Development Cycle Estimation Modeling

with the

Statistical Agent-based Model of Development and Evaluation

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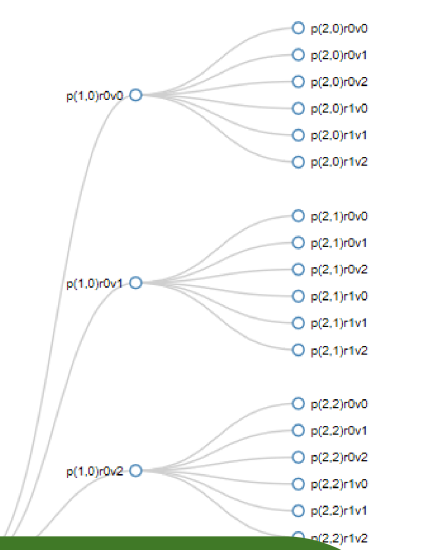
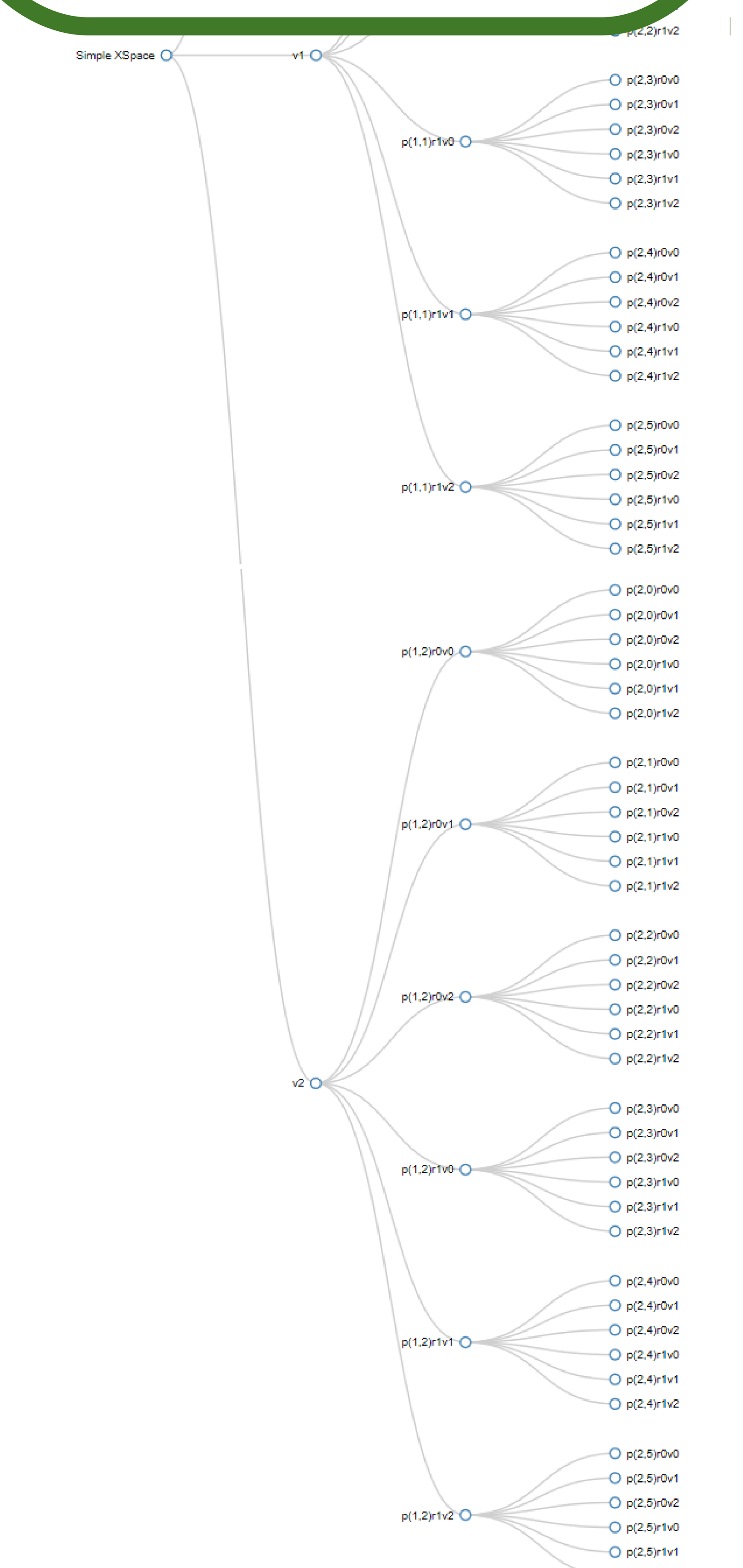
DSpace



Introduction

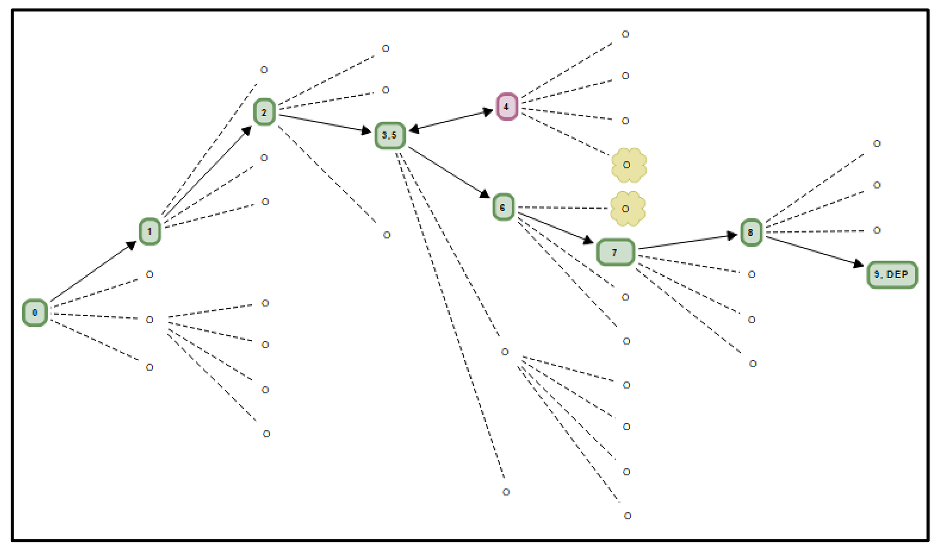
Communication of development risk can be problematic. For software security risk, the Open Web Application Security Project (OWASP) professional standard is commonly used. It is based on a conceptual equation (Risk = Likelihood * Impact) presented with a color-coded 10-point scale [1]. Unfortunately, that presentation is neither compelling nor adequately informative for business and some technical decision-makers. This concern is not limited to software development. Risk assessment professionals have reached similar conclusions in more general cases [2]. A framework or model that allows consistent and quantitative risk calculation is needed.

Motivated by years of application security testing experience, this work presents results from a domain-independent development model. The work's objectives are the derivation of a model property (resource estimation), the successful comparison of that property to empirical data (COCOMO), and the brief listing of the model's risk communication benefits.



DPath

SAbMDE uses Wang's process algebra ideas[3,4] to represent each development cycle phase so that analytical techniques can be uniformly applied across the entire cycle. Wang develops a desired end product (DEP) by sequentially composing intermediate products from sets of fundamental elements: vocabulary items and relations. An agent decides which vocabulary item and relation to compose; and a correct decision set produces the DEP. SAbMDE recognizes (1) that each decision is one of a set of alternatives, (2) that the hierarchical super-set of alternatives forms a development space (dSpace), and (3) that the correct DEP decision set is a path (dPath) through dSpace.



DPath Traversal Probability

At the start of a dPath, what is the probability that an agent will make the correct sequence of decisions needed to traverse dSpace to a DEP? Treat dPaths as Markov Chains with node probabilities defined by the number of forward decisions available at each node; see Eqns 1.x – 3.x where this is done by composition level, l. Additionally, scale the node probabilities to simulate agents' decision-making skill range using Eqn 4.0.

The dPath Probability graph below illustrates these calculations and shows that prediction confidence degrades quickly. So, predictions must be repeated periodically.

$$l = 0: p(l) = 0 \qquad (1.1)$$

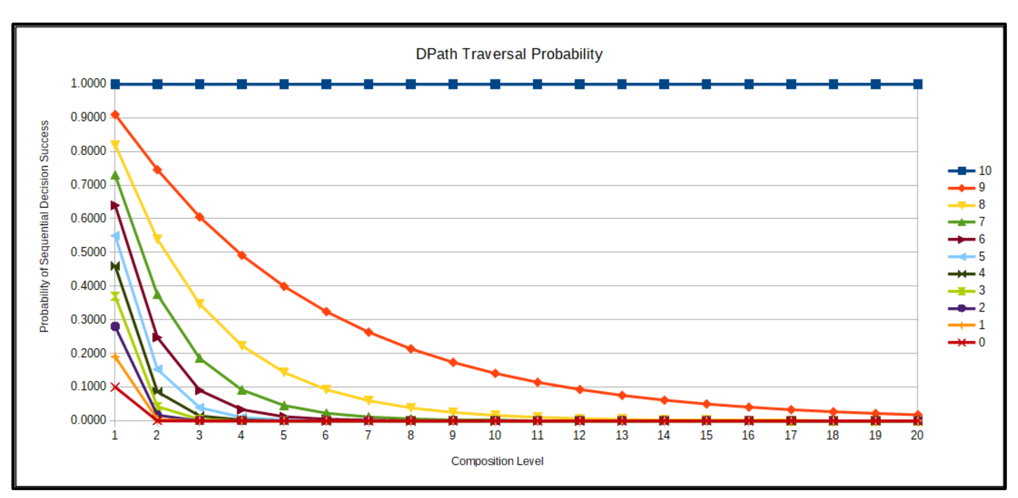
$$l = 1: p(l) = 1/|V| \qquad u = 1/|V| \qquad (1.2, 1.4)$$

$$l > 1: p(l) = 1/(|V||R|) \qquad q = 1/(|V||R|) \qquad (1.3, 1.5)$$

$$p(L) = p(1)\prod_{l=2}^{L} p(l\,|\,(l-1)) \qquad (2.0)$$

$$p(l) = \ |V|^{(-2l+1)}|R|^{(-2l+3)} \qquad p(l) = u^2 q^{(2l-3)} \qquad (3.1, 3.2)$$

$$y = x + \frac{f_s}{10}(1-x), \quad f_s = 0, 1, \ldots 10 \qquad (4.0)$$



Pricing and Resource Utilization

Estimate the resource utilization associated with a dPath by assigning a price to each vocabulary item and relation; and price their composition with some appropriate function. Similarly, assign a price to their decomposition when an agent makes an incorrect decision. The equations below describe a simple pricing system. There, the number of re-tries, n, is calculated with a hypergeometric distribution to ensure that a correct decision is eventually made and that the estimate is an upper limit.

$p_v =$ vocabulary item price, actual or normalized

$p_r =$ relation price, actual or normalized

$g_{cp}(p_v, p_r) =$ composition pricing function

$f_b =$ backtrack factor

$l_b =$ backtrack length

$n =$ number of decision re-tries

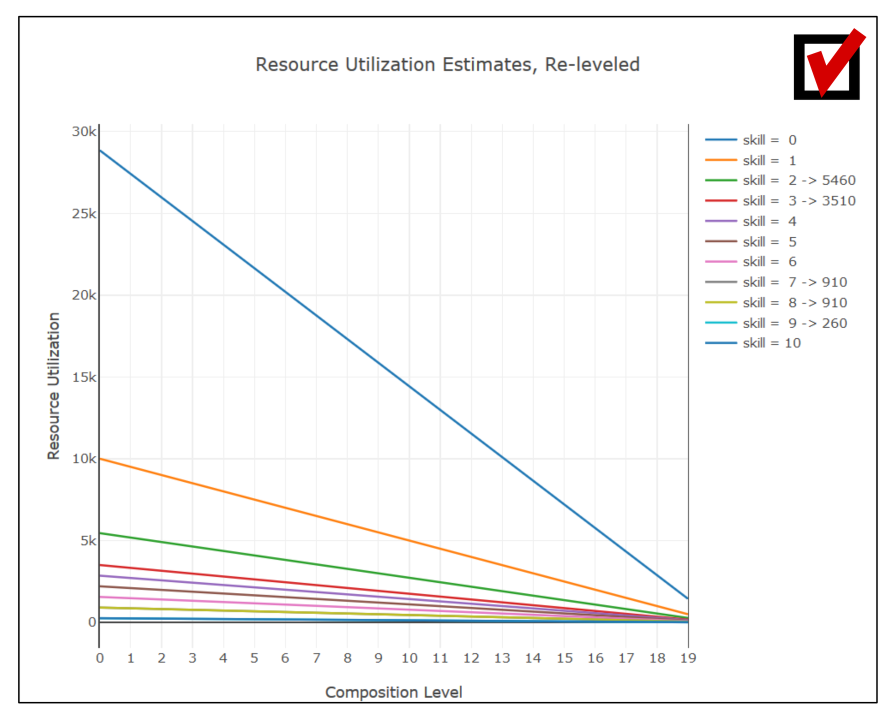
$g_{dp}(p_v, p_r) =$ decomposition pricing function

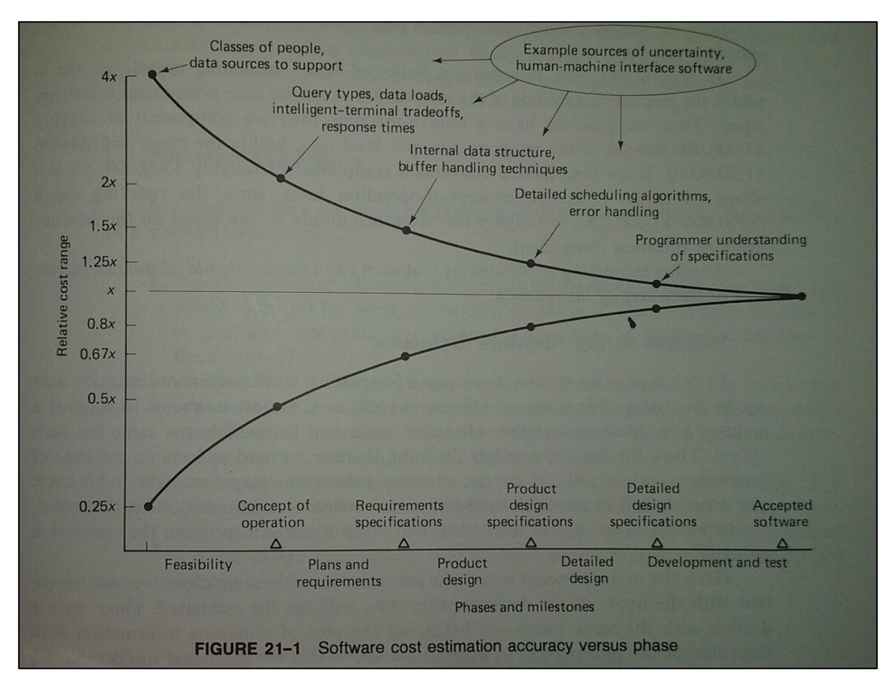
$$g_{cp}(p_v, p_r) = (p_v + p_r) \qquad (6.1)$$

$$g_{dp}(p_v, p_r) = f_b g_{cp}(p_v, p_r) \qquad (6.2)$$

$$p = g_{cp} + (n-1) l_b g_{dp} \qquad (6.3)$$

Calculate a dPath's resource utilization by summing the composition prices for each product in the dPath. Such a summation for as-yet untraversed portions of the dPath is an estimate. The graph below shows such estimates made from each composition level and for each agent skill level. Note that, at composition level 0, the ratio of higher to lower estimates is approximately 16:1. This is similar to Boehm's Cone of Uncertainty (COU).





SAbMDE vs COCOMO II

Pricing Parameters	
|V|	10
|R|	10
L	20
Backtrack Length	1
Backtrack Factor	1.5
Decision Criterion	0.1
Pricing Parameters	

Skill Factors		Prices(Vocabulary Items,Relations)			
Raw	Adjusted	(1,1)	(1,3)	(1,5)	(1,10)
0		8940	17880	26820	49170
1	0	1740	3840	5220	9571
2	1.25	940	1880	2820	5171
3	2.5	640	1280	1920	3520
4	3.75	440	881	1320	2420
5	5	340	681	1021	1870
6	6.25	240	480	721	1320
7	7.5	140	280	420	771
8	8.75	140	280	420	771
9	10	40	81	120	220
10		40	81	120	220

SAbMDE assumes that agent decision-making skill ranges from only random (guessed) to only perfect decisions. COCOMO, however, assumes a minimal level of skill that is better than guessing and a maximum level that is less than perfect. To resolve these assumptions, the smallest and largest SAbMDE data points were set aside and the remainder were adjusted to match the COCOMO data.

COCOMO II SOFTWARE DEVELOPMENT ESTIMATION

Scale Factors	Very Low	Low	Nominal	High	Very High	Extra High
PREC	6.20	4.96	3.72	2.48	1.24	0
FLEX	5.07	4.05	3.04	2.03	1.01	0
RESL	7.07	5.65	4.24	2.83	1.41	0
TEAM	5.48	4.38	3.29	2.19	1.10	0
PMAT	7.80	6.24	4.68	3.12	1.56	0
Sum	31.62	25.28	18.97	12.65	6.32	0

Effort Multipliers	Very Low	Low	Nominal	High	Very High
ACAP	1.42	1.19	1.00	0.85	0.71
PCAP	1.34	1.15	1.00	0.88	0.08
PCON	1.29	1.12	1.00	0.90	0.81
APEX	1.22	1.10	1.00	0.88	0.81
PLEX	1.19	1.09	1.00	0.91	0.85
LTEX	1.20	1.09	1.00	0.91	0.84
Others	1.00	1.00	1.00	1.00	1.00
Product	4.28	2.00	1.00	0.49	0.03

KLOC	100
A	2.94
B	0.91
C	3.67
D	0.28

	Min (Effort)	Max (Effort)
Scale Factor	31.62	6.32
Effort Multipliers	4.28	0.03
E	1.23	0.97

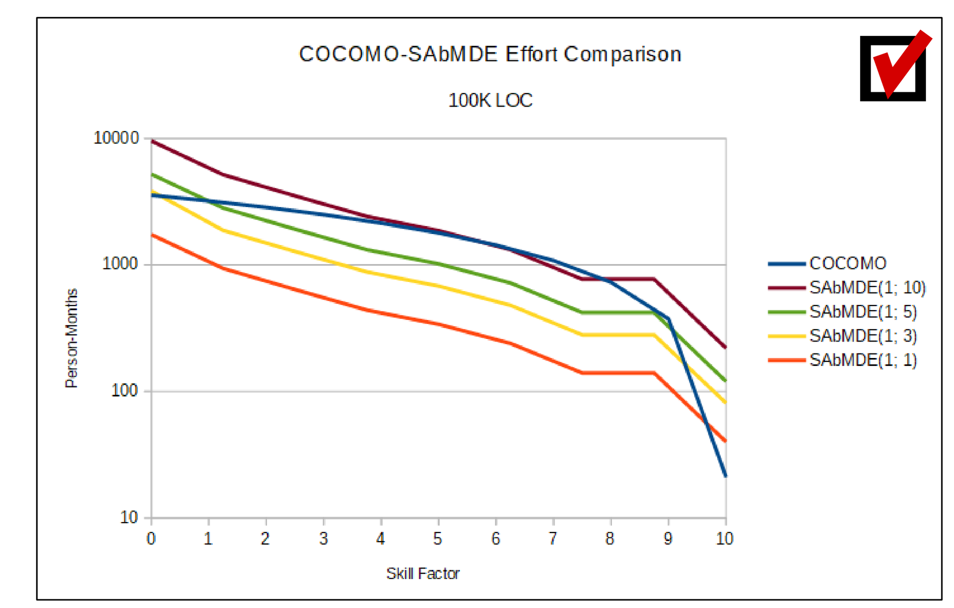
Development Effort

Skill Factor		0	1	2	3	4	5	6	7	8	9	10
		Scaled EM										
	Scaled E	4.28	3.85	3.43	3.00	2.58	2.15	1.73	1.30	0.88	0.45	0.03
0	1.23	3563.02	3208.82	2854.63	2500.43	2146.24	1792.04	1437.84	1083.65	729.45	375.26	21.06
1	1.20	3171.16	2855.92	2540.68	2225.44	1910.19	1594.95	1279.71	964.47	649.23	333.99	18.75
2	1.18	2822.40	2541.83	2261.25	1980.68	1700.11	1419.54	1138.97	858.40	577.83	297.25	16.68
3	1.15	2511.99	2262.28	2012.56	1762.85	1513.13	1263.42	1013.71	763.99	514.28	264.56	14.85
4	1.13	2235.72	2013.47	1791.22	1568.97	1346.72	1124.47	902.22	679.97	457.72	235.47	13.22
5	1.10	1989.84	1792.03	1594.22	1396.42	1198.61	1000.80	802.99	605.19	407.38	209.57	11.76
6	1.07	1771.00	1594.95	1418.89	1242.84	1066.79	890.73	714.68	538.63	362.57	186.52	10.47
7	1.05	1576.23	1419.53	1262.84	1106.15	949.46	792.77	636.08	479.39	322.70	166.01	9.32
8	1.02	1402.87	1263.41	1123.96	984.50	845.04	705.58	566.12	426.67	287.21	147.75	8.29
9	1.00	1248.59	1124.46	1000.34	876.22	752.10	627.98	503.86	379.74	255.62	131.50	7.38
10	0.97	1111.27	1000.80	890.33	779.86	669.39	558.92	448.45	337.98	227.51	117.04	6.57

Development Calendar Time

Skill Factor		0	1	2	3	4	5	6	7	8	9	10
		Scaled EM										
	Scaled E	4.28	3.85	3.43	3.00	2.58	2.15	1.73	1.30	0.88	0.45	0.03
0	1.23	60.78	58.64	56.33	53.83	51.08	48.01	44.52	40.40	35.27	28.07	10.45
1	1.20	56.07	54.12	52.02	49.74	47.23	44.44	41.25	37.49	32.79	26.19	9.89
2	1.18	51.78	50.00	48.09	46.02	43.73	41.18	38.27	34.83	30.53	24.46	9.37
3	1.15	47.87	46.25	44.51	42.62	40.54	38.21	35.55	32.40	28.45	22.88	8.89
4	1.13	44.31	42.84	41.25	39.52	37.62	35.49	33.05	30.17	26.55	21.42	8.45
5	1.10	41.07	39.72	38.27	36.69	34.95	33.01	30.77	28.13	24.80	20.08	8.04
6	1.07	38.10	36.88	35.55	34.11	32.52	30.73	28.69	26.26	23.20	18.84	7.65
7	1.05	35.40	34.27	33.06	31.74	30.28	28.65	26.77	24.54	21.72	17.70	7.30
8	1.02	32.92	31.89	30.78	29.57	28.24	26.74	25.01	22.96	20.37	16.65	6.96
9	1.00	30.65	29.71	28.70	27.59	26.36	24.98	23.40	21.51	19.12	15.68	6.65
10	0.97	28.58	27.71	26.78	25.76	24.64	23.37	21.91	20.17	17.96	14.79	6.37

Above, the COCOMO Effort Multipliers (EM) describe agent skill. The E exponent describes project characteristics. Both parameters are scaled; however, only the highest E values are used to ensure that the estimate represents an upper limit.



The graph of SAbMDE and COCOMO data sets demonstrates their similarity. Evidently, the calculation based on an underlying mechanism matches empirical data. Note that the SAbMDE effort curve shape is not a function of price; it is a function of the dSpace structure and its application, as was hypothesized.

Conclusions

- The reasonably close correlation of SAbMDE estimates to COCOMO estimates implies that SAbMDE has potential.
- Estimates are built entirely on the current project characteristics: vocabulary items, relations, prices, pricing function, and composition count.
- The characteristics are measurable and they can be recorded.
- Each characteristic is well-known. Together, they are a common basis for communication and collaboration among all parties: developers, decision-makers, business managers, etc.
- **Development risk is reduced by getting more vulnerabilities fixed sooner.**

References

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