

Do Design Patterns Impact Software Quality Positively?

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Context

- Design patterns (as presented by the GoF) have been said to have a positive impact on quality characteristics
 - Expandability
 - Reusability
 - Understandability
- But, some studies presented counter-examples, *i.e.*, Wendorff (Assessment of design patterns during software reengineering: Lessons learned from a large commercial project.)



Study Design (1/2)

- Hypothesis: “Design patterns have a positive impact on quality characteristics”
- Objective: prove or disprove the hypothesis with concrete evidence



Study Design (2/2)

- Required choices
 - Quality characteristics
 - Kind of study
- Our choices
 - 10 quality characteristics related to design, implementation, and runtime
 - Empirical study (vs. absolute, vs. relative)
 - Manual activity
 - Developers' perception



Method

- Choice of design patterns of interest
 - 23 design patterns in the GoF book
- Identification and definition of quality characteristics of interest
 - 10 characteristics

Design	Implementation	Runtime
Expandability	Learnability	Generality
Simplicity	Understandability	Modularity at runtime
Reusability	Modularity	Scalability
		Robustness

- Definition of a scale
 - Likert scale of 5 points + "I don't know"



Data Collection

- Questionnaire send out to colleagues with a good knowledge of design patterns between January and May 2007
- Questionnaire posted on mailing-lists
 - `refactoring@yahooogroups.com`
 - `patterns-discussion@cs.uiuc.edu`
 - `gang-of-4-patterns@cs.uiuc.edu`



Data Processing

- Number of received questionnaires: 30
 - Number of complete questionnaires: 18
 - Number of almost complete (90%) questionnaires: 2
 - Incomplete questionnaires or with “I don't know”:10
- Number of kept questionnaires: 20
- Answers A and B aggregated in Positive, C in Neutral, and D and E in Negative
 - Some questionnaire were clearly generally more positive/negative than others

Results (1/2)

Design Patterns	Expendability(%)			Simplicity(%)			Generality(%)			Modularity(%)			Modularity at runtime(%)		
	G	N	B	G	N	B	G	N	B	G	N	B	G	N	B
Rates															
A.Factory	100.0	0.0	0.0	53.33	13.33	33.33	78.57	21.43	0.0	85.71	7.14	7.14	46.15	38.46	15.38
Builder	90.91	9.09	0.0	54.55	27.27	18.18	54.55	9.09	36.36	90.91	0.0	9.09	45.45	36.36	18.18
F.Method	75.0	8.33	16.67	58.33	25.0	16.67	58.33	33.33	8.33	66.67	16.67	16.67	45.45	45.45	9.09
Prototype	58.33	33.33	8.33	53.85	30.77	15.38	76.92	15.38	7.69	38.46	53.85	7.69	53.85	38.46	7.69
Singleton	7.69	30.77	61.54	92.86	7.14	0.0	30.77	38.46	30.77	15.38	46.15	38.46	16.67	50.0	33.33
Adapater	53.85	38.46	7.69	46.15	38.46	15.38	61.54	30.77	7.69	76.92	15.38	7.69	58.33	33.33	8.33
Bridge	83.33	16.67	0.0	18.18	27.27	54.55	70.0	0.0	30.0	75.0	16.67	8.33	50.0	33.33	16.67
Composite	100.0	0.0	0.0	69.23	15.38	15.38	76.92	15.38	7.69	71.43	21.43	7.14	53.85	38.46	7.69
Decorator	91.67	0.0	8.33	27.27	45.45	27.27	90.91	9.09	0.0	72.73	18.18	9.09	72.73	18.18	9.09
Facade	53.85	23.08	23.08	83.33	8.33	8.33	50.0	33.33	16.67	50.0	16.67	33.33	36.36	27.27	36.36
Flyweight	22.22	44.44	33.33	0.0	22.22	77.78	11.11	44.44	44.44	33.33	33.33	33.33	11.11	66.67	22.22
Proxy	41.67	50.0	8.33	61.54	23.08	15.38	61.54	30.77	7.69	76.92	15.38	7.69	38.46	53.85	7.69
Ch.Of.Resp	91.67	8.33	0.0	72.73	9.09	18.18	81.82	18.18	0.0	66.67	16.67	16.67	54.55	27.27	18.18
Command	69.23	15.38	15.38	46.15	15.38	38.46	61.54	23.08	15.38	64.29	21.43	14.29	41.67	41.67	16.67
Interpreter	66.67	25.0	8.33	50.0	16.67	33.33	64.29	14.29	21.43	58.33	33.33	8.33	41.67	41.67	16.67
Iterator	92.31	7.69	0.0	69.23	15.38	15.38	72.73	27.27	0.0	57.14	28.57	14.29	50.0	41.67	8.33
Mediator	58.33	25.0	16.67	27.27	36.36	36.36	45.45	36.36	18.18	50.0	25.0	25.0	33.33	50.0	16.67
Memento	30.0	50.0	20.0	50.0	30.0	20.0	40.0	50.0	10.0	11.11	66.67	22.22	12.5	75.0	12.5
Observer	86.67	6.67	6.67	64.29	21.43	14.29	78.57	7.14	14.29	73.33	20.0	6.67	69.23	23.08	7.69
State	72.73	18.18	9.09	63.64	9.09	27.27	63.64	18.18	18.18	63.64	9.09	27.27	54.55	18.18	27.27
Strategy	78.57	14.29	7.14	66.67	26.67	6.67	71.43	21.43	7.14	85.71	7.14	7.14	78.57	14.29	7.14
T.Method	80.0	20.0	0.0	66.67	20.0	13.33	73.33	20.0	6.67	33.33	53.33	13.33	28.57	64.29	7.14
Visitor	66.67	6.67	26.67	7.14	14.29	78.57	78.57	7.14	14.29	73.33	13.33	13.33	57.14	21.43	21.43

Design Patterns	Learnability(%)			Understandability(%)			Reusability(%)			Scalability(%)			Robustness(%)		
	G	N	B	G	N	B	G	N	B	G	N	B	G	N	B
Rates															
A.Factory	35.71	28.57	35.71	38.46	30.77	30.77	50.0	42.86	7.14	21.43	64.29	14.29	0.0	72.73	27.27
Builder	54.55	18.18	27.27	81.82	9.09	9.09	36.36	45.45	18.18	0.0	81.82	18.18	0.0	90.0	10.0
F.Method	50.0	33.33	16.67	41.67	33.33	25.0	63.64	18.18	18.18	27.27	54.55	18.18	0.0	88.89	11.11
Prototype	46.15	23.08	30.77	53.85	23.08	23.08	58.33	8.33	33.33	33.33	50.0	16.67	9.09	90.91	0.0
Singleton	85.71	14.29	0.0	92.86	7.14	0.0	15.38	53.85	30.77	35.71	57.14	7.14	15.38	69.23	15.38
Adapater	69.23	7.69	23.08	46.15	23.08	30.77	69.23	23.08	7.69	0.0	45.45	54.55	0.0	58.33	41.67
Bridge	27.27	36.36	36.36	50.0	33.33	16.67	41.67	16.67	41.67	10.0	30.0	60.0	10.0	80.0	10.0
Composite	76.92	7.69	15.38	69.23	15.38	15.38	61.54	23.08	15.38	41.67	41.67	16.67	8.33	91.67	0.0
Decorator	41.67	25.0	33.33	41.67	8.33	50.0	33.33	25.0	41.67	18.18	36.36	45.45	0.0	77.78	22.22
Facade	66.67	25.0	8.33	75.0	25.0	0.0	33.33	41.67	25.0	25.0	50.0	25.0	22.22	77.78	0.0
Flyweight	0.0	20.0	80.0	0.0	10.0	90.0	37.5	12.5	50.0	77.78	0.0	22.22	22.22	66.67	11.11
Proxy	46.15	38.46	15.38	30.77	46.15	23.08	50.0	33.33	16.67	27.27	36.36	36.36	10.0	80.0	10.0
Ch.Of.Resp	63.64	36.36	0.0	33.33	33.33	33.33	54.55	27.27	18.18	10.0	50.0	40.0	25.0	58.33	16.67
Command	38.46	30.77	30.77	30.77	30.77	38.46	33.33	16.67	50.0	25.0	33.33	41.67	33.33	58.33	8.33
Interpreter	66.67	0.0	33.33	66.67	0.0	33.33	54.55	0.0	45.45	27.27	18.18	54.55	8.33	83.33	8.33
Iterator	50.0	33.33	16.67	50.0	42.86	7.14	69.23	15.38	15.38	16.67	41.67	41.67	45.45	54.55	0.0
Mediator	54.55	9.09	36.36	58.33	25.0	16.67	20.0	50.0	30.0	25.0	41.67	33.33	9.09	81.82	9.09
Memento	40.0	30.0	30.0	40.0	50.0	10.0	37.5	37.5	25.0	0.0	50.0	50.0	12.5	62.5	25.0
Observer	50.0	14.29	35.71	40.0	33.33	26.67	50.0	28.57	21.43	16.67	50.0	33.33	9.09	63.64	27.27
State	54.55	18.18	27.27	54.55	0.0	45.45	20.0	40.0	40.0	18.18	45.45	36.36	10.0	60.0	30.0
Strategy	73.33	20.0	6.67	64.29	28.57	7.14	46.15	30.77	23.08	21.43	42.86	35.71	33.33	58.33	8.33
T.Method	53.33	33.33	13.33	37.5	37.5	25.0	57.14	28.57	14.29	23.08	61.54	15.38	16.67	75.0	8.33
Visitor	14.29	21.43	64.29	20.0	20.0	60.0	26.67	26.67	46.67	25.0	33.33	41.67	0.0	72.73	27.27



Results (2/2)

- We discuss detailed results
 - Three well-known design patterns
 - Composite
 - Abstract Factory
 - Flyweight
 - Three quality characteristics mentioned in the GoF
 - Reusability
 - Expandability
 - Understandability

Composite

Attributes	Positive	Neutral	Negative
Expandability	100.0	0.0	0.0
Simplicity	69.23	15.38	15.38
Generality	76.92	15.38	7.69
Modularity	71.43	21.43	7.14
Modularity at Runtime	53.85	38.46	7.69
Learnability	76.92	7.69	15.38
Understandability	69.23	15.38	15.38
Reusability	61.54	23.08	15.38
Scalability	41.67	41.67	16.67
Robustness	8.33	91.67	0.0

- Overall positive impact on quality attributes
- Scalability and robustness not so positively impacted

Abstract Factory

Attributes	Positive	Neutral	Negative
Expandability	100.0	0.0	0.0
Simplicity	53.33	13.33	33.33
Generality	78.57	21.43	0.0
Modularity	85.71	7.14	7.14
Modularity at Runtime	46.15	38.46	15.38
Learnability	35.71	28.57	35.71
Understandability	38.46	30.77	30.77
Reusability	50.0	42.86	7.14
Scalability	21.43	64.29	14.29
Robustness	0.0	72.73	27.27

- Overall neutral impact on quality attributes
- Expandability, generality, and modularity as expected
- Robustness surprising

Flyweight

Attributes	Positive	Neutral	Negative
Expandability	22.22	44.44	33.33
Simplicity	0.0	22.22	77.78
Generality	11.11	44.44	44.44
Modularity	33.33	33.33	33.33
Modularity at Runtime	11.11	66.67	22.22
Learnability	0.0	20.0	80.0
Understandability	0.0	10.0	90.0
Reusability	37.5	12.5	50.0
Scalability	77.78	0.0	22.22
Robustness	22.22	66.67	11.11

- Overall negative impact on quality attributes
- Positive impact only on scalability as expected

Reusability

Positive	Neutral	Negative
A.Factory F.Method Prototype Adapter Composite Ch.Of.Resp. Iterator Observer Strategy T.Method	Builder Singleton Facade Mediator Memento Proxy	Bridge Decorator Flyweight Command Interpreter State Visitor

- 10 positive impacts
- 6 neutral impacts
- 7 negative impacts

Expandability

Positive	Neutral	Negative
A.Factory Builder F.Method Prototype Adapter Bridge Composite Decorator Facade Ch.Of.Resp. Command Interpreter Iterator Mediator Observer State Strategy T.Method Visitor	Flyweight Memento Proxy	Singleton

- 19 positive impacts
- 3 neutral impacts
- 1 negative impact

Understandability

Positive	Neutral	Negative
A.Factory	Proxy	Decorator
Builder	Memento	Flyweight
F.Method	T.Method	Ch.Of.Resp.
Prototype		Command
Singleton		Visitor
Adapter		
Bridge		
Composite		
Facade		
Interpreter		
Iterator		
Mediator		
Observer		
State		
Strategy		

- 15 positive impacts
- 3 neutral impacts
- 5 negative impacts

Null Hypothesis Test

Design Patterns	Expendability(%)		Simplicity(%)		Generality(%)		Modularity(%)		Mod. at runtime(%)		
	E	R(%)	E	R(%)	E	R(%)	E	R(%)	E	R(%)	
A.Factory	+	0.00	+	30.36	+	1.76	+	0.37	-	30.36	
Builder	+	0.15	+	30.36	+	30.36	+	0.15	-	30.36	
F.Method	+	1.76	+	30.36	+	30.36	+	5.92	-	30.36	
Prototype	+	30.36	+	30.36	+	1.76	-	15.09	+	30.36	
Singleton	-	0.15	+	0.15	-	5.92	-	0.37	-	0.37	
Adapter	+	30.36	-	30.36	+	15.09	+	1.76	+	30.36	
Bridge	+	0.37	-	0.37	+	5.92	+	1.76	+	50.00	
Composite	+	0.00	+	5.92	+	1.76	+	5.92	+	30.36	
Decorator	+	0.15	-	5.92	+	0.15	+	5.92	+	5.92	
Facade	+	30.36	+	0.37	+	50.00	+	50.00	-	15.09	
Flyweight	-	1.76	-	0.00	-	0.15	-	5.92	-	0.15	
Proxy	-	30.36	+	15.09	+	15.09	+	1.76	-	15.09	
Ch.Of.Resp	+	0.15	+	5.92	+	0.37	+	5.92	+	30.36	
Command	+	5.92	-	30.36	+	15.09	+	15.09	-	30.36	
Interpreter	+	5.92	+	50.00	+	15.09	+	30.36	-	30.36	
Iterator	+	0.15	+	5.92	+	5.92	+	30.36	+	50.00	
Mediator	+	30.36	-	5.92	-	30.36	+	50.00	-	5.92	
Memento	-	5.92	+	50.00	-	30.36	-	0.15	-	0.15	
Observer	+	0.15	+	15.09	+	1.76	+	1.76	+	5.92	
State	+	5.92	+	15.09	+	15.09	+	15.09	+	30.36	
Strategy	+	1.76	+	5.92	+	5.92	+	0.37	+	1.76	
T.Method	+	0.37	+	5.92	+	1.76	-	5.92	-	5.92	
Visitor	+	5.92	-	0.15	+	1.76	+	1.76	+	30.36	
		19 + / 4 -		16 + / 7 -		19 + / 4 -		18 + / 5 -		11 + / 12 -	

Design Patterns	Learnability(%)		Understandability(%)		Reusability(%)		Scalability(%)		Robustness(%)		
	E	R(%)	E	R(%)	E	R(%)	E	R(%)	E	R(%)	
A.Factory	-	15.09	-	15.09	+	50.00	-	1.76	-	0.00	
Builder	+	30.36	+	0.37	-	15.09	-	0.00	-	0.00	
F.Method	+	50.00	-	30.36	+	15.09	-	5.92	-	0.00	
Prototype	-	30.36	+	30.36	+	30.36	-	5.92	-	0.15	
Singleton	+	0.37	+	0.15	-	0.37	-	15.09	-	0.37	
Adapter	+	5.92	-	30.36	+	5.92	-	0.00	-	0.00	
Bridge	-	5.92	+	50.00	-	30.36	-	0.15	-	0.15	
Composite	+	1.76	+	5.92	+	15.09	-	30.36	-	0.15	
Decorator	-	30.36	-	30.36	-	5.92	-	0.37	-	0.00	
Facade	+	5.92	+	1.76	-	5.92	-	1.76	-	1.76	
Flyweight	-	0.00	-	0.00	-	15.09	+	1.76	-	1.76	
Proxy	-	30.36	-	5.92	+	50.00	-	5.92	-	0.15	
Ch.Of.Resp	+	15.09	-	5.92	+	30.36	-	0.15	-	1.76	
Command	-	15.09	-	5.92	-	5.92	-	1.76	-	5.92	
Interpreter	+	5.92	+	5.92	+	30.36	-	5.92	-	0.15	
Iterator	+	50.00	+	50.00	+	5.92	-	0.37	-	30.36	
Mediator	+	30.36	+	30.36	-	1.76	-	1.76	-	0.15	
Memento	-	30.36	-	30.36	-	15.09	-	0.00	-	0.15	
Observer	+	50.00	-	30.36	+	50.00	-	0.37	-	0.15	
State	+	30.36	+	30.36	-	1.76	-	0.37	-	0.15	
Strategy	+	1.76	+	15.09	-	30.36	-	1.76	-	5.92	
T.Method	+	30.36	-	15.09	+	30.36	-	1.76	-	0.37	
Visitor	-	0.37	-	1.76	-	1.76	-	1.76	-	0.00	
		14 + / 9 -		11 + / 12 -		11 + / 12 -		1 + / 22 -		0 + / 23 -	

Conclusion (1/2)

- Globally, design patterns have a positive impact on quality attributes

Quality Characteristics	Expandability	Simplicity	Reusability	Learnability	Understandability
Number of Positive/Negative Patterns	19+ / 4-	16+ / 7-	11+ / 12-	14+ / 9-	11+ / 12-

Quality Characteristics	Modularity	Generality	Mod. at runtime	Scalability	Robustness
Number of Positive/Negative Patterns	18+ / 5-	19+ / 4-	11+ / 12-	1+ / 22-	0+ / 23-



Conclusion (2/2)

- Pattern by pattern, their impact on quality varies and includes negative impact!
- So, design patterns do not always improve the quality of systems, thus they should be use with caution



Help Wanted

- Please help us refine this study by downloading and filling in the questionnaire

<http://www.ptidej.net/downloads/>