Pricing Crowdsourcing-based Software Development Tasks

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Overview

- Background
  - Crowdsourcing: Micro task VS. Complex task
  - The TopCoder Platform
- Motivation
  - New Phenomenon
  - The Pricing Issue
- Methodology
- Experiments & Insights
- Conclusion

Overview

- Background
  - Crowdsourcing: Micro task VS. Complex task
  - The TopCoder Platform

A Recent News…

- Typical work day of one star developer:
  - 09:00 a.m. – Arrive and surf Reddit, watch cat videos
  - 11:30 a.m. – Take lunch
  - 01:00 p.m. – Ebay time
  - 02:00 p.m. – Facebook updates – LinkedIn
  - 04:30 p.m. – End of day update e-mail to management
  - 05:00 p.m. – Go home

Introduction to Crowdsourcing

- A proper way…
  - Labor of the Internet
  - Low cost
  - Suprising deliverable

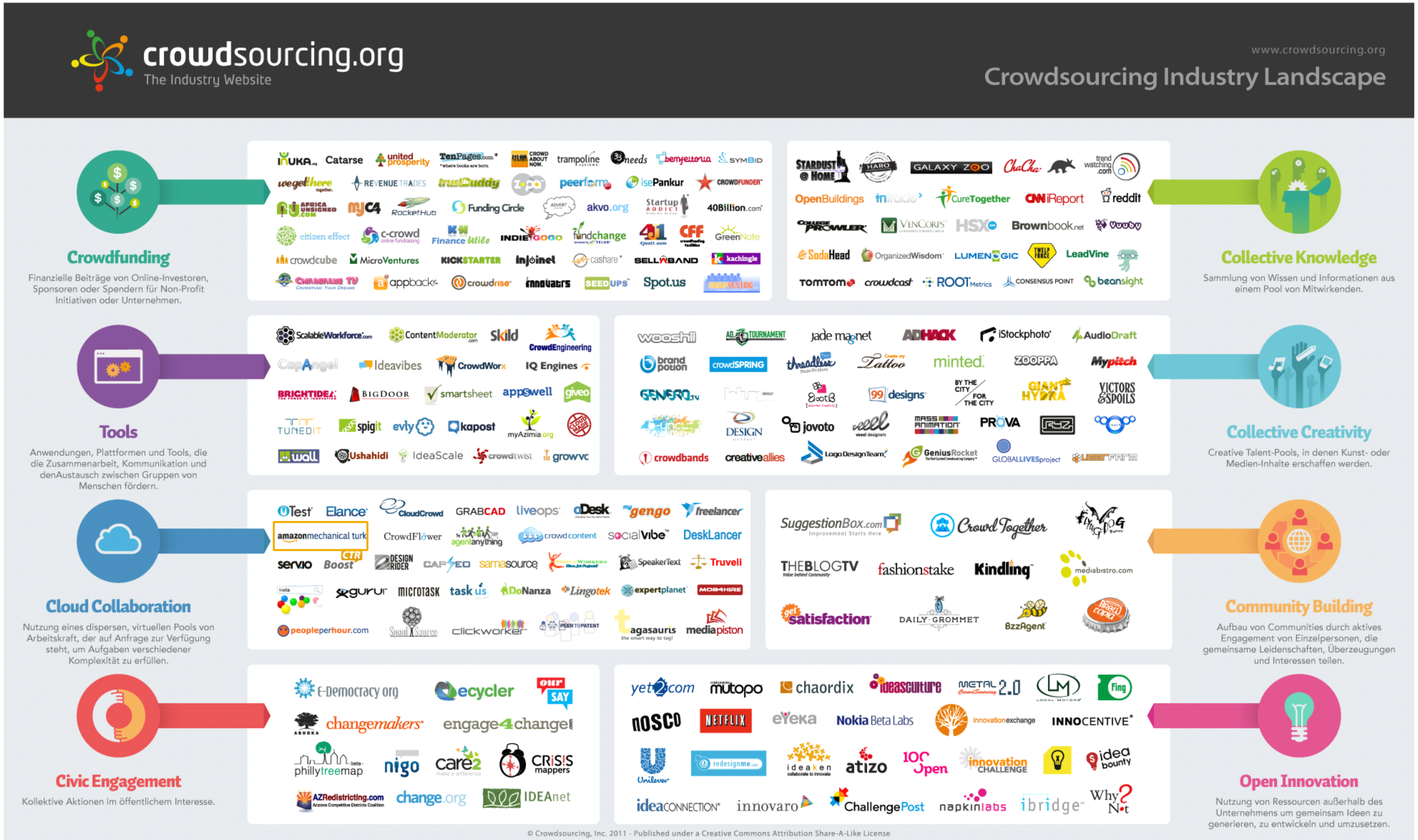
- Wisdom of the **Crowd**

What is Crowdsourcing ?

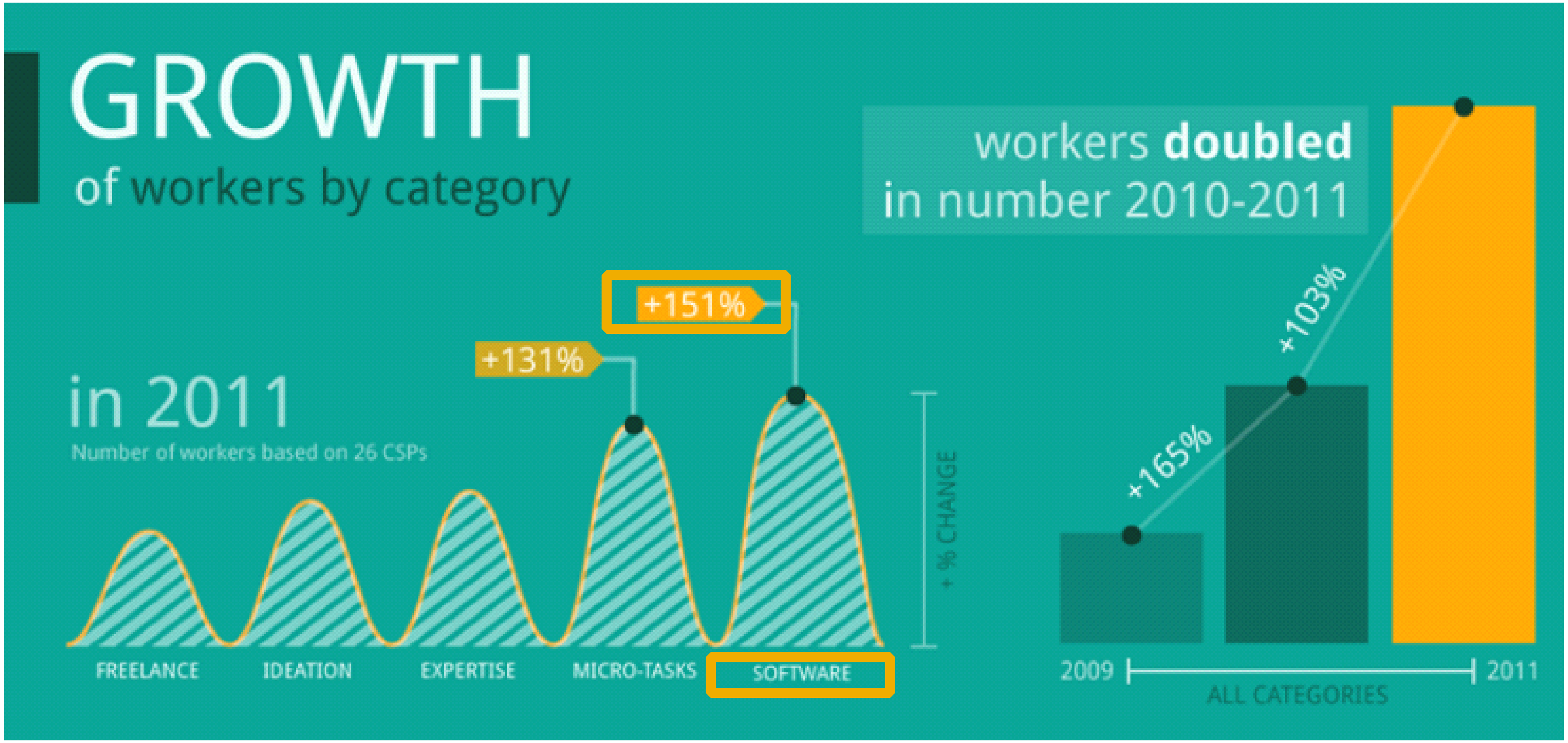
- "Crowdsourcing" defined by Jeff Howe:
  - The act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call.

- Crowdsourcing VS. Outsourcing:
  - The crucial prerequisite is the use of the **open call format** and the **large network** of potential laborers.

Micro Task VS. Complex Task



Micro Task VS. Complex Task



Credit: http://sandfishdesign.co.uk, © 2012, Crowdsourcing, LLC

What is TopCoder ?

- The world's largest competitive community for crowdsourced software development

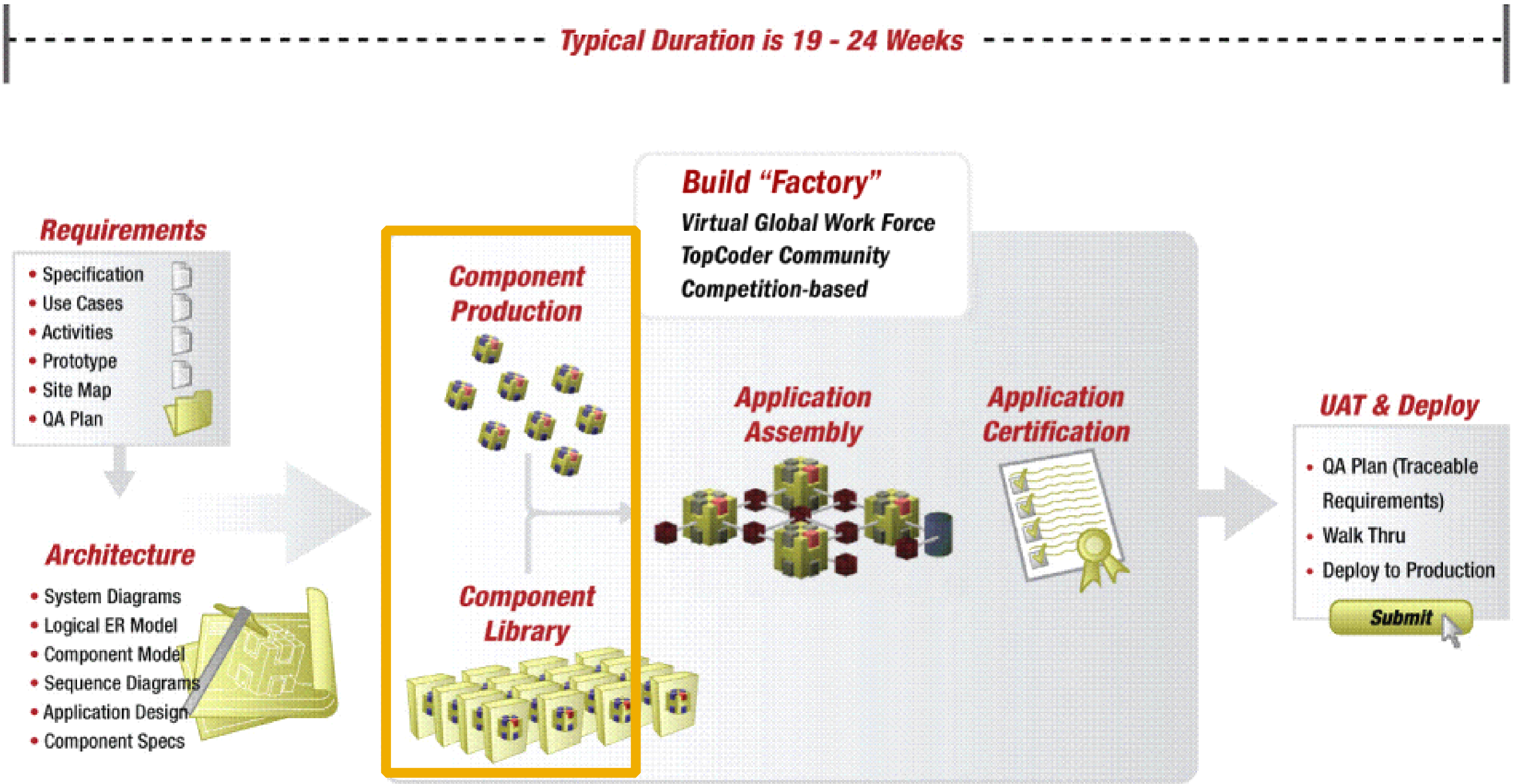
- The TopCoder Community is 425,993 strong

- Membership
  - China
  - India
  - U.S.

What is TopCoder ?

- **What kinds of projects can I do with TopCoder?**
  - Mobile Applications
  - Analytics and Optimization
  - Scientific Algorithm Development
  - Online Communities
  - Open Platforms
  - Digital Media
  - Business Systems
  - …

How Does It Work ?



Credit: www.topcoder.com, © 2007, TopCoder, Inc

Overview

- Motivation
  - New Phenomenon
  - The Pricing Issue

Motivation - New Phenomenon

- New Paradigm
  - Crowdsourced development
    - 1. Open call format
    - 2. Large networked potential labor

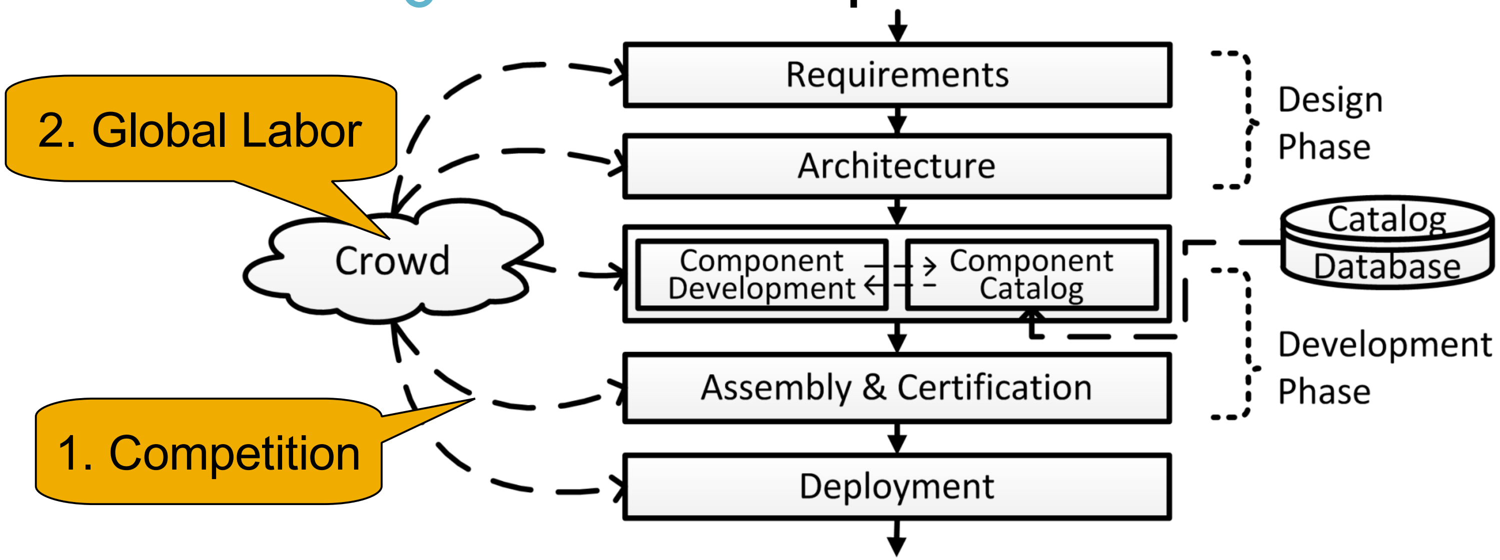


Fig.1 Illustration of crowdsourcing-based software development process.

Motivation - New Phenomenon

- New Phenomenon In SE activity
  - 2 examples that challenge traditional law
    - Parkinson's Law
    - COCOMO Model

Motivation - New Phenomenon

- Parkinson's Law

("Work expands so as to fill the time available for its completion. ")

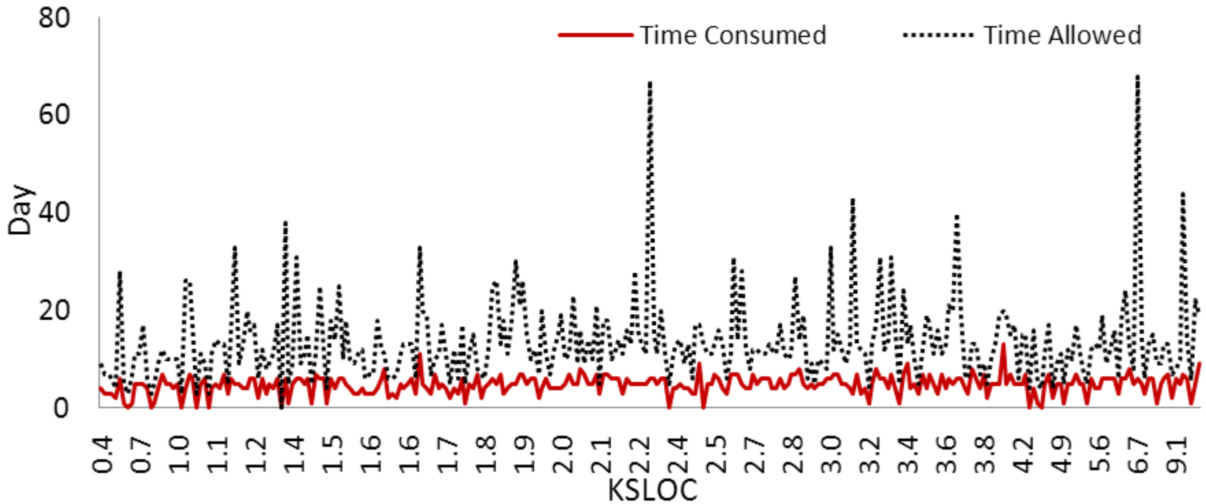


Fig.2 Correlation between the time allocated and the actual time consumed

Motivation - New Phenomenon

- Basic COCOMO Model

$$(EFFORT = a * SIZE^{b})$$

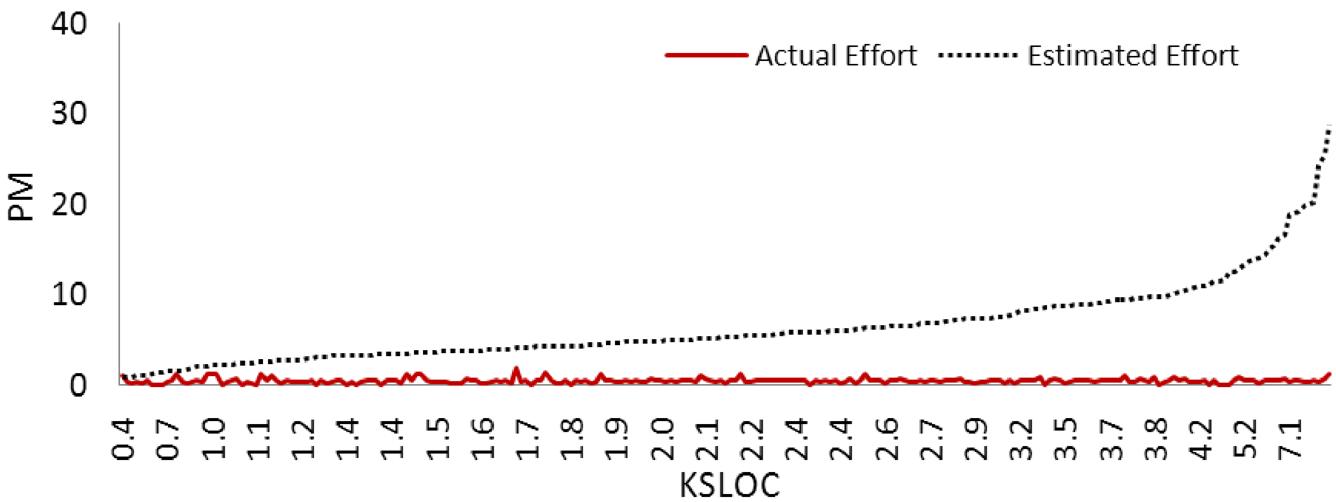


Fig.3 The effort estimated by COCOMO model, compared to the actual effort.

Motivation - The Pricing Issue

Active Component Development Contests

Catalog	Component		Register by	Submit by	Payment*	Reliability Bonus	DR Points	Registrants Rated/ Unrated	Submissions
.NET CUSTOM	PXV2 Integration Service Part 1 Version 1.0	TCO13	**02.02.2013** 10:25 EST	**02.05.2013** 10:30 EST	$700.00	$140.00	315	5 / 3	0
JAVA CUSTOM	Media Conversion Engine Front End 2 Version 1.0	TCO13	**02.02.2013** 09:18 EST	**02.04.2013** 09:23 EST	$600.00	$120.00	270	10 / 5	0
JAVA CUSTOM	Benchmarking and Reporting Tool Rewrite Release 1 Core DAO Version 1.0	TCO13	01.30.2013 23:18 EST	**02.01.2013** 23:23 EST	$400.00	$80.00	180	17 / 8	0
JAVA CUSTOM	Benchmarking and Reporting Tool Rewrite DAO Base Service Version 1.0	TCO13	01.30.2013 08:00 EST	**02.01.2013** 08:05 EST	$500.00	$100.00	225	14 / 12	1

Fig.4 Active Component Development Contests on TopCoder.com

- Inappropriate price often lead to low capital efficiency and task starvation
- **How to build empirical pricing models?**

Overview

- Methodology

Methodology

- Price Drivers

Input Complexity

Quality of Input

Previous Phase Decision

Development Type

Variable	Meaning	Statistics					Regression Coefficients		
		Min	*Max*	*Mean*	*Medn*	*S.Dev*	*β*	*t*	*p*
TECH	number of technologies which will be used	1.0	7.0	2.1	2.0	1.3	-6.265	-0.569	0.570
DEPE	number of component dependencies	[illegible]	[illegible]	[illegible]	2.0	3.0	2.555	0.606	0.545
REQU	number of pages of requirement specification	[illegible]	[illegible]	[illegible]	3.0	1.8	-9.422	-1.332	0.183
*COMP**	number of pages of component specification	[illegible]	[illegible]	[illegible]	10.0	5.7	8.480	3.414	0.001
*SEQU**	number of sequence diagrams of the des[illegible]	[illegible]	[illegible]	[illegible]	3.0	5.5	7.666	2.922	0.004
SCOR	score of winner's submission of design phase	[illegible]	[illegible]	[illegible]	92.0	6.5	-3.032	-1.360	0.175
*AWRD**	winner's award of design phase, measured in dollars	0.0	4200.0	920.1	900.0	457.6	0.503	17.912	0.000
*EFRT**	winner's effort in design phase, measured in days	0.0	468.0	29.0	5.0	77.2	0.273	1.607	0.109
SUML	size of UML design file, measured in KB	[illegible]	[illegible]	[illegible]	142.0	85.5	-0.293	-1.386	0.166
WRAT	rating of the winner in design phase	[illegible]	[illegible]	[illegible]	1632.0	629.3	-0.021	-0.994	0.321
REGI	number of registrants in design phase	[illegible]	[illegible]	[illegible]	8.0	5.2	2.692	0.914	0.361
SUBM	number of submissions in design phase	1.0	26.0	2.8	2.0	2.4	-10.416	-1.601	0.110
*ISUP**	indicating if the task aim at component update	0.0	1.0	0.2	0.0	0.4	-71.352	-1.998	0.046
ISJA	indicating if the development language is Java	0.0	1.0	0.5	1.0	0.5	-	-	-
ISCS	indicating if the development language is C#	0.0	1.0	0.5	0.0	0.5	23.986	0.808	0.419
*SIZE**	estimated size of the component, measured in KSLOC	0.4	21.9	3.0	2.3	2.3	29.772	4.189	0.000
*const**	the constant term.	-	-	-	-		463.194	2.437	0.015

TABLE I. DESCRIPTIVE STATISTICS AND REGRESSION COEFFICIENTS OF PROPOSED FACTORS

Methodology

- Predictive Models
  - Multiple Linear Regression Model:

$$PRICE = \beta_1 TECH + \beta_2 DEPE + \beta_3 REQU + \beta_4 COMP + \beta_5 SEQU + \beta_6 SCOR + \beta_7 AWRD + \beta_8 EFRT + \beta_9 SUML + \beta_{10} WRAT + \beta_{11} REGI + \beta_{12} SUBM + \beta_{13} ISUP + \beta_{14} ISJA + \beta_{15} ISCS + \beta_{16} SIZE + \beta_0 + \varepsilon \quad (1)$$

  - 8 other Machine Learning & Statistical models

3 Decision Tree based learners	**2 Instance based learners**	**1 Neural Net**	**1 Support Vector Machine**	**1 Logistic Regression**
C5.0, CART, QUEST	KNN-1, KNN-k∈[3, 7]			

Overview

- Experiments & Insights

Experiments

- Aim:
  - To answer the following RQs.

- RQs:
  - Baseline Comparison
    - How much better?
  - Performance Assessment
    - Which is the best?
  - Actionable Insights
    - What guidance can we offer?

Experiments

- Dataset
  - Sep 29th 2003 to Sep 2nd 2012
  - 2,895 design and 3,015 development tasks
  - 490 successful sw dev projects from TopCoder
- Validation method
  - LOOCV

Experiments

- Performance Measures:

$$MRE_i = |\ actual_i - estimated_i\ |\ /\ actual_i$$

$$MMRE = \textstyle\sum_i MRE_i\ /\ T$$

$$MdMRE = median(MRE_1, MRE_2, \ldots, MRE_i, \ldots, MRE_T)$$

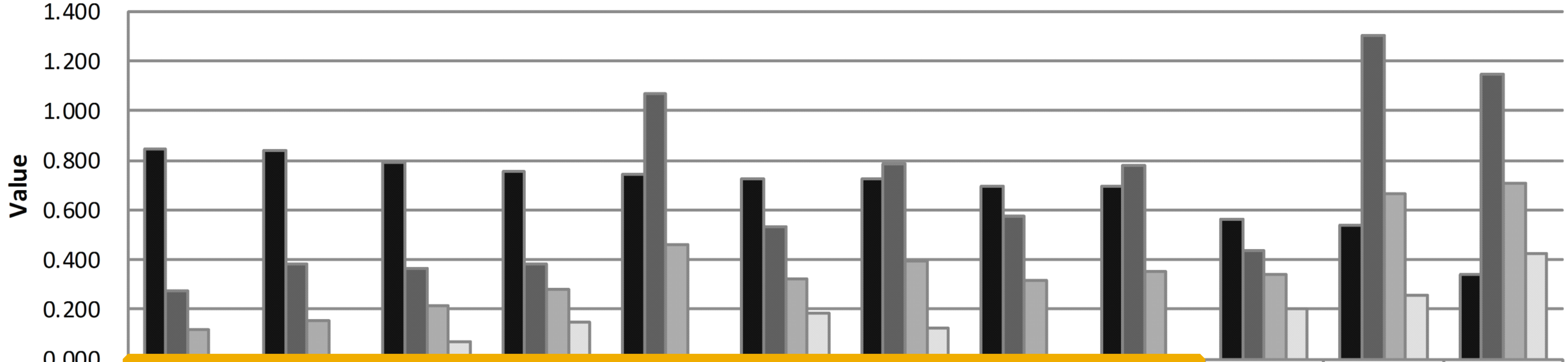
$$StdMRE = \frac{1}{T-1}\sqrt{\sum_i (MRE_i - MMRE)^2}$$

$$Pred(N) = \frac{1}{T}\sum_i \begin{cases} 1 & if\ MRE_i \le N/100 \\ 0 & otherwise \end{cases}$$

(where $i \in \{1 \ldots T\}$)

Experimental Results

- Answer to RQ1:
  - Outperformed by all 9 predictive models, according to Pred(30) measure



	C5.0	QUEST	CART	LReg	SVMR	NNet	KNN_1	Logistic	KNN_k	Naive	Random	COCOMO
Pred30	0.845	0.841	0.794	0.757	0.743	0.724	0.724	0.698	0.694	0.561	0.537	0.341
StdMRE	0.272	0.384	0.365	0.384	1.069	0.533	0.788	0.574	0.782	0.434	1.301	1.145
MMRE	0.116	0.157	0.216	0.279	0.461	0.324	0.397	0.315	0.350	0.340	0.665	0.711
MdMRE	0.000	0.000	0.070	0.151	0.003	0.186	0.125	0.000	0.000	0.200	0.259	0.425

Fig.5 Performance of pricing models learned by each approach

Experimental Results

- Answer to RQ2:
  - Decision tree based learners
    - C5.0, QUEST, CART

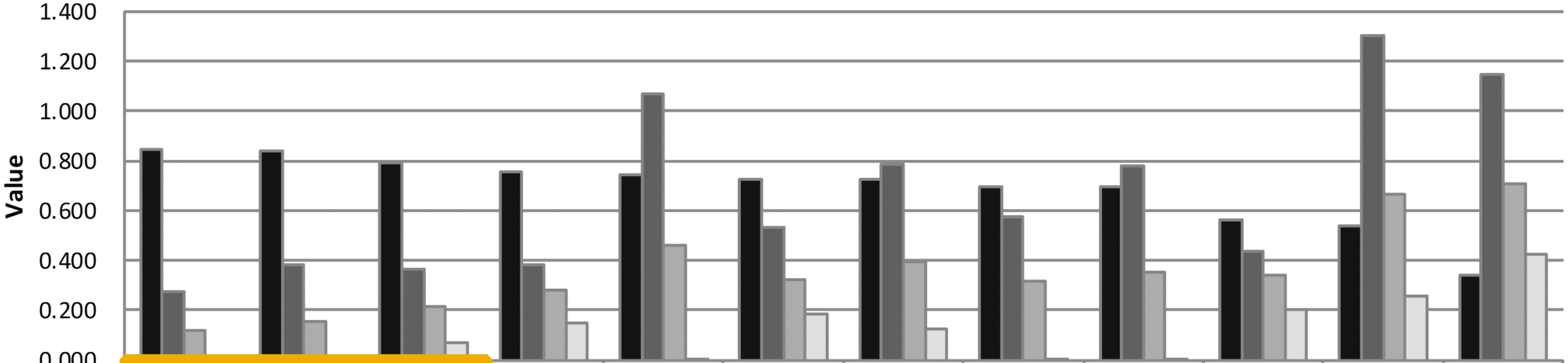


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Fig.5 Performance of pricing models learned by each approach

Insights

- Answer to RQ3:
  - Significance Anlysis

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Insights

- Answer to RQ3:
  - Rules of Thumb
    - ISUP => $70 ↓
    - COMP(4 pages) => $30 ↑
    - SEQU(4 diagrams) => $30 ↑
    - SIZE(1 KSLOC) => $30 ↑
  - May not alway be right
    - But "Why am I bucking the trend?"

Overview

- Conclusion

Conclusion

- Analyzed 5,910 sw dev tasks on TopCoder
- Proposed 16 price drivers
- Assessed 12 empirical pricing models
- Useful prediction quality is achievable (Pred(30)>0.8)
- Actionable advice can be extracted from our models to assist the developers on TopCoder

Future Work

- Quality & Risk Factors
- Price / Quality Trade off
  - Assessing task complexity via UML design
- Muti-objective Optimization
  - Price / Quality / Risk

Thanks !