

Table of contents

Copyright notice and disclaimer	i
Table of contents.....	ii
Table of Figures	viii
Table of Tables	xii
Preface.....	xiv
1 Introduction	1
1.1 What makes software interesting?	1
1.1.1 Software is different.....	1
1.1.2 Software is ubiquitous.....	2
1.1.3 Software makes our environment interactive	2
1.1.4 Software is important.....	2
1.1.5 Software is about people.....	3
1.1.6 Software can be better.....	3
1.1.7 The software industry is undergoing radical change	3
1.1.8 Creating software is social	3
1.1.9 Software is sophisticated and complex	4
1.1.10 Software can be tamed	4
1.2 Organization and summary	5
1.3 Research and discussion issues.....	8
2 Information technology	9
2.1 Information	9
2.1.1 Digital representations	10
2.1.2 Copying and replication.....	13
2.1.3 Some properties of information	14
2.2 The constituents of IT	15
2.2.1 Material vs. immaterial	15
2.2.2 Three underlying technologies.....	16
2.2.3 Hardware and software are interchangeable	16
2.2.4 What distinguishes software	17
2.2.5 Layers of technology.....	17
2.2.6 Categories of software	19
2.3 Moore's law	19

2.3.1	Metrics of performance.....	19
2.3.2	Statement of Moore's law	21
2.3.3	Instrumenting Moore's law.....	22
2.3.4	Impact of Moore's law on software.....	23
2.3.5	Systems bottlenecks.....	25
2.3.6	Why Moore's law?.....	25
2.4	Research and discussion issues.....	28
2.5	Further reading.....	29
3	Users.....	30
3.1	Applications present and future	30
3.1.1	Application traditions.....	31
3.1.2	Type of end-user	33
3.1.3	Applications are increasingly heterogeneous.....	33
3.1.4	Sociotechnical applications.....	34
3.1.5	Applications are increasingly diverse	34
3.1.6	Conceptualizing new applications	35
3.2	User value	36
3.2.1	Productivity and impact	36
3.2.2	Meeting needs	37
3.2.3	Network effects.....	38
3.2.4	Usage.....	40
3.2.5	Functionality and fidelity	40
3.2.6	Performance	41
3.2.7	Learnability and usability	42
3.2.8	Security	43
3.2.9	Privacy	43
3.2.10	Flexibility and extensibility	44
3.2.11	Satisfaction.....	45
3.2.12	Operational costs.....	45
3.2.13	Composability	45
3.3	Research and discussion issues.....	46
3.4	Further reading.....	47
4	Creating software	48
4.1	Elements of success	49
4.2	Organizing software creation	49
4.2.1	Sequential development.....	50
4.2.2	Iterative development.....	52
4.2.3	Organizational vs. project efficiency	55
4.2.4	Community-based development	56

4.2.5	Agile development	58
4.2.6	Beyond computer science and engineering.....	59
4.2.7	End-user contributions	60
4.3	Software architecture	60
4.3.1	Why it is needed.....	61
4.3.2	What it is	62
4.3.3	Modularity.....	63
4.3.4	Interfaces and APIs	65
4.3.5	Emergence.....	67
4.3.6	Achieving composability	67
4.4	Program distribution and execution	68
4.4.1	Application and infrastructure	69
4.4.2	Platform and environment.....	70
4.4.3	Portability.....	71
4.4.4	Compilation and interpretation	73
4.4.5	Trust in execution	77
4.4.6	Operating system	78
4.4.7	Development tools	78
4.5	Distributed software.....	79
4.5.1	Network effects in distributed applications	79
4.5.2	Internet interoperability	80
4.5.3	Client-server and peer-to-peer architectures.....	82
4.5.4	Network software distribution	84
4.5.5	Mobile code	85
4.5.6	The network cloud and its future	86
4.6	Research and discussion issues	88
4.7	Further reading.....	89
5	Management	90
5.1	Value chains.....	90
5.1.1	Analysis and design	93
5.1.2	Implementation	93
5.1.3	Provisioning	97
5.1.4	Operations	99
5.2	Total cost of ownership.....	99
5.3	Social issues in software management.....	100
5.3.1	Security	100
5.3.2	Privacy	104
5.4	Security as a distributed management example	108
5.4.1	The security challenge	109

5.4.2	Access control: enforcing privileges.....	110
5.4.3	Authentication: establishing identity	112
5.4.4	Secrets and credentials: the digital certificate.....	115
5.4.5	Confidentiality: encryption	119
5.4.6	Accountability: non-repudiation and the digital signature.....	120
5.4.7	A security system	122
5.4.8	Other issues.....	123
5.5	Research and discussion issues.....	123
5.6	Further reading.....	125
6	Software supply industry.....	126
6.1	Industrial organization and software architecture.....	126
6.2	Organization of the software value chain	127
6.2.1	Decomposition of natural business functions	127
6.2.2	Composition of business functions	130
6.2.3	Unnatural decomposition of business functions	135
6.3	Business relationships in the software value chain.....	136
6.3.1	Types of customers	136
6.3.2	Software distribution.....	136
6.3.3	Software pricing.....	139
6.3.4	Acquiring industry-specific applications	141
6.3.5	Acquiring infrastructure.....	142
6.3.6	Accounting issues	143
6.4	Research and discussion issues.....	144
7	Software creation industry	146
7.1	Industrial organization of the software industry	146
7.1.1	Applications and infrastructure.....	146
7.1.2	Expanding infrastructure.....	149
7.1.3	Vertical heterogeneity: layering.....	151
7.1.4	Core competencies.....	162
7.1.5	Horizontal heterogeneity.....	164
7.1.6	Competition and architecture.....	168
7.2	Cooperation in the software industry	169
7.2.1	Supplier-consumer relationships.....	169
7.2.2	Application program interface	170
7.2.3	Open standards.....	171
7.2.4	Why standards?	172
7.2.5	How standards arise	173
7.2.6	The evolution of standards processes	175
7.2.7	Minimizing the role of standards	177

7.3	Component software	181
7.3.1	Make vs. license decisions	181
7.3.2	What is a component?	183
7.3.3	Component portability	186
7.3.4	Component evolution	186
7.3.5	An industrial revolution of software?	187
7.3.6	Component standards and technology	189
7.3.7	Web services	193
7.4	Research and discussion issues.....	196
7.5	Further reading.....	198
8	Government.....	199
8.1	Intellectual property	199
8.1.1	Trade secrets and patents	199
8.1.2	Copyrights.....	201
8.1.3	Software licensing.....	202
8.1.4	Trademarks	204
8.1.5	Rights management.....	204
8.2	Regulation	211
8.2.1	Law enforcement and national security	211
8.2.2	Security	213
8.2.3	Privacy	215
8.2.4	Access and free speech	216
8.2.5	Antitrust and competition	218
8.3	Research and education.....	220
8.3.1	Workforce	220
8.3.2	Technology transfer	222
8.3.3	Publicly supported research	225
8.4	Research and discussion issues.....	226
8.5	Further reading.....	227
9	Economics	228
9.1	Demand	228
9.1.1	Market share.....	229
9.1.2	Direct and indirect network effects.....	229
9.1.3	Lock-in.....	234
9.1.4	Open systems vs. proprietary solutions	237
9.2	Supply	238
9.2.1	Economies of scale	238

9.2.2	Risk	239
9.2.3	Complementarity.....	239
9.2.4	Dynamic supply chains	240
9.2.5	Rapidly expanding markets.....	240
9.2.6	Whence competitive advantage?.....	240
9.3	Pricing	241
9.3.1	Spreading revenue over time	242
9.3.2	Different prices for different customers.....	244
9.3.3	Bundling.....	246
9.3.4	Terms and conditions.....	248
9.3.5	Who pays?.....	248
9.4	Rationale for infrastructure	249
9.4.1	Sharing	249
9.4.2	Reuse and multiple use	252
9.4.3	Tools	252
9.5	Software as an economic good	252
9.5.1	Demand side: software as material product or service	253
9.5.2	Supply side: software as a plan and factory.....	255
9.6	Research and discussion issues.....	255
9.7	Further readings	256
10	The future	257
10.1	Slowing technological advance.....	257
10.2	Information appliances.....	258
10.3	Pervasive computing.....	260
10.4	Mobile and nomadic IT.....	261
10.5	Research and discussion issues.....	263
10.6	Further reading.....	264
11	Postscript	265
	Glossary	267
	References.....	281
	The authors.....	291