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A Statistical Approach for Context-Awareness of Mobile Applications

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Outline

Definition of context, context variables, contexual situations, context-awareness

Research idea and contribution

The statistical Approach

Quick example

Conclusions

Context Definitions

“**Context** is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.”

Context variable is any type of contextual information affecting the system behavior.

Contextual Situation can be defined by a group of context variables and their values, under which a system will eventually run.

“A system is **context-aware** if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task. ”

Context Variables

$C \in \{val1, val2, ... valz\}$ for discrete values

$C \in \{[vala, valb],[valc, vald], ..\}$ for range of values

Example:

$B \in \{SufficientBattery, NonSufficientBattery\}$

$NC \in \{AvailableConnectivity, NonAvailableConnectivity\}$

Contextual Situations

S = { C1(valC1), C2(valC2), . . . , Cx(valCx) }

Example:

S1={B(SufficientBattery),NC(AvailableConnectivity)}

S2={B(SufficientBattery),NC(NonAvailableConnectivity)}

S3={B(NonSufficientBattery),NC(AvailableConnectivity)}

S4={B(NonSufficientBattery),NC(NonAvailableConnectivity)}

Research General Idea

Context awareness increasingly becomes an essential attribute for software systems.

Mobile applications may benefit from context awareness since they incur to context changes during their execution.

Mobile applications can adapt their structure and behavior as a way to preserve the service quality they offer under the different contexts.

Research Contributions

Introducing a statistical approach that helps in determining contextual situations that require adaptation.

The approach depends on transition probabilities and system quality at each state in order to decide when it is necessary to apply context-awareness.

A Statistical Approach for Context-Awareness

The approach starts from monitoring mobile context variables values, modeling their states, and deducing from these models a Markov chain model, where each state represents a contextual situation.

Context modeling can be used for analyzing QoS of mobile systems, determining the different contextual situations under which one needs to study the system behaviors and deciding at which contextual situation to adapt.

A Statistical Approach for Context-Awarenes s

1

Monitoring context variables evolution

$$C \in \{val_1,\ val_2,\ \dots\ val_z\ \}$$

$$BL \in \{LowBattery,\ HighBattery\}$$
$$BS \in \{Charging,\ NotCharging\}$$

2

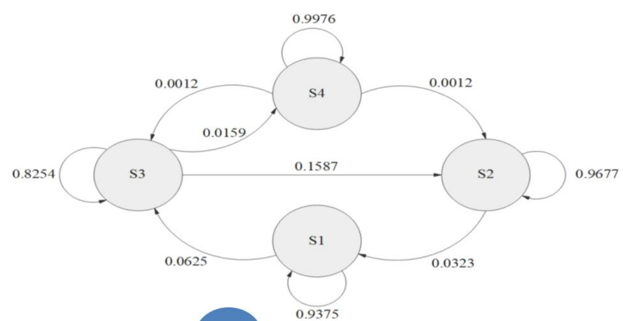
Defining context variables states

$$S = \{\ C_1(val_{C_1}),\ C_2(val_{C_2}),\ \dots,\ C_x(val_{C_x})\ \}$$

$S1$={BL(LowBattery), BS(Charging)}
$S2$={BL(LowBattery), BS(NotCharging)}
$S3$={BL(HighBattery), BS(Charging)}
$S4$={BL(HighBattery), BS(NotCharging)}

3

Extracting contextual situations states



4

Building Markov chain model

$$M_{transition} = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_4 \end{array} \\ \begin{pmatrix} 0.9375 & 0 & 0.0625 & 0 \\ 0.0323 & 0.9677 & 0 & 0 \\ 0 & 0.1587 & 0.8254 & 0.0159 \\ 0 & 0.0012 & 0.0012 & 0.9976 \end{pmatrix} \end{array}$$

5

Computing Transition Matrix

S_i	S_1	S_2	S_3	S_4
$\sum_{j=1}^{n} P_{S_j,S_i}$	0.333	0.975	1.704	0.979

	S_1	S_2	S_3	S_4
Availability	o.3825	0.4122	0.4381	0.4208

6

Reasoning on states of high transitions probabilites and its effect on Software quality

Monitoring Context Variables Evolution

Log file

Ping Request Number	Ping state	GPS Location Lat., Long.	Time	Network	Signal Level	Signal Strength	Battery Level	Battery State	Ping Success	AVG round trip
65	Normal	42.3689841, 13.3491289	2017-06-15 15:24:28	wifi network "eduroam"	3	-71 dbm	100.0	NotCharging	failed	none ms
66	Normal	42.3689841, 13.3491289	2017-06-15 15:26:28	wifi network "eduroam"	3	-71 dbm	100.0	NotCharging	failed	none ms
67	Normal	42.3689841, 13.3491289	2017-06-15 15:28:28	wifi network "eduroam"	3	-71 dbm	100.0	NotCharging	failed	none ms
68	Normal	42.3689841, 13.3491289	2017-06-15 15:30:28	wifi network "eduroam"	3	-71 dbm	100.0	NotCharging	failed	none ms
69	Normal	42.3689841, 13.3491289	2017-06-15 15:32:28	wifi network "eduroam"	3	-71 dbm	100.0	NotCharging	failed	none ms
70	Normal	42.3689841, 13.3491289	2017-06-15 15:34:28	wifi network "eduroam"	2	-76 dbm	100.0	NotCharging	failed	none ms
71	Normal	42.3689841, 13.3491289	2017-06-15 15:36:28	wifi network "eduroam"	2	-76 dbm	100.0	NotCharging	failed	none ms
72	Normal	42.3689841, 13.3491289	2017-06-15 15:38:28	wifi network "eduroam"	2	-76 dbm	100.0	NotCharging	failed	none ms
73	Normal	42.3689841, 13.3491289	2017-06-15 15:40:28	wifi network "UNIVAQ"	2	-76 dbm	99.0	NotCharging	0% packet loss	28.510 ms
74	Normal	42.3689841, 13.3491289	2017-06-15 15:42:28	wifi network "UNIVAQ"	3	-72 dbm	99.0	NotCharging	0% packet loss	28.562 ms
75	Normal	42.3689841, 13.3491289	2017-06-15 15:44:28	wifi network "UNIVAQ"	3	-72 dbm	99.0	NotCharging	0% packet loss	31.295 ms
76	Normal	42.3689841, 13.3491289	2017-06-15 15:46:28	wifi network "UNIVAQ"	3	-72 dbm	99.0	NotCharging	0% packet loss	29.133 ms
77	Normal	42.3689841, 13.3491289	2017-06-15 15:48:28	wifi network "UNIVAQ"	3	-74 dbm	99.0	NotCharging	0% packet loss	31.489 ms
78	Normal	[illegible]	2017-06-15 15:50:28	mobile network: 3G	none	-75 dbm	99.0	NotCharging	error	none ms

Context Variables

Contextual Situations

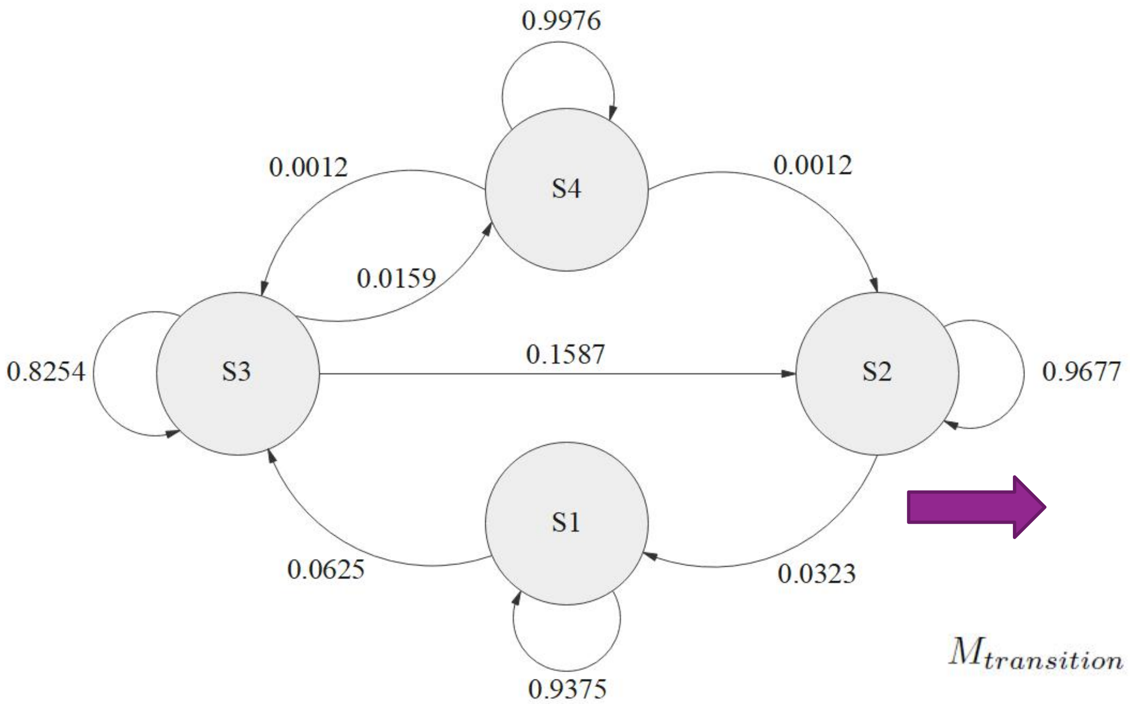
State Transitions

Staying in the same contextual situation
S1 {BS= “Charging”, BL=“Low Battery”}

Moving from the contextual situation
S1 {BS= “Charging”, BL=“Low Battery”}
to
the contextual situation
S3 {BS= “Charging”, BL=“High Battery”}

Context Time	Battery Level	Battery State
2017-06-16 10:34:21	25.0	Charging
2017-06-16 10:36:21	27.0	Charging
2017-06-16 10:38:21	28.0	Charging
2017-06-16 10:40:21	30.0	Charging
2017-06-16 10:42:21	31.0	Charging
2017-06-16 10:44:21	33.0	Charging
2017-06-16 10:46:21	34.0	NotCharging
2017-06-16 10:48:21	34.0	NotCharging

Markov Chain Model and Transition Matrix for the Contextual Sitiuations



$$M_{transition} = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_4 \end{array} \\ \begin{pmatrix} 0.9375 & 0 & 0.0625 & 0 \\ 0.0323 & 0.9677 & 0 & 0 \\ 0 & 0.1587 & 0.8254 & 0.0159 \\ 0 & 0.0012 & 0.0012 & 0.9976 \end{pmatrix} \end{array}$$

. Transitions probabilities summation at each state

S_i	S_1	S_2	S_3	S_4
$\sum_{k=1}^{n} \mathrm{P}_{S_k, S_i}$	0.9698	1.1276	0.8891	1.013504

Quick Example

Running the Approach on OSApp Mobile Application

OSApp is an Android mobile

application connected to the "OffSiteArt | Art- bridge for L'Aquila".

OFF SITE ART Artbridge connects the public to the arts

A PROJECT FOR L'AQUILA

The project aims to cover the scaffolding of the buildings in reconstruction after the 2009 earthquake with pieces of art of emergent artists selected under a call for art.

OFF SITE ART

Art'bridge

connects the public to the arts

A PROJECT FOR L'AQUILA

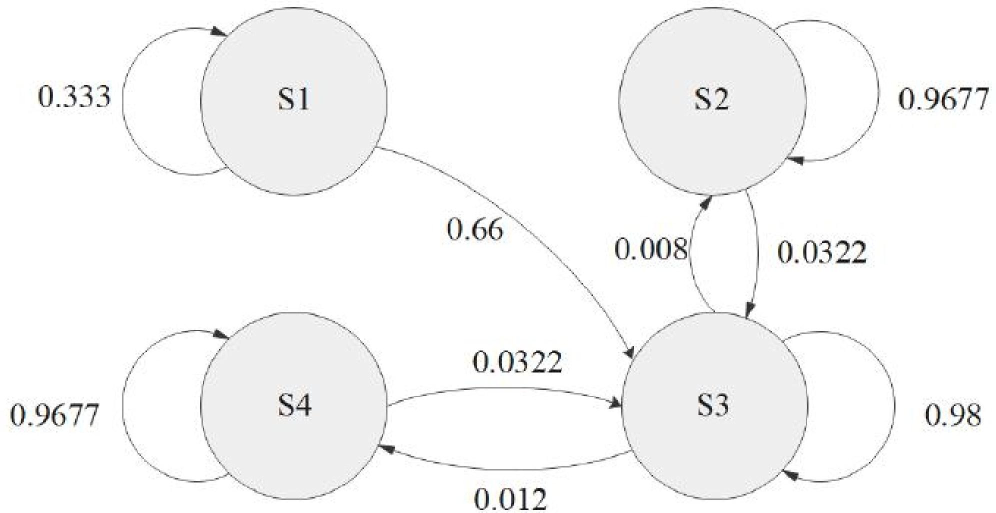
Applying the approach

We use several contextual situations to analyze at each state the mobile application behavior in terms of transitions probabilities and user perceived service availability (QoS).

We aim to understand the relevant contextual situations to context awareness.

$$NC \in \{GoodConnectivity\ ,\ PoorConnectivity\}$$
$$BL \in \{LowBattery\ ,\ HighBattery\}$$

$$S_1 = \{NC(PoorConnectivity), BL(LowBattery)\}$$
$$S_2 = \{NC(PoorConnectivity), BL(HighBattery)\}$$
$$S_3 = \{NC(GoodConnectivity), BL(HighBattery)\}$$
$$S_4 = \{NC(GoodConnectivity), BL(LowBattery)\}$$



$$M_{transition} = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_4 \end{array} \\ \begin{pmatrix} 0.333 & 0 & 0.666 & 0 \\ 0 & 0.9677 & 0.0322 & 0 \\ 0 & 0.008 & 0.98 & 0.012 \\ 0 & 0 & 0.0322 & 0.967 \end{pmatrix} \end{array}$$

$$M_{transition} = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_4 \end{array} \\ \begin{pmatrix} 0.333 & 0 & 0.666 & 0 \\ 0 & 0.9677 & 0.0322 & 0 \\ 0 & 0.008 & 0.98 & 0.012 \\ 0 & 0 & 0.0322 & 0.967 \end{pmatrix} \end{array}$$

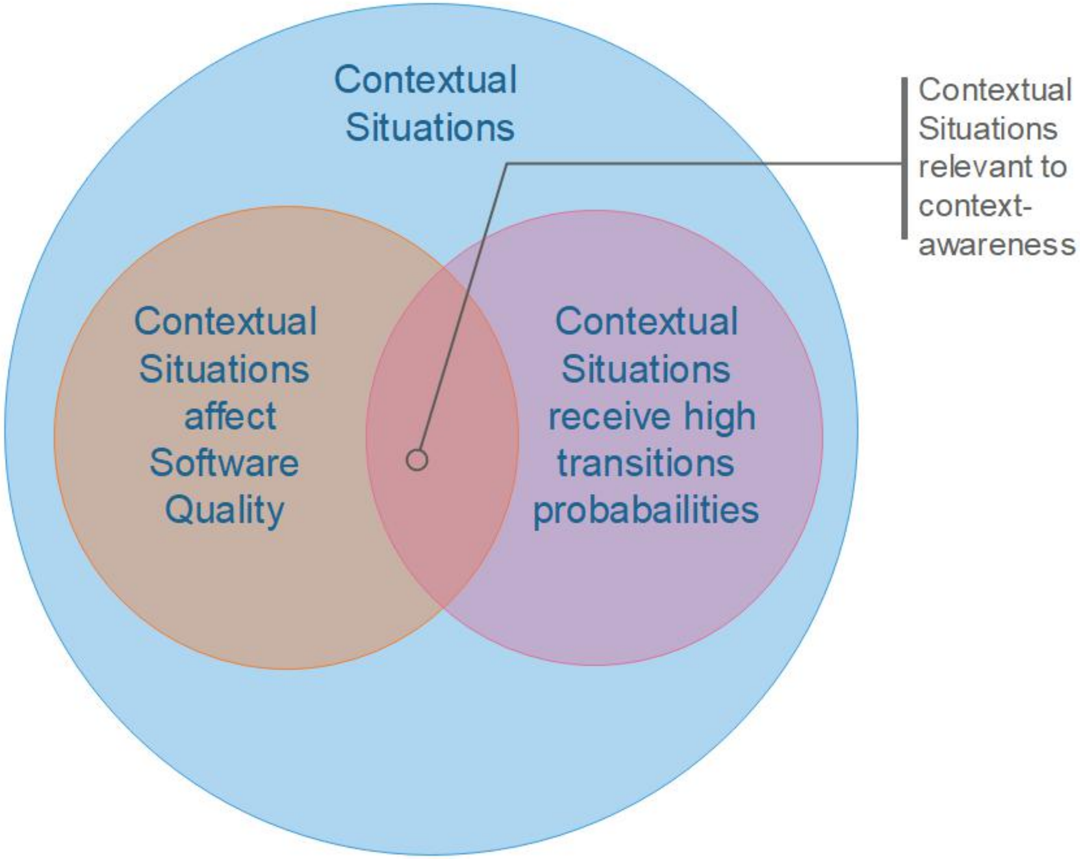
S_i	S_1	S_2	S_3	S_4
$\sum_{k=1}^{n} \mathrm{P}_{S_k,S_i}$	0.333	0.975	1.704	0.979

	S_1	S_2	S_3	S_4
$UPSA$	36.34%	37.71%	41.04%	39.22%

During a user interaction (session) with the system, the user issues multiplerequests at different time points for different system resources. The unavailability of requested resource will cause the request to fail. The service availability is the probability that all requests are successfully satisfied during the user session.

Conclusion

Determining contextual situations transitions that represents the context changes at a time, is essential for analyzing the system quality when it goes under these changes, it can also help in deciding the context awareness to be considered when designing the adaptation.



Thanks

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