a computer-model intends to give this collection of skills and ideas a consistent environment.

The following part of the text considers simpler computer-models, computer-languages, operating-systems and file-systems. Extensive information about end-user interfaces of various operating-systems can be found in the last part of this text beginning with page 507.

Elementary Computer-Models

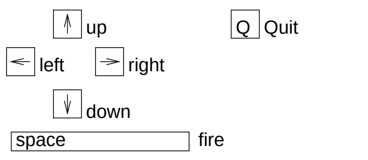
Elementary Computer-Models — First, this table shows different ways to use a computer:

recreationalist	uses a computer-game	with joystick, CD-ROM, monitor
writer	uses a text-formatter	with keyboard, monitor, black and white printer
layouter in press	uses graphics-software	with scanner, printers
application-programmer	uses interpreter, compiler, debugger, component-construction software to program: graphics-software, text-formatters or computer games for an operating-system environment	with keyboard and monitor, modems
utility-programmer infrastructure-programmer system-programmer	programs drivers, assembler, interpreter, compiler, debugger, low-level network-software, operating-systems for a specific hard- or software	with keyboard and monitor, modems
person, task	uses software	with additional hardware

Different users have different ideas how they access their computers and receive services from their computers, they have different ideas about their computer's physical components and software functionalities. End-users, who want to be helped by the computer in solving some of their real-life-tasks cannot be required to have the knowledge of a programmer. To be able to discern pure technicalities from skills for effectively solving real-life-problems with the computer, often requires a considerable knowledge in advance.

Depending on the software or hardware the user faces, each user assigns the computer-system a different set of functionalities. Such a set of functionalities can be described coherently by constructing an appropriate computing-model. In that sense the model can be used to "explain" the specific computing system (to the user).

A part of a game player´s computer model

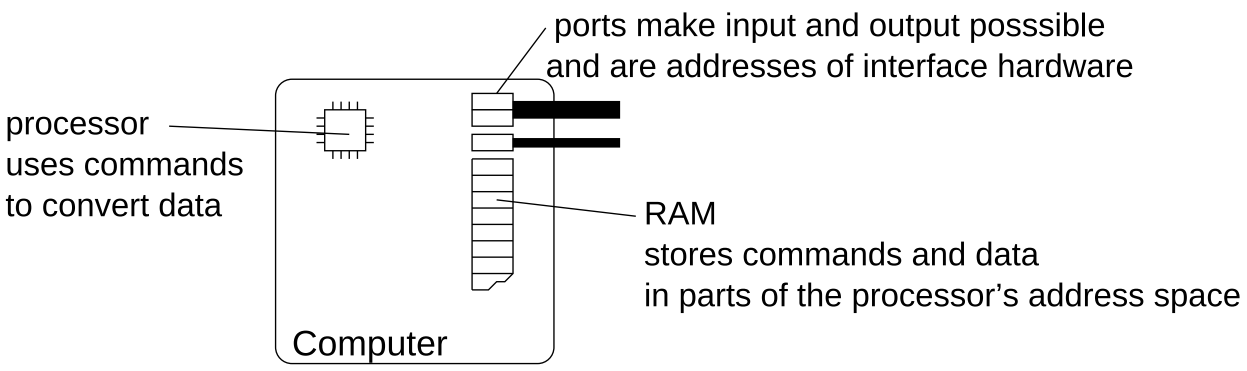


Some computing models are simple, like a computing model for a video game. Although the computing-model for the video game tells what can be done, it doesn't reflect complexity and richness of the video display and it does not tell how to acquire the skill to master the game.

The more functionalities the software furnishes, the longer the list of commands and the more difficult it may be to remember them. Even well-designed models have to reconcile contradicting perspectives: Simplicity of design makes learning and standard work fast, complexity of the models slows the learning-process but adds flexibility, opening ways to more efficient work.

A Computer-Model for Programmers

A Computer-Model for Programmers — For programmers an introductory model of a computer can be made fairly simple:


ports make input and output posssible
and are addresses of interface hardware
processor
uses commands
to convert data
RAM
stores commands and data
in parts of the processor's address space
Computer

The processor, its address-space, within that space the Random Access Memory (RAM) and the ports are given here as central notions of a computer-model. Input-data appears in the Random Access Memory (RAM) of the computer via ports, that occupy address-space which the RAM does not use. Output-data leaves the computer's Random Access Memory (RAM) by transferring the data to addresses occupied by output-ports. The Random Access Memory (RAM) stores the data. Part of the data gets recognized by the processor as sequences of processor-commands. Thus the processor can convert, manipulate or process data autonomously. A processor[3] manipulates, changes data which has been stored in the Random Access Memory (RAM).

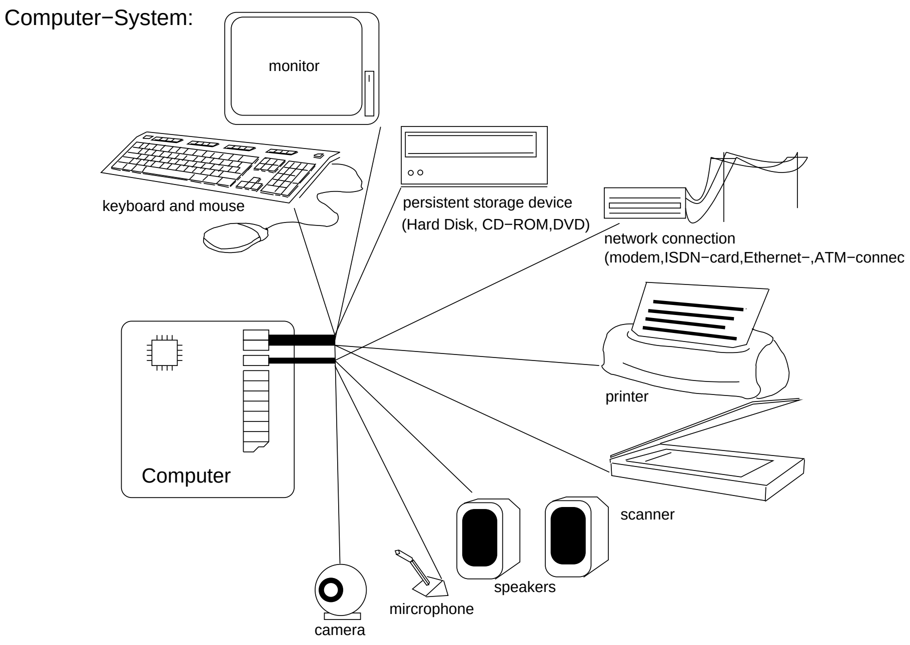
Processor: The piece of hardware inside a computer that manipulates the data it fetches from the Random Access Memory or hardware-ports. After the processor has fetched and manipulated the data, the new data is put back into the Random Access Memory or written into a port that represents a connection to a hard-disk or a computer-network. Multiprocessor-computers have multiple processors built into them; their function has to be coordinated by appropriately designed hard- and software.
CPU: Acronym for Central Processing Unit. 1. The processor(s) of a computer; the part of a computer-hardware that does the main data-manipulation. 2. A Central Processing Unit consists of the microprocessor(s), the Random Access Memory (RAM) and busses that connect both with Input/Output interface-hardware. 3. An entire personal computer, excluding keyboard and monitor.

Again: The acronym CPU stands sometimes for the processor alone, sometimes for the processor and the RAM and more seldom even for an entire personal computer (which includes an internal hard-drive but without monitor and keyboard).

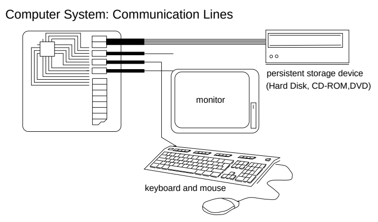
The command-sequences, that make the processor work on the data, are stored together with the data-to-be-manipulated in the Random Access Memory (RAM).

RAM: Acronym for Random Access Memory. Often simply denoted "memory". Stores data, which includes coded information and sequences of processor-commands. Generally, the processor can access each unit of information of the Random Access Memory directly. Access to data usually happens fast (in comparison with devices like hard-disks and network-connections). But data residing in Random Access Memory usually is stored non-persistently, that means the data is lost if not saved to a hard-disk before turning off the computer's power.

[3]Most processors in personal computers are, technically speaking, special integrated circuits – so-called chips – that have been given a set of very general functions. An integrated circuit is made of a collection of connected transistors and other electronic elements built into a chip primarily made of crystalline silicon. ("silicon*e*" denotes a rubbery compound of silicon)



A **computer-system** is made of the computer itself and additional devices like low data-rate input/output (I/O) devices, for example keyboard and mouse, and higher data-rate I/O devices like monitor, storage devices (hard-drive, CD-ROM), printer, scanner, microphone, loudspeakers, camera, modem or network-card (usually of the Ethernet-technology). The maximal data-rate of the communication-lines between components of a computer and the maximal data-rate of the components itself determine the performance of parts or the overall computer-system. (Analogously to a network of several computer-systems which draws its overall performance from the data-rate of the data-lines and the rate with which the individual computers can process the data.) That's much like a system of pumps and pipes for transporting water: The pipes' capacities have to measure up to the pump's power and vice versa. computer-system


Computer System: Communication Lines
persistent storage device
(Hard Disk, CD-ROM,DVD)
monitor
keyboard and mouse

A communication-line, given by a bundle of wires (more than two usually around fifty or hundreds), is called "**bus**". Those lines are usually more efficient than the single lines. Busses generally are used between hardware-components of a computer-system that have to maintain a high data-rate. Communication lines of different technologies are connected either by a "**bridge**" or by an "**interface**" (**card**); that's an electrical circuit for establishing the connection between otherwise unreconcilable types of communication-lines. If the user is not concerned with modifying the hardware of the computer, then there won't occur many occasions for handling hardware-interfaces.

Above have been described some conceptual similarities of different computer-systems. But different types of computer-systems differ significantly in technical details. For example, different makes of processors take different sets of commands.

Especially the technical development, which furnishes faster and hopefully easier-to-use hardware, makes older technical architectures obsolete. Consider some averaged performance-data of computer-systems:

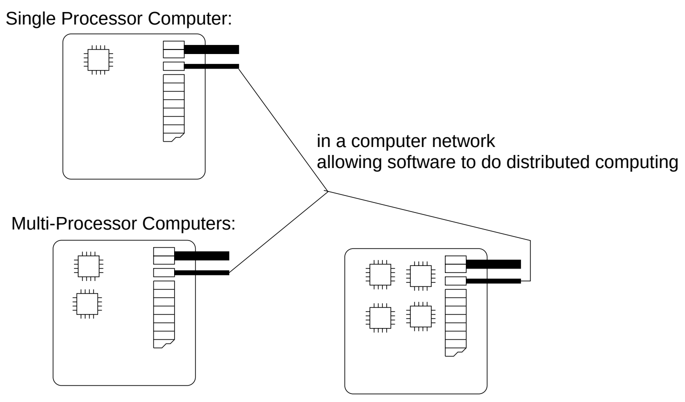
year	processor-speed (roughly in commands per second):	Random Access Memory size:
1990	20MHz	4MB
1998	200MHz	40MB
2002	2000MHz	400MB

Next to the computer's internal bus that connects the processor and the Random Access Memory, there are communication-"lines" *within* the computer: The PCI (Programmable Communication Interface) with up to 64 parallel data-lines yielding a data-flow of up to 132MB per second. The EIDE (Enhanced Integrated Device Equipment) bus with up to 33MB per second. Also, predominantly for adding external hardware to a given computer, are mentioned the SCSI (Small Computer Systems Interface) bus with up to 40MB per second for connecting up to seven external devices to the Central Processing Unit. The IEEE1394-line (also called FireWire or iLink) with up to 50MB per second and the USB (Universal Serial Bus) with up to 15MB per second as well as the Ethernet hardware with up to 100MB per second. The technological data is changing and may have changed when this has been published.

The acronym MHz (Mega-Hertz) indicates the processing-speed and the acronym MB (MegaByte) indicates the volume of the data. For what purposes may be possibly needed such information? When buying a computer, various computer-systems can be roughly compared. Then, using a computer, performance limits can be assessed, thus making it possible to quantify the volume of the Random Access Memory (RAM) or to estimate the dimension of a needed storage-device. For example, error-messages like “out of memory” may get a clearer meaning and may actually result in adding RAM to the computer. For more on these units see the subsections past the next for “MHz”, and for more on the unit of the data-“volume” (MB) see the page 34.

Computers with Multiple Processors and Networks

Computers with Multiple Processors and Networks — Multiprocessor-computers consist of several processors, connected with each other by the fast computer-internal bus-system. These multiple processors (usually 2, 4, 8, or 16) use more or less the same Random Access Memory (RAM) and usually can access the same hardware-ports. Non-expensive consumer computers usually are equipped with only one processor. But those one-processor-computers can emulate a multiprocessor-environment to allow multi-threaded programming too (see page 197 for multi-threaded programming in Java).


Single Processor Computer:
in a computer network
allowing software to do distributed computing
Multi-Processor Computers:

Networks connect entire computers mostly by external wiring, for example with versions of Ethernet-hardware, or even by wireless radio-connections. These external connections among computers usually do transfer data slower than the internal bus-systems of the individual computer. The difference between a network and a multiprocessor-computer also can be formulated as follows: Each computer in a network has its own Random Access Memory (RAM). In a multiprocessor computer the processor have to share the Random Access Memory. For more about networks see the part of this text, beginning on page 337.

Summary: Computer-Models

Summary: Computer-Models — There are imaginable different computer-models; one of those models, that gives many details independently of the technology, has been presented more extensively: The processor takes commands and data and returns transformed data. The Random Access Memory stores data, part of that data are sequences of processor-commands. Communication-lines like busses transfer the data between components of the computer-system. Why, next to Random Access Memory (RAM), are needed other storage-devices such as hard-drives (magnetic disks) or CD-ROMs? RAM works fast, is expensive and looses the data (and programs) in the moment the computer-system’s power is turned off. Compared to RAM, hard-drives are inexpensive and hold the data permanently (persistently) until deleted by the user. For storage-purposes their slowness doesn’t matter. CD-ROMs are what the name indicates, Read Only Memories on compact-disks of about 600MB. They are easy to transport and their data cannot be changed, which can be seen as a security advantage. The same applies to DVD-RAMs and DVD-ROMs, but they can store about 5000MB, about ten times the data-volume of a CD-ROM.

How to start a computer? The model described above lacks any related description. In the technical context, this process requires additional features to be included into the model. An end-user may answer that question saying: “By pressing the power button.” This turns out to be a workable and rather sensible answer on the level of the end-user’s model and working-requirements.

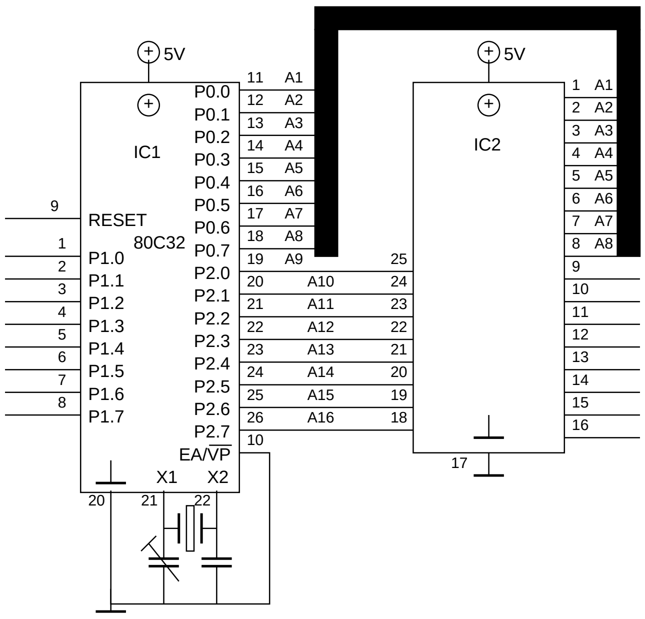
A Computer-Model for Hardware Technicians

A Computer-Model for Hardware Technicians — Even hardware technicians use computer-models. Their models are much more refined towards the technical aspect of computing.

The graphic below is meant only for getting a feeling for the technicalities involved. The large rectangles represent individual silicon-chips. Each line represents a single electrical connection. The symbol that looks like a little sandwiched rectangle, in the lower left part of the graphic, near the number 22, represents the oscillating crystal, which gives the frequency (also called clock-rate) according to which the computer works. The number of times an event reoccurs per time-interval is called frequency. The crystal inside the computers wobbles millions of times per second. This frequency of oscillation (millions of times per second) of such a crystal is called one Mega-Hertz. An average car-engine turns about hundreds of times per second (thousands of rotations per minute), which is slower about a factor ten-thousand than the frequency of a computer's oscillating crystal.

frequency

Mega-Hertz



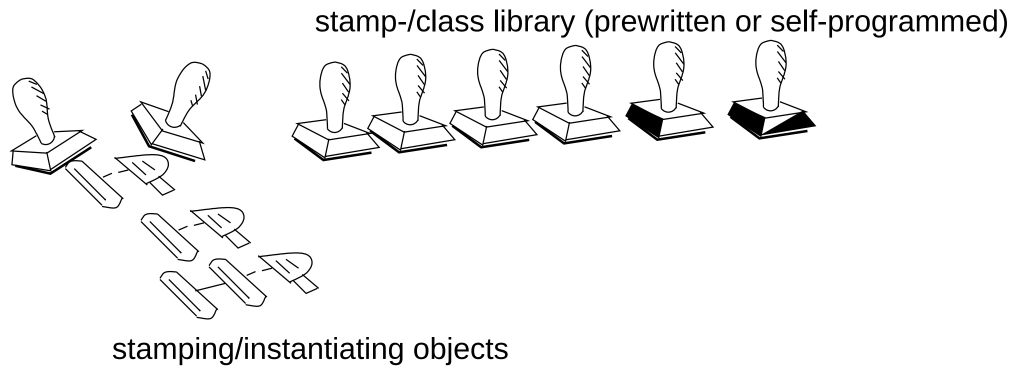
Structuring Code and Data: Object-Orientation

Structuring Code and Data: Object-Orientation — Methods and, if those methods properly encapsulate their functionality, the associated Application Programming Interfaces (APIs) are useful for structuring source-code. If properly designed, even large pieces of source-code, which have been structured with the means of proceduralization, do work and can be maintained. Nevertheless there are many (real-life) programming problems that are open to another way of structuring: Object-Oriented Structuring of source-code.

Historically the object/class-model emerged from trying to simulate physical real-life objects and their interactions[45]. There, classes characterize sets of objects with common properties; this approach can be seen as the more general one.

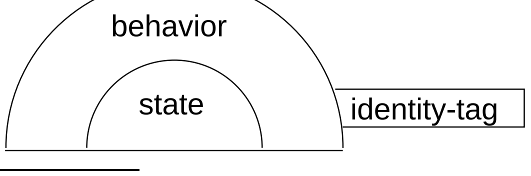
Another approach starts by developing programmer-defined types: A number may be thought as being characterized by its data AND the methods for its manipulation, like addition and subtraction, multiplication and division.

Since real-life objects often can be seen as displaying a considerable complexity, their relevant properties have to be isolated. That process of model-building is also called abstraction. Object-Orientation has a considerable conceptual overhead, but a readily approachable aspect can be shown with the stamp-analogy: Classes within object-oriented structuring are like stamps (which the programmer can carve or take from a library). With these classes the programmer can instantiate objects, much like the stamps can be used to produce several prints, into which it is possible to write data by hand. There even may be little stamp collections, which appropriately combined ("extended") produce an new type of printed matter.


stamp-/class library (prewritten or self-programmed)
stamping/instantiating objects

Concept: Object/Class-Model

Concept: Object/Class-Model — This section just introduces the central notion of the Object/Class-Model: An object is defined as an entity having a state, a behavior and an identity[46].



[45]Nygaard, Kristen and O. J. Dahl. *The Development of the Simula Languages* in History of Programming Languages. Academic Press. New York, NY. 1981.

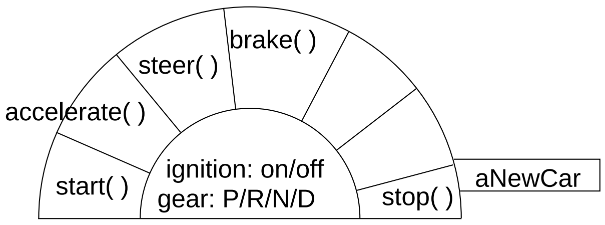
[46]In object-oriented programming-languages the "state" of an object usually is given by variables and the "behavior" is given by methods. Though the identity often may be thought as being given by a variable-name, this may not be true when variable-names are pointers, that may change their pointing-direction! This is the case in Java; there, an identity-tag has to be retrieved by a special `hashCode()`-method, as introduced on page 161. CAUTION: Variable-names in Java do not fix the identity of an object!

In the graphical representation the identity-tag often is omitted, because of self-evidence. But the identity gives the means to discern two objects with the same state and behavior. Two objects with the same state and behavior are called equal (but they are not the same due to their different identities).

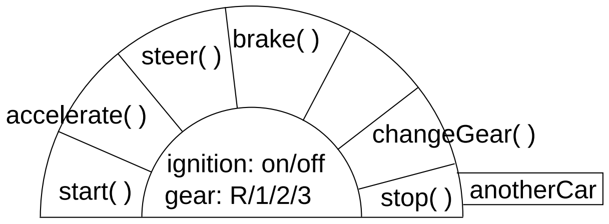
Later, the object-model is supplemented by an equally generally defined class-model, see page 140.

Example: Object, Class and Class-Hierarchy

As an example of such a general object-notion may be taken a new car coming from a production line: Although the cars look alike, the car under consideration is a unique one, it has an identity. It has also a state describable by the gauges for gasoline, motor oil, braking fluid, gear box fluid, cooling water, battery voltage, engine on/off, lights on/off, blinker right on/off, blinker left on/off, warning blinker on/off and other dashboard indicator positions. The behavior of that car, starting the engine, driving forward, driving backward, changing the direction of driving is described by more or less complex sequences of actions as found in the handbook of the car (or to be learned by driving it). The graphic below presents two objects which can be seen as simplified representations (so-called abstractions) of a real car:



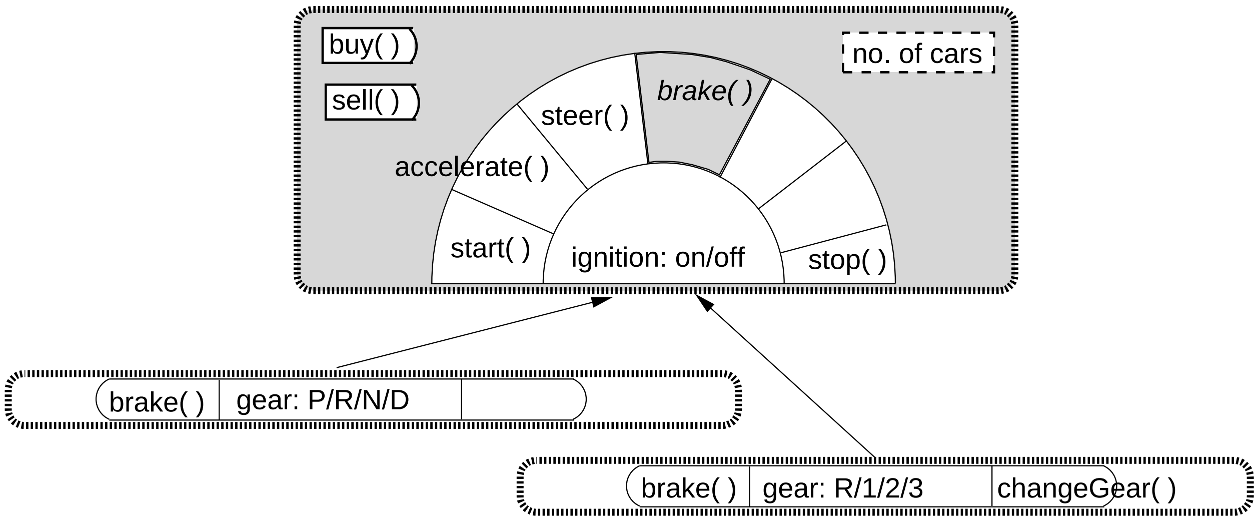
car with automatic transmission



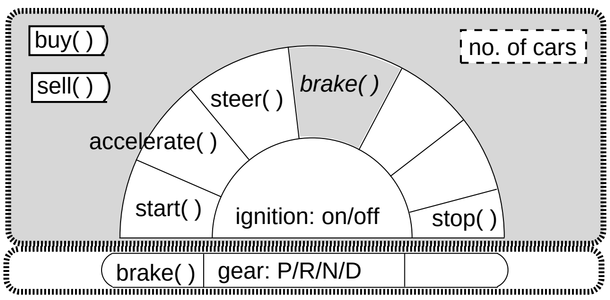
car with mechanical gearbox

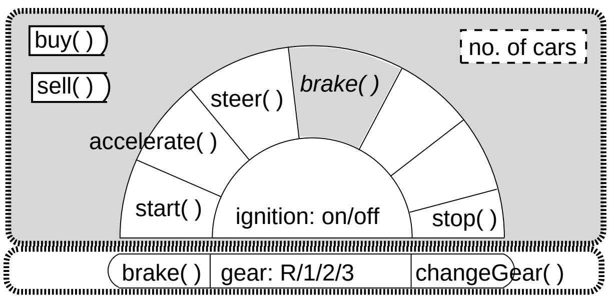
One car may have an automatic transmission. Another car may have a mechanical gearbox, this changes the possible state of the car (possible gear-positions are 1/2/3 instead of P/N/D) and this even extends the behavior of the car by an explicit complex changeGear()-procedure. So far, the structure of the above objects can be overseen easily. This view may change in cases where ten or hundred cars have to be considered, abstracted in the way above. If more cars are to be collected, then the different structure of the objects would become clearer by isolating common states and behaviors to get the pure structure of the collection of objects:

Car- Class Structure



(The various features, like rounded frames and grayed backgrounds, of the graphic above will be described successively in the following paragraphs.) Of course, the pure structure above does not relate directly to any individual object, but any given individual object can be classified fast and easily by using the structure above. The structure just collects all the different features used to describe the two kinds of cars above. The iglu-shaped part of that analysis describes a sort of basic car structure giving no information about what gearbox-system such a car contains. The extension of that structure produces two new structures: One of those extensions describes a car with an automatic transmission, and the other describes a car with a mechanical gearbox. The rounded frame with the iglu-like figure inside represents a structure, called a **class**. That **class can be extended** by adding one of the little frames: class class-extension





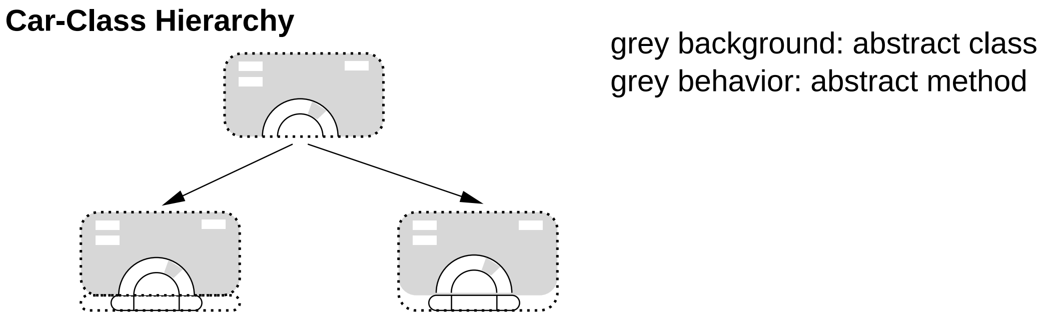
The resulting new classes above can be used as templates for producing objects (Car-objects[47] with automatic transmission and Car-objects with a mechanical gearbox). The frame around the iglu-shape, or around the burger-like shape indicates that it is a class or part of a class-structure. Producing objects from a class is also called instantiating the class or **generating an instance of the class** or **deriving the object from the class**. This instantiating process in a way resembles the stamping-act: The class is used as a stamp for printing out one or more objects. instantiating a class

The structural analysis of the Car-objects produced a **class-hierarchy** given by the abstract Car-class, without any gear-specification, and the two extended classes, above: A class for cars with a mechanical gear-box and a class for cars with an automatic gearbox. class-hierarchy

Buying a car can be seen as instantiating the car in your living area. Selling removes it. Buying, selling or scrapping the same car more than once in the time of your ownership would be unusual. So buying, selling, scrapping can be seen as actions that are part of the behavior of the Car-class rather than reformulating them for individual Car-objects (The sales-man or the car-crunching machine are not integral parts of the car's state or behavior!). These behaviors can be assigned to the Car-*class* and then are called **class-behavior**. class-behavior

The number of Car-objects, which are described with this class-model, neither characterizes the individual Car-object; but that number describes the *set of Car-objects* which is considered. So, the "number of Car-objects" can be seen as a **class-state**, to be associated with the Car-*class*. In the frame that fixes the class-structure, the class-states and class-behavior are collected as squares or square-like boxes in the upper corners. class-state

The graphics above allow another interesting observation: The base-class, that can be extended, cannot be sensibly instantiated; the Car-object would have an undefined gearbox and therefore couldn't describe an average real-world car. – Such classes which cannot be sensibly instantiated are also called **abstract classes**. But, as can be seen above, abstract classes can be used for devising clearer structures and abstract classes can have a defined behavior and a definable state which they transfer onto the extended classes (the ignition on/off state and the other behaviors) and instantiated objects thereof. Abstract classes here are written with a gray-underlaid frame, to make them discernable from non-abstract, instantiable classes. (The Java-implementation of the notion "abstract class" is given on page 183 and an elementary example in Java can be found on page 181.) abstract class


Car-Class Hierarchy
grey background: abstract class
grey behavior: abstract method

methods and variables

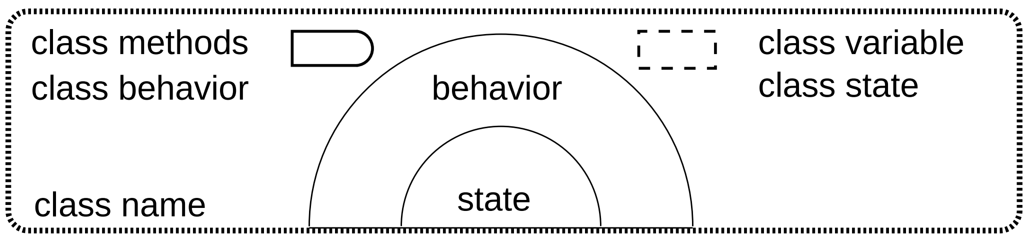
As could be seen above, the very general notion of "behavior" usually is realized as a set of actions or procedures also called **methods**. Whereas the notion of a "state" usually is realized as a set of **variables**. There can be discerned so-called **instance-variables** (ignition with the values on/off, gear position with the values P/R/N/D) used for describing the state of an object and so-called **class-variables** (number of Car-instances) describing the state of the class. instance-**variables** and class-variables

[47]The upper-case letter "C" indicates that "Car-object" denotes a mental image — the model — of a car, not the real thing!

instance-**methods** and class-methods

The same classification can be applied to the *behavior* of classes and objects: There are **instance-*methods*** (start(), accelerate(), ...) that describe the behavior of the individual object. These instance-methods can be invoked for each object individually (car1.accelerate(slow) and car2.accelerate(fast)). – But there are also **class-*methods*** which describe behavior of the entire class: Like Car.buy(car1) and Car.buy(car2). The act of buying is taken as a class-method, because the buying-process can be described independently from the individual car, whereas for example the price of the car describes an aspect of the car's individual state. Later, in the context of programming-languages, the equivalent to producing and buying a car can be seen as the instantiation of an object by using a class-specific constructor-method.

These remarks make it possible to identify the various abstracted notions in the graphical representation of the class-model:



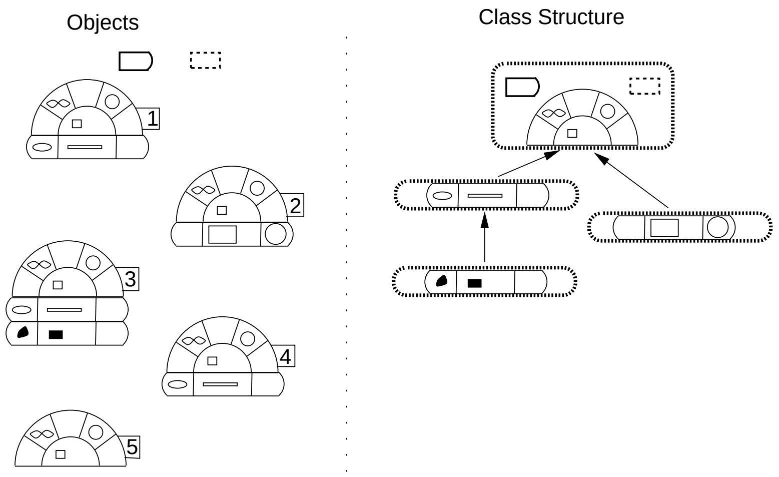
abstract method

Finally, consider a reason why even unimplemented methods, so-called **abstract methods** may be a sensible idea: The brake()-method is a method of the abstract Car-class. But the braking-process differs in a car with a mechanical gearbox from that in a car with an automatic gearbox (The clutch should be released during a heavy braking-process.). So, specifying the braking process for the entire Car-class becomes difficult because the brake()-method has to be implemented differently for the two derived classes. But still it may be useful to have at least the idea of a brake()-method within the Car-class, because braking is what every car should be able to do. This necessity can be indicated with a non-implemented (abstract) brake()-method in the Car-class. (The Car-class itself couldn't be instantiated, because there exists no conventional car without a transmission of any kind, and therefore the entire Car-class has to be called abstract.) Of course, a class with at least one abstract (unimplemented) method automatically has to be declared abstract, because objects with unimplemented methods violate the idea of a defined behavior.

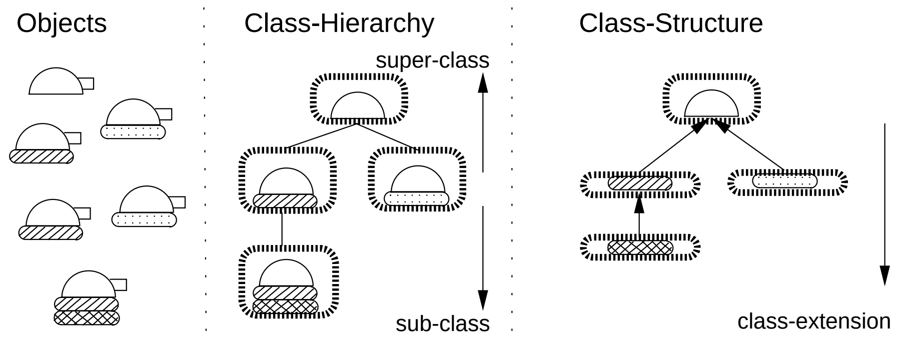
abstract class

What has done with the brake()-method could have been done also with the accelerate()-method, assuming that acceleration is thought of involving a changing of gears. Why the difference? There exists no particular reason for that difference: Class/object-structures are models chosen by an onlooker for describing an area of interest or a problem according to the onlooker's necessities. THERE IS NO INHERENT ULTIMATE TRUE STRUCTURE TO BE FOUND, the choice above was taken just to illustrate the class/object-model. Of course this freedom, or seemingly arbitrary approach, can be used to properly design classes to depict real-world-problems; with the intention of letting this class/object-model be re-used as much as possible. — Making class-design, problem-oriented as well as anticipating future needs, can turn out to be more difficult than expected!

The relation between a collection of objects, class-methods or class-variables and a given class-structure is restated in the following graphic:



Observe that all objects share the class-variables and the class-methods. Objects Number 1 and Number 4 are equal but not the same! (Their state and behavior are the same but they have been given different identities.)



extension-hierarchy

A given class-structure, like that of the Car-class, makes it easy to construct sub-classes by adding class-extensions. In the (resulting) class-hierarchy, also called extension-hierarchy, those classes that have been extended often are called **super-classes**, their extensions consequently are also called **sub-classes**. Observe also that THE MOST COMPACT DESCRIPTION OF THE CLASSES CONSIDERED GIVES THE ORGANIZATION OF THE CLASS-STRUCTURE. Therefore in programming and documentation, classes are economically declared or described by using the more fragmented but least redundant representation given by the class-structure (and avoiding the organization as a class-hierarchy or worse as a collection of objects).

super-classes and sub-classes

class-structure: most compact description, thus widely used!

The notions “object” and “class” thus can be seen from two sides:

(Class as Template for Creating Objects) A class can be seen as a collection variables and methods that can be of the instance- or class-kind. A class-hierarchy is given by a structured collection of these variables and methods. The class then serves as a template for objects; and the hierarchy of classes represents a tree-structure of successively refined templates. Class-methods and class-variables can be used independently from the existence of an object.

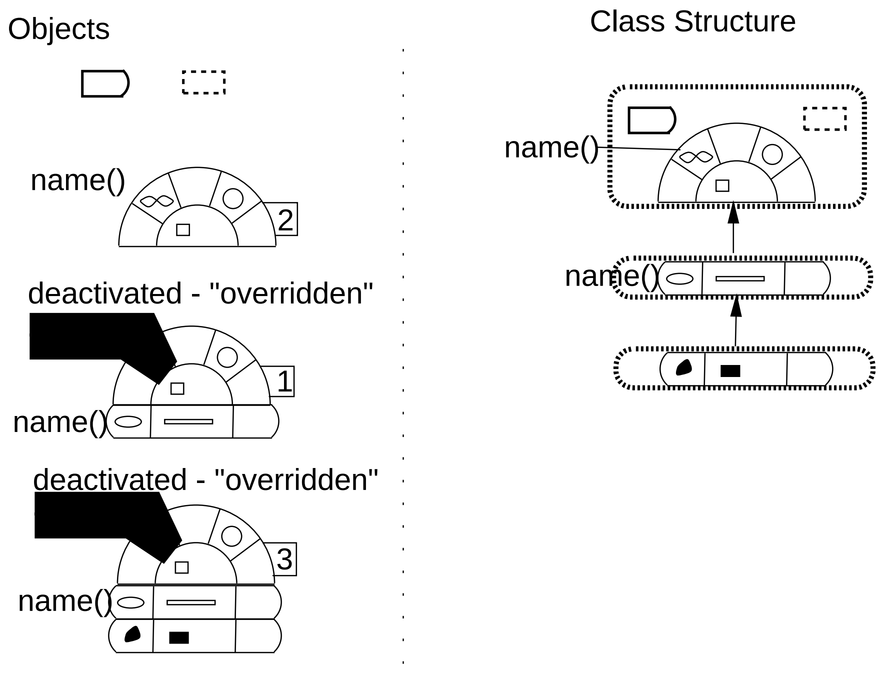
(Object Collection is abstracted to Class) Consider several similar objects *together* with methods that describe how to construct and how to destruct an object: The methods that exist independently from the existence of any object are called class-methods. There may be a variable that has the same value for all objects under consideration, that variable is likely to become a class-variable. Another variable that occurs in some of the objects and contributes to the object’s individuality by having different values from object to object needs to be an object’s state- or instance-variable. Depending on the variety of the given objects, there are compilable different collections of variables and methods. These collections constitute the classes that can be arranged into a class-hierarchy.

So both approaches, the one starting with the class-notion, or the one starting from the object-notion are part of - or result in the same object/class-model.

OUTLOOK: The class-structure is what will be used to define class-hierarchies in Java on page 163. An example of a larger class-hierarchy is given by the graphic on page 564 in the context of arranging a Graphical User Interface; details of the emerging class-structure of the three base-classes (`Component`, `Container`, `JComponent`) are given successively in the lists on pages 553, 556 and on page 559.

Overriding Methods and Shadowing Variables

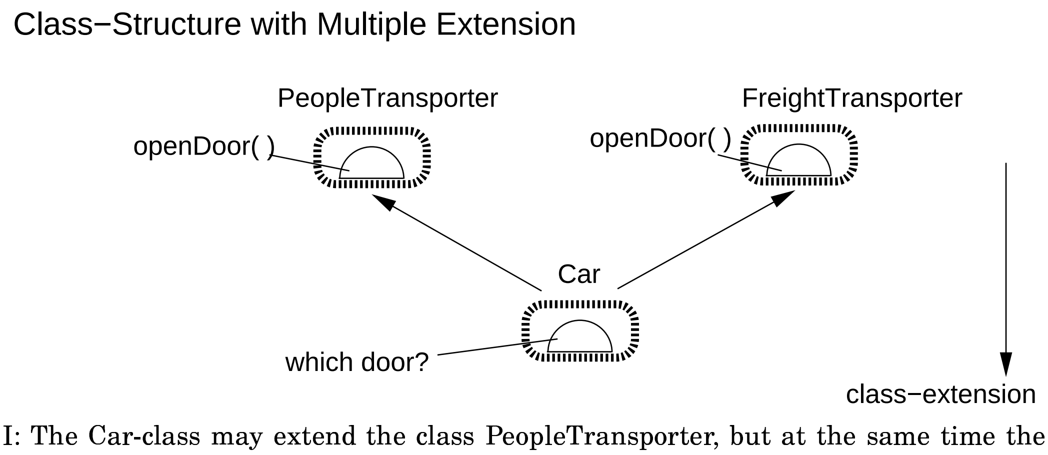
Overriding Methods and Shadowing Variables — Consider the brake()-method in the graphics around page 132; there the abstract method has been redefined differently in both sub-classes. What about re-defining non-abstract methods of super-classes? Or formulated conversely, what if a method or a variable in a class-extension has the name of a method or variable in the super-class? First, objects derived from (one of) the super-classes use the original method, BUT all objects derived from the class-extension or its sub-classes use the newly defined (instance-)method or (instance-)variable. The overriding of a method has been visualized in the graphic below:



Remember the shadowing of variables by local variables of Java methods as introduced on page 123, shadowing of variables by class-extension can be imagined likewise. Overriding class-methods and shadowing class-variables would produce *class*-specific variants. For an example consider the Java source-code on page 167 and the corresponding footnote following that source-code.

Class-Extension — Inheritance with multiple Super-Classes

Class-Extension — Inheritance with multiple Super-Classes — Another approach to the process of extending classes may be thought of by imagining a class having *several* super-classes. Example: Below the Car-class extends the class PeopleTransporter and the class FreightTransporter. Each instance of a Car may be used to transport people as well as freight:



Example I: The Car-class may extend the class PeopleTransporter, but at the same time the Car-class may extend the class FreightTransporter. This makes it possible to construct an ambiguity: Both classes may use a method openDoor(), but as can be seen with the example of a standard car, such a method usually means different doors (doors to the area with seats or door of the car's trunk). Though, here, the ambiguity may seem constructed, a general method for structuring contexts should be designed to spare the programmer or the user unnecessary complexities. (Sketch the class-structure for this example, the graphic above may serve as an orientation.)

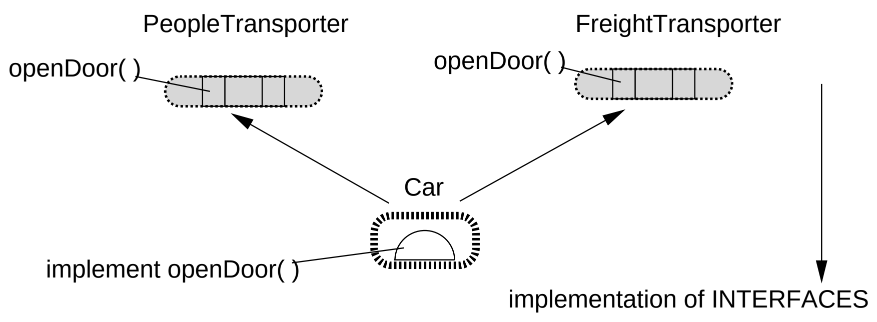
From above emerges a BASIC PROBLEM: MULTIPLE INHERITANCE BECOMES AMBIGUOUS IF TWO BASE-CLASSES HAVE METHODS OR VARIABLES OF THE SAME NAME. The question may arise about which member takes precedence when they both have the same name. Therefore, using classes that extend multiple super-classes should be considered rather careful.

again abstract methods

A tricky workaround concerning this predicament can be formulated as follows: Consider a class having only named, but unimplemented methods, also called **abstract methods**. This makes such a class automatically abstract, because it obviously cannot be sensibly instantiated. This kind of class, with no apparent functionality, furnishes a kind of template and this seems to be the best one can get, to formulate multiple inheritance without an inherent source of contradictions or unnecessary considerations about precedence.

Example I (continued): So, using the example above, PeopleTransporter's openDoor() and FreightTransporter's openDoor() may be unimplemented. When both are extended to the Car-class, the openDoor()-method has to be implemented considering the two types of doors for loading people and for loading freight.

Class−Structure with Interfaces (fully abstract, multiply implementable)



"Classes" which contain only unimplemented, so-called abstract, methods AND allow other inheriting "classes" of the same kind at their side are called "interfaces" in Java. The name "interface" signals the option to realize a kind of multiple inheritance as described above. Java[48] classes can implement *multiple* "interfaces" and thus furnish a version of multiple inheritance that proves relatively free of inherent complexities. For more see page 185.

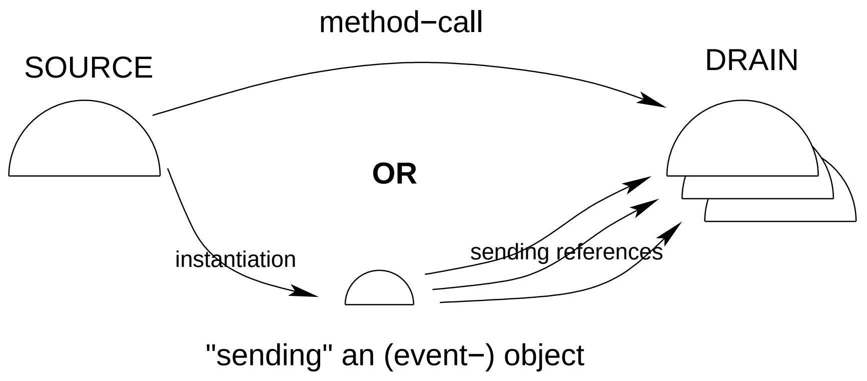
Java's "interfaces"

Communication-Mechanisms

Communication-Mechanisms — The structuralizing of objects by classes and class-hierarchies may be considered as useful, but coexisting objects should be able to communicate to simulate real-life interaction or just to make the object-model more efficient:

Method-Activation or method-calling represents the natural means of communication between objects. This requires the objects to know each other well, but this knowledge of each other may also involve an unwanted specialization of the objects.

Communication by method−call or by dispatching an Event−Object



Message-Objects exchanged between communicating objects generally requires the objects to know very little about each other: The only knowledge, that remains necessary, is to know how to interpret the message-objects, how to send them and how to listen for them. The communication is thus realized by exchanging messages between objects, this "uncouples" objects. Then, the methods that have to

[48]The programming-language C++ allows multiple inheritance which has to cope with making inherited behavior non-ambiguous.

be called, are only listening- and dispatching methods, which, by following conventions, generally simplifies matters! For an object in a message-exchange context, a carefully-designed set of message-objects furnishes a relatively lean interface to its outside world. The rest of the implementation of the object could be changed, if necessary, without changing the behavior of the object. This isolation of the inner workings of an object exemplifies the concept called **encapsulation**. Like in proceduralization, encapsulation of object-functionalities means hiding the details of the implementation.

For more Java-related information on general messaging see pages after page 271. If the interaction between objects is realized by exchanging message-objects rather than by issuing object-specific method-calls, then this is one first step towards what is often called **component-model**. There, objects usually send and filter highly normed event-objects. For more information on the area of software-components, see page 311.

Object/Class-Model Keywords

Object/Class-Model Keywords — The following paragraph gives a small glossary on the main notions of the object/class-model:

abstract- or virtual class A CLASS THAT CANNOT BE INSTANTIATED, this means that no instances of that class can be created. Abstract- or virtual classes are collections of common states and behaviors; but these become only part of an object that is an instance of some sub-class of the abstract- or virtual class. Some of the methods may be implemented and others may be declared abstract. Example: A Car-class which lacks the specification of the transmission type is an abstract class, the brake()-method may be abstract but the accelerate()-method may already be implemented.

abstract method A named method with no functionality defined. A class which contains at least one such unimplemented method automatically cannot be instantiated; that means a class with a single abstract method becomes implicitly abstract itself! A standard use of abstract methods can be found in multiple inheritance, where these method-declarations (in Java “interfaces”) are used as templates. But as could be seen with the example of the Car-class, when considering the brake()-method non-abstract, classes can be considered to be abstract without having abstract methods. A car has to have either an automatic transmission or a mechanical gearbox! (Unless it is an electrical car; this option has been ignored as the Car-model was introduced.)

class A collection of possible states and behaviors, either gathered from a set of similar objects or established from a given problem or area of interest **(class as collection of states and behavior), (class as an abstraction of a collection of objects)**. In programming, a class can ALSO be taken as a programmable type-concept **(class as a customizable type)**. A class can be seen as a template that furnishes the fields (state) and methods (behavior) of an object **(class as a template)**. A class gives the behavior and the possible states; an object of that class has the same behavior but only one fixed state and an identity. Due to the given identity (a registration-number or some other tagging-instrument) of an object, there can be several objects with the same state, instantiated from the same class.

class-extension Defining a new (sub-)class by adding other kinds of states and behaviors, respectively kinds of variables and methods to an existent class.

class-hierarchy A collection of classes, arranged according to their dependencies in form of sub- and super-classes. These kind of dependencies usually form a tree-like structure.

class-methods Methods which are associated with the class, not with an individual object. For example, methods (also called constructors) for creating instances of that class. In Java, beside constructors, so-called **static methods** are the class-methods.

class-variables Variables that are associated with the class, not with an individual object. For example the number of objects that have been instantiated during the use of the class can be counted by using a class-variable. In Java, class-variables are also called **static variables**.

container-object An object which contains a list of references pointing to other objects. Container-objects typically implement buffers, stacks or little non-persistent databases. Java supplies container-objects like instances of the class `java.util.Vector`. CAUTION: Though Java array-types can index objects, array-types are something different than class-types (See the syntax-diagram on page 143, and the introduction on page 234.). Only from Java class-types can be instantiated objects!

encapsulation Hiding, often complex, self-contained solutions of problems and giving them a much easier programmer- or user-interface. This allows a relative ease of use without having to grasp inner complexities. Proceduralization offers a means of encapsulation by needing only to know the method's signature and return-value to use it. Object-Orientation can be made to work similarly on the level of the entire object. Encapsulated code may document its functionality in a so-called (Application) Programming Interface (API). Especially in the context of networking, the effects of simplifying things, by encapsulation of code, are circumscribed by the notion "transparency".

inheritance All sub-classes (or class-extensions) receive the methods and the variables furnished by their super-classes (sometimes also called parent-classes). INHERITANCE DESCRIBES THE SAME AS CLASS-EXTENSION; but inheritance focuses on the sub-classes whereas extension stresses its starting-point being the super- or parent-classes.

instance of a class An object derived or instantiated from that class. The class represents a template for state and behavior; an object bears a concrete state, a concrete behavior and and identity(-tag). Also refer to the item "object" below.

instance-method A method associated with an individual object (in contrast to a class-method which is associated with the entire class). The nature of that association, for example, makes the method change one of the object's variables. Instance-methods are taken to represent the behavior of their object.

instance-variable Instance-variables are associated with an individual object (in contrast to a class-variable which is associated with the entire class). Instance-variables describe the state of their object.

method A method can be called (for example by other objects) to alter the object's state or to send messages to other objects. In programming practice, a method (also called function, procedure, subroutine) usually represents a kind of named piece of code associated with an object or class. Usually methods are the means by which another object can change the object's variables (alter the object's state).

message A signal from a source-object to a target-object, usually requesting a method-invocation of the target-object. Sometimes, simply calling the method of another object and transferring information within the method's arguments is considered as sending a message! But, often messages are objects themselves, then they bear a standardized structure, which is known to all communicating instances. Then, the method-calls used for communication of objects become highly standardized. Usually a message-object contains the name of the sending object, the name of the receiving object, the name of the method to invoke and some variables that are used as the invoked method's arguments. This concept has been developed further beginning with page 271 and on page 571.

multiple inheritance The case where a class inherits state and behavior of multiple super-classes (In Java, multiple super-interfaces). To avoid ambiguities of the super-classes with same variable- or method-names, only abstract methods and unassigned variables should be used. The Java `interface`-construct furnishes this restriction.

object An entity with a **state**, a **behavior** and an **identity**. In programming, an object is given as an entity of variables and methods together with an identity. This generality often reduces to an object being seen as a variable that has been instantiated from a class-definition, where the class is taken to be a sort of generalized type-definition.

overloaded methods Methods are identified by their object's name, their own name and their parameter-list. So even in their own class, different methods can have the same name but a differing parameter-list to remain valid. Such methods are called overloaded. Remember the section beginning with page 124.

overridden methods Overridden methods always occur in the context of a class-extension: A class-extension may define a method with the same name and the same list of parameters as a method given by the super-class. The newly defined method becomes the default method of any objects instantiated from this extension or any further extensions. An analogon on the level of variables presents itself: Two variables with the same name but different overlapping scopes produce the following effect: The variable with the limited scope overshadows the other. (Why are there no overridden variables? Because overriding variables would amount to redefining the type of the variable-name, nothing more.)

Pragmatics: Constructing class-hierarchies, to describe a problem efficiently, usually turns out to be demanding and even may need redesign efforts. But there are some simple rules and conventions that may ease the task: When describing the real-life problem, using the everyday language,

nouns indicate an object or a class to be used in the object-oriented analysis,

verbs indicates a method's functionality and the formulation

is a *name* indicates something to be an object or a sub-class.

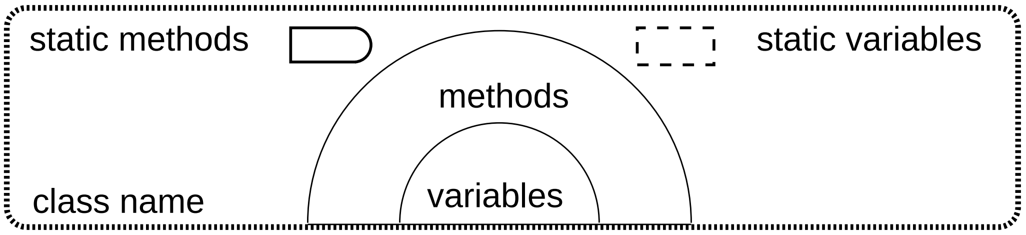
Object-oriented analysis of problems can happen without using a programming-language. Object analysis represents a problem-oriented method of program-design and therefore usually happens *before* constructing source-code. But object-oriented design usually addresses itself to EXTENSIVE real-life problems with less dominant algorithmic complexities. The wealth of approaches and methodologies of object-oriented-analysis and -design is described in books or related Internet-sites.

Concept: Object/Class-Model within Programming-Languages

Concept: Object/Class-Model within Programming-Languages — In many programming-languages, aggregates of variables are called `records` or `structs`. Aggregates of command-sequences and variables are described by functions, methods or subroutines. Here aggregates of variables AND methods are called **class**es.

```
class name
{
  variables;
  methods;   // usually for manipulation of the variables
}
```

In that context, remember the object-model on page 131 and the graphic of the general class-model on page 134. The general class-model, introducing state and behavior, changes in the context of a programming language to a class-model given by an aggregate of methods and variables:



Classes in programming-languages can be given another variant of definition: Classes just furnish a way for the user to aggregate data (variables) and methods (functions, subroutines). Object-oriented programming-languages also furnish ways to introduce static class-members and ways to derive individual objects from a given class.

For practical programming purposes the notion of a class can be used

- to introduce programmer-defined types,
- to use a class as a self-contained program and
- to use a class-structure as an index for reference when re-using software:

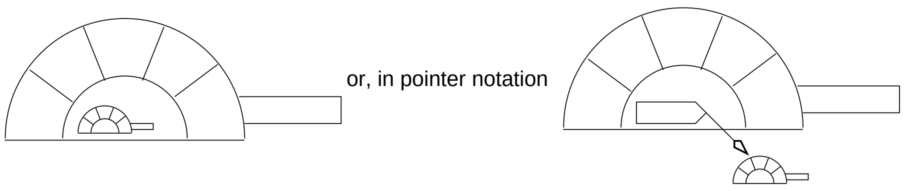
Classes as Custom-Programmed Types **Classes can be used to define programmer-specified types** within the programming-language. These programmer-defined types give templates for the data and furnish the methods to manipulate the data. The central idea aims at presenting the data and methods for the data-manipulation as an entity. Thus, in other contexts, methods for data-manipulation do not have to be re-written. To the programmer, both, the data and the methods, are related intrinsically; just like any integer type furnishes mathematical functions like addition, subtraction, multiplication and division for its manipulation:

```
class Integer // this is a concept-class and does not work in Java
{
  int i;
  addTo(int j){return i+j;}; multiplyWith(int j){return i*j;}; // etc...
}
```

If the standard types of the given programming-language can be supplemented by types defined by classes, then variables of class-type even can be declared inside classes:

```
class ClassName1
{ ClassName2 identifierOfObject; // declaration of variable of class-type
}
```

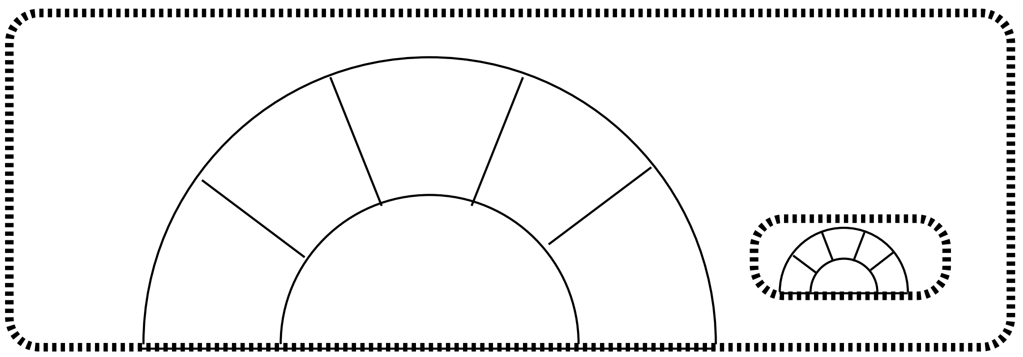
Thus a variable of class-type — an object itself — can be seen as part of the state of an object:



So the state of an object is given by objects (pre-programmed or programmed by the application-programmer) or by variables of primitive-type. Objects of standard classes given by the programming-language (Java: `String`) or variables of primitive-types (Java: `int`) finish the recursion indicated by the diagram above (objects in objects in objects . . .). For example, in the concept-class above, named Integer, the `int`-variable of primitive-type, given by the programming-language, defines the state. A practical example of this idea is given on page 142, where a newly-defined type (VarInteger) is used for declaring and instantiating a variable (there the variable can be seen as an equivalent to an object).

Instead of containing only a variable-declaration, a class even may contain a class-definition, a so-called inner class, giving a kind of local type:

```
class ClassName1
{ class ClassName2 // class-definition
  { ...
  }
  ...
  ClassName2 name; // declaration of a variable of that local type (inner class)
}
```



Inner classes are described further beginning with page 157.

Class as a Program A class can be a flexible type, or **if a class is furnished with a `main()`-method, then a class can be a program**:

```
class Program // this is a concept program and does not work in Java
{
  main(){ statements }
}
```

If the source-code inside the main()-method references other classes or creates and references other objects, then the class with the main()-method does represent the central piece of a program! Conventionally, classes with a main()-method enable an end-user to issue some command on the level of the operating-system, eventually triggering a call of the main()-method (the java-command entered into a terminal-window of the native operating-system triggers a call of the main()-method). This peculiarity gives classes with a main()-method all the characteristics of a regular program. Thus, in most object-oriented programming-languages, the class-notion becomes more than simply a flexible way to define new types.

Class-Structure as Index to Software-Library But the perspective of the class/object-model gives another important functionality to object-oriented programming-languages: As can be seen in the graphic on page 135, class-extension lets the code be positioned in a sort of programmer created hierarchical index-structure for easier identification. Successive class-extensions and the ensuing class-hierarchy can be used to **realize a structure of the involved objects**. Since the super-classes may be used multiply (remember the car example above), that kind of structuring also makes it possible to easier re-use code.

Java: Classes as Programmer-Definable Types and Programs

Java: Classes as Programmer-Definable Types and Programs — Java classes can be more than templates for objects. A Java class with a main()-method constitutes the center of a program. The fully-functional example below defines two Java-classes: The first class introduces a programmer-defined type and the second class acts as a program due to its main()-method. (The use of the modifiers public, static and void is described elsewhere: public on page 175, static on page 147 and void beginning with page 117)

```
// a Java class: a programmer-defined type or a program
class VarInteger                                // programmer-defined type
{ int i;                                           // state: instance-variable
  VarInteger( int x ){ i = x; };                   // class-method: constructor
  public void set( int x ){ i = x; }               // behavior: instance-methods
  public int get(){ return i; }
  public void increment(){ i = ++i; }
  public void print(){ System.out.println( i ); };
}
public class Program                             // program or application
{ public static void main( String unused[] )     // class-method: static main()
  { VarInteger theObject = new VarInteger( 0 );
    String theOtherObject;
    theOtherObject = new String( "Hello" );
    theObject.print();
    System.out.println( theOtherObject );
} }
/*
[localhost:~/JavaCodeFiles/Basics1/SCObjectOrientation1] andreadipietro% javac Program.java
[localhost:~/JavaCodeFiles/Basics1/SCObjectOrientation1] andreadipietro% java Program
0
Hello
[localhost:~/JavaCodeFiles/Basics1/SCObjectOrientation1] andreadipietro%
*/
```

Another example of a programmer-defined type is shown in the source-code on page 76, where the Pair-class has been introduced. These two approaches for using Java classes (program and custom-defined type) are the most typical and elementary ones. – A class may also be used to just furnish a collection of methods; as does the java.lang.Math-class which just offers a range of mathematical functions to the Java programmer (for more see pages 94 and 257).

A class with a main()-method remains instantiable!

An instantiation of a class with a main()-method has no special meaning with respect to the main()-method and its program-character: The main()-method just remains one of the static methods, except that it can be activated by an external event (the issuing of the “java”-command). A first example of such a case is given on page 159.

Java: Reference-Types and their Instantiation with the new-Keyword

Java: Reference-Types and their Instantiation with the new-Keyword — Remember the introduction of primitive-types on page 83. Variables of primitive-type have their identifier fixed to an address in the computer’s Random Access Memory (RAM). These types, with identifiers being an unchangeable reference, thus being glued to the RAM-address and exhibiting a fixed behavior (addition, division with number types), are called atomic- or primitive-types. Primitive-types constitute an integral part of the Java language and prescribe the data-format (`int`: 4bytes) and the possible manipulations (Addition, Subtraction, Multiplication, Division). With variables of primitive-type assignment happens by-value, this means that an assignment copies the value to the variable-name's part of the RAM. Usually a computer processes variables of primitive-types faster than Java objects of class-type. remember: assignment by-value

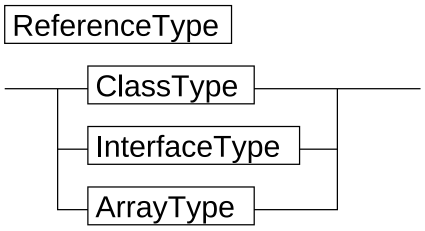
Java offers two kinds of basic non-primitive-types, the so-called reference-types :

class-type Currently discussed. A variable of that type is instantiated by prefixing a constructor-call with a new-keyword; for more see page 145.

array-type Realizes a simple form of aggregation of values or object-references. Variables of class-type as well as variables of primitive-type always can be aggregated as an array. Variables of array-type are recognizable by the brackets [ ] used in declaration and referencing, for more see page 234.

An example of introducing a class-type has been given in the preceding program on page 142. There has been defined a class(-type) "VarInteger" and from this class has been instantiated an object (referenced by an identifier "theObject").

The interface-type gives a variant of the class-type for cases of multiple-inheritance, for more see page 185.



ReferenceType := *ClassOrInterfaceType* | *ArrayType*

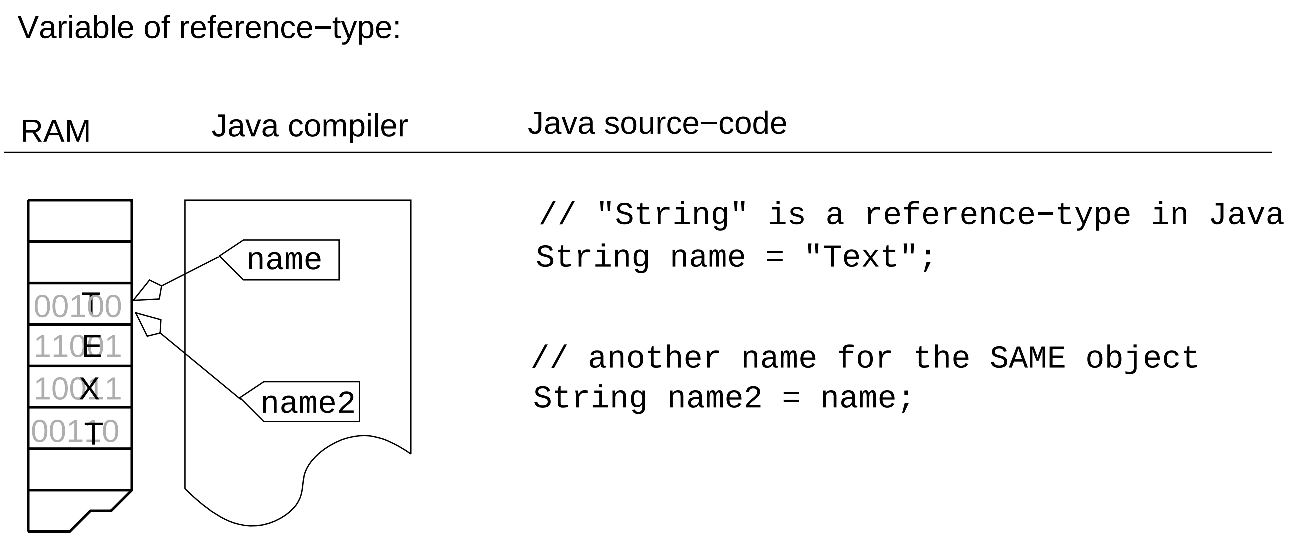
ClassOrInterfaceType := *ClassType* | *InterfaceType*

ClassType := *TypeName*

InterfaceType := *TypeName* — ClassType 146, InterfaceType 187, ArrayType 234

(ClassOrInterfaceType is used in ClassInstanceCreationExpression on page 151)

Like variables of primitive-type, variables of reference-type have identifiers that point to an address in RAM-space. But, the RAM-space-address of variables of reference-type is changed by assignment (=), NOT the value stored there, as it is the case with variables of primitive-type. IMPORTANT TO NOTE: IDENTIFIERS OF VARIABLES OF REFERENCE-TYPE CAN BE SEEN AS ALIASES AND THEIR POINTING-TARGET CAN BE CHANGED BY ASSIGNMENT:



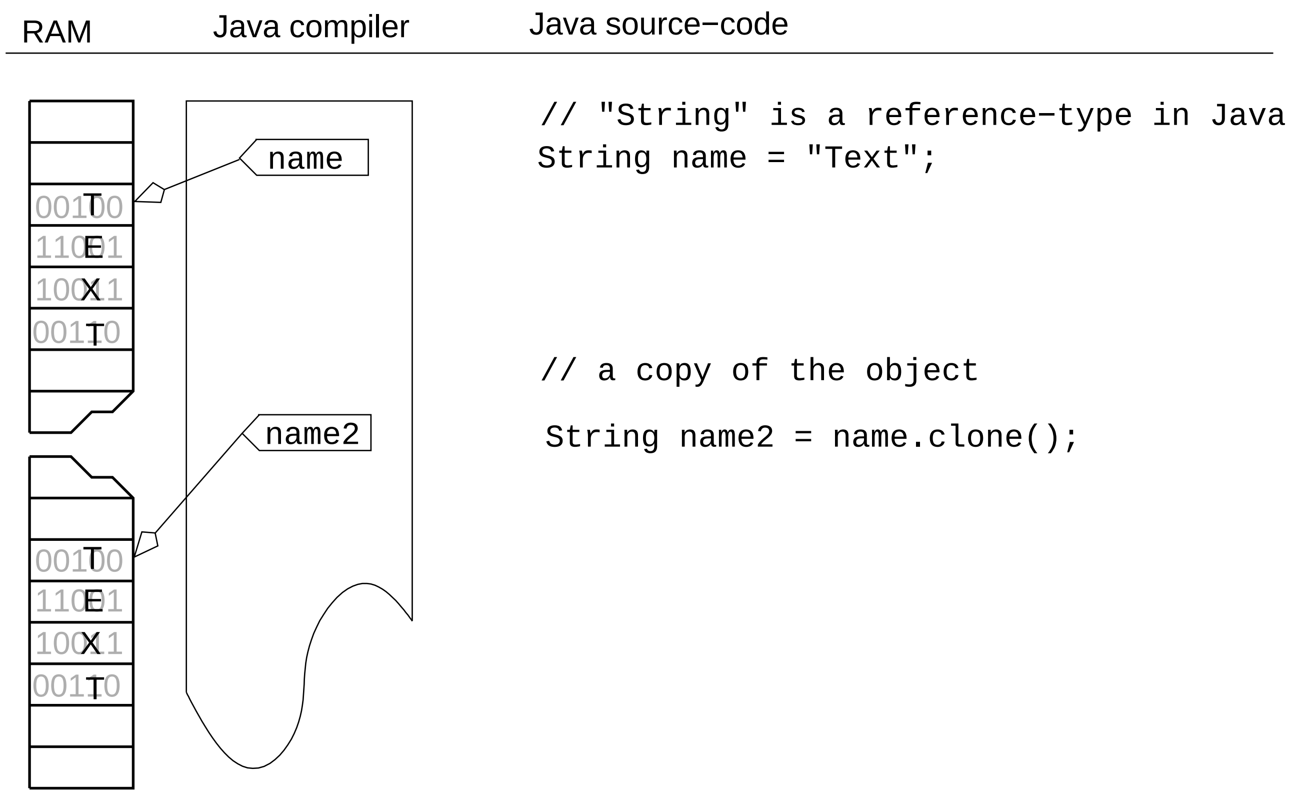
```
// "String" is a reference−type in Java
String name = "Text";

// another name for the SAME object
String name2 = name;
```

A reference is a container for a RAM-address which can be changed by the programmer by assignment. That's an important difference to Java variables of primitive-type where the references are fixed to an address of the RAM-space. And the act of assigning variables of primitive-type to each other with the equal sign (=) means copying. (see the graphics on page 83) For variables of reference-type assignment assignment by-reference

(**=**) means: If objects and associated names are given, reassignment of names by using the equal sign (=) only exchanges references, not the entire object, as indicated within the graphic above.

Copying of an object, a variable of reference-type, is done with a `clone()`-method as described below:

Copying a variable of reference−type with the clone()−method:

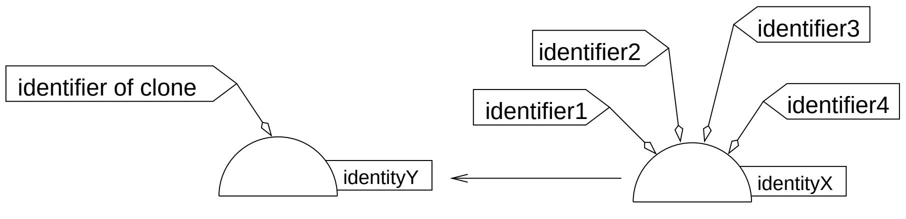


```
// "String" is a reference−type in Java
String name = "Text";

// a copy of the object
String name2 = name.clone();
```

The `clone()`-method PRODUCES A NEW OBJECT that contains the same data AND RETURNS A REFERENCE TO THAT NEW OBJECT! (It does NOT "return the new object" itself!)

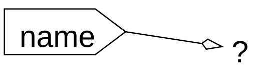
This statement is true in all generality: Java-methods with return-types of the primitive kind return the variable-value itself. But if the RETURN-TYPE OF ANY JAVA METHOD IS OF REFERENCE-TYPE, then, like the `clone()`-method, the method returns only a reference to the object!

The name of every reference-type could be suffixed with the name "Pointer" (StringPointer instead of `String`), to reflect the difference to the named value of data that has a primitive-type. Data of primitive-type has only one name, assignment with the "="-operator copies that value. Whereas data of reference-type can have multiple names, meaning that multiple pointers are referencing the same data; here assignment with the "**=**"-operator just makes the pointers equal. The assignment-operator, used with identifiers of reference-type, does not copy the data!



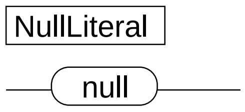
```
identifierOfClone = identifier1.clone();
```

Any name of reference-type can be assigned the literal `null`, which lets the name reference nothing.



```
name = null;
```

```
    variableName = null; // an identifier of reference-type not yet assigned
```



NullLiteral := null

Instances of reference-types (to be more precise, instances of non-abstract classes and arrays) are created by prefixing so-called **constructor-method**s with the **new**-keyword or by calling so-called **factory-method**s, described later on page 151. (The `clone()`-method is a factory-method, because calling this method creates a new object and this method returns a reference to that object.)

constructors and factory-methods

```
    ClassName variableName = new ClassName();
    // Class-methods with the class-name are called constructors.
```

The `new`-keyword in conjunction with a constructor allocates the memory, creates and initializes the object. Then the variable-name (identifier) represents a reference to the object; the variable-name does not represent the object itself, contrary to names of variables with primitive-type!

Below the processes of declaration, memory allocation and instantiation are compared for variables of primitive-type and variables of reference-type:

variables of type-		Declaration	Allocation	Instantiation	
-primitive		`PrimitiveType name`	=	`value;`	
-reference		**`ClassType name`**	**= new**	**`ClassType();`**	← **a constructor-call**
-reference (array)		`PrimitiveType [] name`	= new	`PrimitiveType[];`	(arrays, see page 234)
-reference (array)		`ClassType [] name`	= new	`ClassType[];`	

Java's **`String`** **exception**

In Java, the `String`-class has been allowed an exception to the general class-usage; a Java `String`-object can be instantiated like a variable of primitive-type:

`String s ="text";`

Only in this special case of the `String`-class, Java allows an instantiation like those used with variables of primitive-type. Actually the `String`-class also allows every `String`-object to be instantiated using the `new`-keyword prefixing the `String`-constructor:

`String s = new String("text");`

This standard way of instantiating objects of class-type has been used multiply in the previous programs.

Java: Classes

Java: Classes — The following sections use the class-concept together with the idea of a reference-type to describe the Java-specific realization of programmer-defined classes. This includes, for example, inner classes, anonymous classes and anonymous objects, supplemented by scoping- or accessibility considerations.
In the previous chapter, the description of proceduralization by using methods had more implications than could be forseen by the pure concept[49], the same is true with the implementation of the class-concept by the Java programming-language.

Java: Class-Declaration

Class-declaration may also be called class-definition or class-implementation. The standard Java-form can be seen below:

```
    class ClassName { classMembers }
```

[49]Starting with considering named blocks of code, ending up with local variables making possible overloading, recursion and call-back.

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