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Supply Chain Control building on Emergent Self-Organizing Effects

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1 Introduction

Service platforms have become a centerpiece of collaborate value creation (e.g. eBay, Netsuite, Facebook, Apple App store), benefiting from renewed strategies of open innovation through platform ecosystems of autonomous service providers. To be able to focus on core competencies, companies started delegating the process of value generation into the supply chain (Fischer et al., 2009), limiting themselves to a role of substantiating basic value contribution. In consequence, established supply chains are increasingly being deconstructed (Scholten et al., 2009). "Successful enterprises now focus on value nets, in which partnerships with customers and suppliers operate in a network, supported by real-time information flows and integrated IT systems"(Cherbakov et al., 2005). To benefit from these dynamics and creativity of external origin, purely centralistic control concepts in supply chain management need to be opened up. But what change in paradigm is required to embrace dynamic and self-organized value networks, without losing control on strategic goal accomplishment? How do these concepts handle two-digit-growth rates (Salesforce, 2009) and targets like SAP's goal to reach 1 billion users by 2014 (SAP, 2010)?

As well as building on our group's efforts on innovation management in platform-based ecosystems (Scholten & Scholten, 2010), this work draws on our findings w.r.t. software architectures to support control mechanisms based on service interaction data, the data which accumulates while value is generated in dynamic service networks (Scholten et al.; 2009, Fischer et al., 2010; Fischer et al., 2009). In this paper, we specifically extend on our research on control mechanisms for dynamic decentralized supply chains, which we first introduced at Supply Management 2010 (Scholten et al., 2010). We now formalize the control mechanisms and suggest possible control sequences that help to improve service quality and service portfolio in an automated way. This new interpretation of our concept enables the clear illustration of the differing impact of direct (linear) control mechanisms on the one hand and indirect control mechanisms – being dynamic and non-linear in nature – on the other hand. In a major innovation we have taken results from hysteresis research and adapted them to the context of dynamic value chains. As our work distinctly focuses on stimulating the network of service providers to align with the platform provider's strategic goals, our research clearly contrasts with research that is being done in the context of influencing consumer behavior, e.g. marketing research or business intelligence research. State of the art work that closely relates to our work has several centers. The e3value group[1] models value flows in networks. The group suggests generic solutions for common control problems, so called 'control patterns' (Kartseva et al., 2007). This transactional design is helpful to describe and depict direct control relationships. However, non-linearity and emergent effects are not covered and require further investigation. A research group at Karlsruhe Service Research Institute (KSRI) focuses on one variant of motivational control: financial incentives (e.g. Conte et al., 2010). The results are highly complementary and can be positioned within our framework of control mechanisms. Last, efforts at the University of Tilburg are related to ours as they aim at 'explaining and predicting the structure and behavioral dynamics of smart service systems, and particularly, smart service networks' (v. d. Heuvel, 2009). The group is currently refining an analytical framework based on global resource dependencies, aggregated transaction costs, actor-network relationships, complexity and degree of 'smartness.' Placed into this research agenda, our findings can shed light on actor-network relationships and complexity.

The paper is structured as follows: Motivated with system theory (section 2) and based on feedback control, we present a conceptual architecture for feedback control (section 3). In section 4 and 5, we describe the necessary control mechanisms for platform ecosystems and ways for their parameterization. Hereafter, we describe results of experimental implementations and work in progress. The paper closes with a conclusion and an outlook on further research.

2 Controlling Platform-based Value Nets

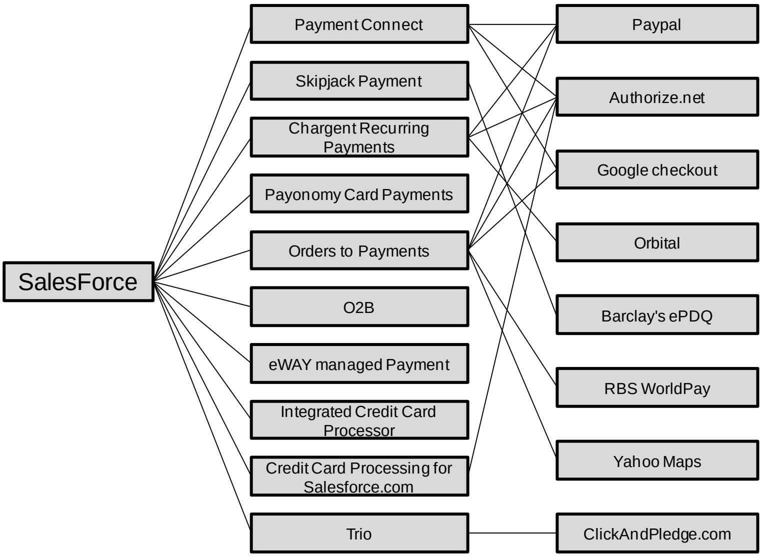
2.1 Market Examples

In the context of IT-service platforms, composite services can be described as the outcome of service value networks (SVNs). An SVN on the other hand can be regarded as a consumer-driven instance of a business ecosystem, consisting of a service ecosystem of autonomous service providers and (clusters of) consumers interlinked through relations that transfer value (Fischer et al., 2010). Based on specific customer requirements, value nets are formed and maintained during the time of service request and delivery. Figure 1 and 2 show two tiers from real-life examples on payment processing and storage that are based publically available information. PayPal for instance, a second tier service provider in fig. 1, is interconnected on subsequent tiers with the

[1] For publications and details see: www.e3value.com

ZKA (EC-cards), Giropay, VISA, MasterCard, American Express and many others. Services depicted without links into a second tier – like O2B – are either explicitly not using any further service or did not provide network information.

Figure 1: *Platform based SVN, Payment processing example from the Salesforce platform*

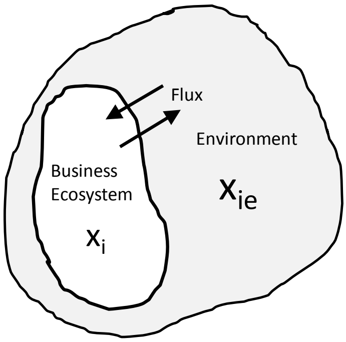


2.2 Grounding Theory

With growing service portfolios, service providers and transaction types, handling system complexity in service ecosystems turns into a difficult challenge. Complexity even aggravates, when system dynamics and evolution are taken into account.

Which theoretical embedding is the most suitable to capture complexity? Which is able to supply mechanisms to cope with it? Dynamic business ecosystems are characterized by a continuous flux of new entrants and exits of service providers and consumers under strong influence of external stakes such as competition, but also by factors like business climate, marketing etc., which impact consumer preference patterns (see fig. 2). To pay respect to the prevalent openness to external inputs, dynamics and adaptivity of business ecosystems (Bovet & Martha, 2000) and to take the autonomy of service providers and their self-organizing behavior into account, we apply system theory (Scholten et al., 2010; Wiener, 1948; and Prigogine & Nicolis, 1977). Fig. 3 provides a simplified, systemic view of a business ecosystem in the context of its environment.

Figure 2: *Schematic representation of an open system (adapted from Prigogine & Nicolis, 1977, p. 55), denoted by a set of properties x_i in the business ecosystem and a set of properties x_{ie}*



Based on this systematization of business ecosystems (see fig. 2), we will introduce relevant phenomena of system theory, which will play an important role in our further research. The non-vanishing flux between an open system (business ecosystem) and its environment (e.g., information or influence) demands a formalization that takes account of permanent non-equilibrium systems. Fast and frequently changing systems are even called 'far-from-equilibrium-systems'. Prigogine & Nicolis (1977), however, provide no accurate demarcation, which defines when a non-equilibrium system may be called 'far-from-equilibrium-system'.

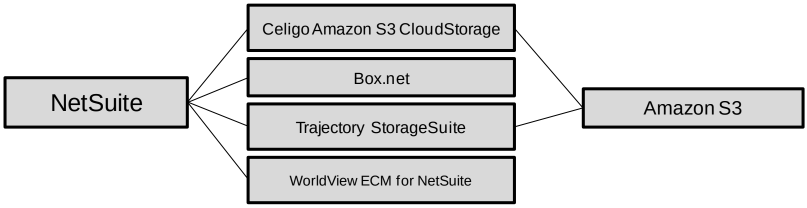
The business ecosystem's set of properties $\{x_1 \ldots x_n\}$ evolves over time. Their timely evolution takes the form $\delta x_i/\delta t = F_i(x_1, \ldots, x_n, t, \ldots)$. The conditions responsible for the permanent flux between business ecosystem and environment and hence also for the permanent evolution within the business ecosystem are called constraints. According to Prigogine & Nicolis (1977, p. 56), 'in a non-equilibrium state, detailed balance will not hold', because of the continuous action of constraints. Small changes in the system will not be 'obliterated by an instantly developed counteraction but rather, can be accepted and even amplified by the system, thus becoming source of innovation and diversification'. In the example of a payment-processing ecosystem a new service provider adds to the ecosystems feature set (e.g. PayPal adds email-based transactions). Many consumers may rapidly evoke a service, if it is well accepted. As a consequence, the service ecosystem will react with direct impact on consumption behavior, e.g. other service providers offering similar services will rapidly join the ecosystem. To further formalize the set X_i, or even the evolution function F_i will be doomed to failure, as the properties that need to be addressed are countless. However, we can apply control theoretical concepts (Föllinger, 1990) to actively and selectively influence ecosystems towards system improvement[2], without knowing every detail of the overall system and its respective properties.

We now introduce two important system-theoretical phenomena – 'self-organization' and 'emergence'. Both play an important role within ecosystems theory.

Self-organization describes the dynamic and adaptive increase in structure of service ecosystems without external control (De Wolf & Holvoet, 2005) that is driven by each service provider's individual pursuit of profit maximization (Schumpeter, 1926). The increase in order can be read as the system's orientation towards a more beneficial structure. It reduces the total number of possible outcomes within a system. The totality of possible outcomes is denominated 'attractor space'. When a system self-organizes the attractor space becomes smaller. Researchers like Prigogine & Nicolis (1977) or Luhmann (1975) even modeled self-organization in human systems in coherence to ecological evolution, yet admitting that only qualitative conclusions can be taken out of such models (for details see Prigogine & Nicolis, 1977, pp. 238-242). Following this path is not in our interest. Our goal is to influence service ecosystems, hence to incite or even enforce positive developments (i.e., developments in-line with platform provider goals) and to hamper counter-active movements. Thus, formal descriptions need to be introduced helping to optimally influence the service ecosystems. This approach reduces system complexity as not necessarily all driving forces behind each change within the system are to be understood. However, the necessity to measure or readout selected properties (e.g. service quality parameters or functional feature) within the system is compulsory. In a first step towards turning the abstract world of self-organizing, open systems more tangible, we now have another look at the value net, described in fig. 1. We look at these networks from a centrally controlled and from a completely self-organized point of view and then develop hybrid solution between the two antipodes. In the example, level-one service providers are interconnected with a maximum of five level-three providers. Their orientation towards this limited choice of service providers reflects 'order' in the system. Not every potential outcome is possible, only a specific set of finite possibilities is offered. We cannot know the driving factors of individual service provider's strategic decisions, but we can assume a logical, economic decision behind. The example in fig. 3 shows that the ecosystem evolved towards an exceptional case of order: the level 3 position is exclusively held by Amazon's storage service. This can be explained with the competitive position of Amazon in the segment of IT-infrastructure services. Systems with such dominant players forfeit dynamics, as alternatives lack. This indicates a (temporary) lock-in situation in the field of storage services; an effect that (Peltoniemi, 2005) describes as one risk in business ecosystems.

[2] Prigogine & Nicolis, 1977, pp. 238ff., rule out the existence of a global optimum and rather speak of many local optima in human systems. We therefore speak of system improvement rather than system optimization with respect to the pursuit of a platform provider to his goals.

Figure 3: *Platform based SVN, Storage example from the Netsuite platform*



Emergence describes a novel and coherent macroscopic behavior of the ecosystem as a result from the interaction between service providers (De Wolf & Holvoet, 2005), hence as a result of self-organization. This loop of self-organization and emergence continues until a new temporary equilibrium is reached, i.e. all service providers concerned have re-aligned. Emergent self-organization leads, due to the absence of central control, to a reduction of complexity w.r.t. individual interactions (in particular for platform providers). Causing a new macroscopic behavior, again, incites self-organization as the loop continues until a new temporary equilibrium is reached. We use explicit examples to make these effects tangible, first in a centralized and next in a decentralized frameset.

Given the formula for complexity (Scholten et al. 2010, adapted from Shannon, 1948):

$$C = \sum_{i=1}^{T}(pt_i * \sum_{j=1}^{N}(-\left(\frac{pn_j}{pt_i}\right)\log_2(pn_j/pt_i))), \qquad (1)$$

C: System complexity;

Cp: Complexity w.r.t. individual; interaction from the platform; providers' perspective; Cp ⊆ C;

T : Number of types of transactions in the network;

N: Number of nodes (services) in the network;

pt_i: Probability of a type i transaction;

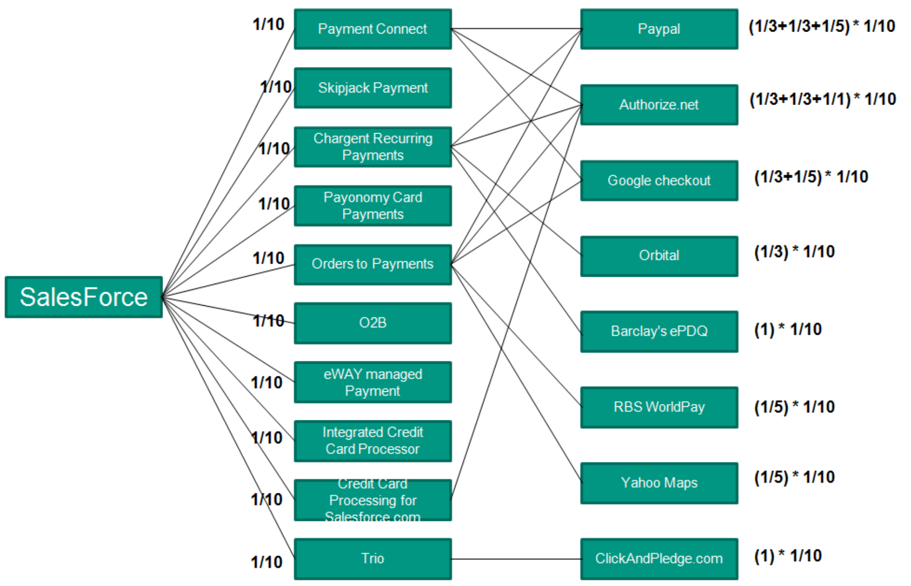
pn_j/pt_i : Conditional probability of the j^{th} node, given the transaction i.

In case of centralized value net control, we can assume C = Cp. However, given complete self-organization of the network in all layers subsequent to tier-1, we reach a situation, equivalent to a pure tier-1 consideration of services. In consequence, complexity decreases significantly.

We will now apply the two scenarios on the Salesforce example (see fig. 1). Results are summarized in fig. 4. The calculation is based on the simplifying assumption of equal probability of node selection with respect to the precedent node. Complexity decreases in the Salesforce case from C_P =5.34 (if centrally orchestrated) to C_P = 3.32 (in the case of decentralized orchestration). The scissor between the two complexities will become wider, once multiple transaction types (i.e., not only payment processing transactions) and more than two tiers are considered. Let us now assume that platform providers allows for self-organized value creation to benefit emergent effects. However, to achieve an improved competitive position with respect to other platforms, the platform provider monitors (and influences) quality and portfolio of atomic services in his domain (for instance a satisfactory level of service availability is required for all services). Let us assume that all tier-1 services (fig. 4) are native, meaning deployed on the platform in conformity with rules and regulations given by the platform provider. Let us further assume, all tier-2 services are external, but service availability in the course of service invocation is monitored. Concerning quality management of atomic services (neglecting possible value net interconnection), all tier-n services respectively service providers can be considered dyadically connected with the platform provider. Given our assumption that consumers autonomously choose services and tier-1 providers choose their tier-2 providers respectively, the platforms purpose of interacting with service providers only is of service quality management concerns. Assuming all services are of equal importance, we can consider the conditional probabilities of each service as equal (in the example of fig. 4 it is 1/18). C_P for maintained services in the example of Salesforce equals 4.17. This complexity value is unsurprisingly positioned in-between a completely self-organized network and the centrally controlled one. Formula (1) shows that with an increasing number of nodes and transaction types, complexity in the centrally controlled case grows significantly faster that in the quality-managed self-organized alternative. To limit complexity respectively its negative consequences (e.g. increased transaction costs, lack of emergence) with regard to service composition, quality and portfolio management, many of the players in these markets have already introduced such degrees of autonomy to the service enablers. Giving up much of the shaping influence on product-mix and reducing it to substantiating services, migrates value creating activities into the service ecosystem. For platform providers, focus shifts towards federation of capabilities (Cusumano & Gawer, 2002). However a mix of direct and indirect control is necessary to guarantee quality of service and coherent ecosystem evolution w.r.t. platform provider's strategic goals (Scholten & Scholten, 2010).

In summary, continuously adapting far-from-equilibrium systems are 'more fragile and sensitive to changes in the environment, but are in consequence also more capable to react' (De Wolf & Holvoet, 2005). Applying this system theoretic statement and concept of autonomously thinking and acting entities into the platform world, reduces complexity and promises to be a fertile environment to quickly re-align on rapidly changing conditions. As central keystone, the platform provider's task is to guarantee suitable frame conditions such as minimum availability (e.g. 99.6% per atomic service) as well as goal congruence to his strategic goals (e.g. the amount of 100 accounting services conforming to US-GAAP standard to satisfy the requirements of the platforms target group of US-companies). In consequence, pure performance monitoring is not sufficient to successfully position a platform. In the contrary, Scholten et al. (2009) showed that intermediaries lacking stakeholding power were not able to sustain in the long term. Thus, control of decentralized ecosystems of autonomous service providers in a frameset of quality and portfolio management needs to be in the focus of the platform providers; hence, are the goal of the subsequently introduced control mechanisms.

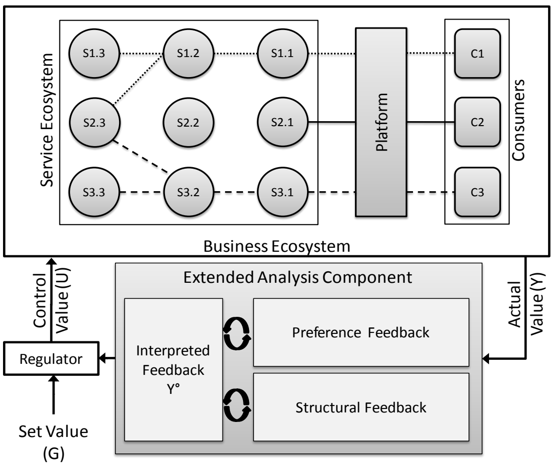
Figure 4: *Salesforce example with conditional probabilities and respective complexity calculation*



3 Control Loop

Fig. 5 shows the control loop model, which provides the frameset for all subsequent control activities. The business ecosystem is considered the control path of a regulatory process. The entirety of data at a given point of time within such a business ecosystem can be called actual value Y. We restrict our focus on a selection of known and measurable data i.e. financially important consumption clusters and their preferred composite services. Y is a vector, which embraces a finite set of parameters. The known data is read out from the service description of each service. The service descriptions are automatically readable and comparable, as service providers are obliged to describe their services in conformity (e.g. according to the eClass[3] standard). Monitored data includes non-functional quality parameters of services (e.g. availability, successability), the interactions between services per value net, functional and non-functional preference clusters of consumers and the financial relevance of each individual cluster (i.e., financial value of the totality of all transactions made by a specific consumer cluster during a given period of time). To provide the service provider with preprocessed information of commercial value, we introduce a component for extended analysis that filters and enhances the actual value Y into the 'interpreted actual value' (or 'interpreted feedback') Y°. Set value G describes the strategic goals of a platform provider. The offset of set value and interpreted actual value (G – Y°) describes the optimization effect that is still to be achieved. Once the interpreted actual value has reached the level of the set value, the offset turns zero and feedback abates (G -Y° = 0). The regulator uses the offset to actively influence the ecosystem. To do so, the offset is transformed into a 'control value' U, dedicated to steer the service ecosystem in an optimal way towards the set value. The control value can be considered as a vector of signals, interfering with the system at various toeholds. The offset evolves over time, because of a steady change in the external environment, respectively in the consumer preferences. The evolving inputs into the regulator incite rapid re-leveling of the system. Control mechanisms within the regulator are subject of the following chapter.

Figure 5: *Feedback Control System (based on Fischer et al. 2010)*



We use a sample set of Web services (see fig. 6) to illustrate our control concept. All data was retrieved in a study of the following Web sites: Seekda (www.seekda.com),

3 www.eClass.de

StrikeIron (www.strikeiron.com), ServiceObjects (www.serviceobjects.com), QAS (www.qas.com). Five exemplary prices have been added based on comparative data, as they were not publicly available. Those prices are marked with an asterisk. All services are parts of n-tier value nets as they make use of third party data (e.g. the Royal Mail postal address database). Current analysis, however, focuses on tier-1 services. It will be closed with reflections on tier-2 data analysis. Figure 6 lists two candidate pools[4] of substitutive services from the fields of address checking. One group checks emails, the second postal addresses. Having a closer look at the services within each pool, they are not exactly congruent, but deviate from each other. They have been classified in allusion to the eClass standard. Figure 7 describes this sample classification. The classification shows the existing options to check postal or email addresses.

Figure 6: *Existing web-services from the field of address checking*

	Service Name	Features	Provider	Price (USD) per month	Licence	Rating	Availability	URL
1	Validate Email	Address checking; Email Address; Validation; international	webservicex.net	0,00	open	3,5	87,96%	http://www.webservicex.net/ValidateEmail.asmx?WSDL
2	USAddressVerification	Address checking; Postal Address; Verification; USA	webservicex.net	0,00	open	5	87,81%	http://www.webservicex.net/usaddressverification.asmx?wsdl
3	DOTSEmailValidation2	Address checking; Email Address; Validation; international	serviceobjects.com	119,00	closed	5	99,63%	http://ws.serviceobjects.com/ev2/emailvalidation2.asmx?WSDL
4	DOTSValidateCanada	Address checking; Postal Address; Validation; Canada	serviceobjects.com	119,00	closed	no rating	99,63%	http://ws.serviceobjects.com/avca/ValidateCanada.asmx?WSDL
5	QAS Pro Web	Address checking; Postal Address Verification; International	QAS Ltd	98,00*	closed	no rating	98,17%	http://webservices.seekda.com/cache?uri=https%3A%2F%2Fws.ondemand.qas.com%2FProWebIntermediary%2FOnDemandProWebIntermediary.asmx%3FWSDL&type=html
6	Email Verification	Address checking; Email Address; Validation; International	StrikeIron	50,00*	closed	no rating	100,00%	http://webservices.seekda.com/goto?uri=http%3A%2F%2Fws.strikeiron.com%2Femailverify_2_5%3FWSDL
7	UKAddressVerification	Address checking; Postal Address; Validation; Canada	StrikeIron	70,00*	closed	no rating	100,00%	http://ws.strikeiron.com/UKAddressVerification?WSDL
8	Email Verify	Address checking; Email Address; verification; International	StrikeIron	75,00*	closed	no rating	99,63%	http://ws.cdyne.com/emailver...emailvernotestemail.asmx?WSDL
9	Global Address Locator	Address checking; Postal Address; Validation; international	StrikeIron	150,00*	closed	no rating	100,00%	http://ws.strikeiron.com/GlobalAddressLocator?WSDL

4 Blau et al. , 2009: "Service offers that are substitutes – i.e. providing roughly similar functionality – are clustered in candidate pools […]. A candidate pool is a set of potential service offers that are substitutes and can therefore be replaced on-demand."

The services s1, s3, s6 and s8 check email addresses; the services s2, s4, s5 and s7 check postal addresses. Those addresses can be either validated (i.e. the service corrects the address if possible, otherwise it produces an error message) or verified (i.e. the consumer is informed whether the address is correct or wrong). Lastly, some services do international verification; others are limited to one geographical region.

Figure 7: *Classified service description for address checking in allusion to eClass*

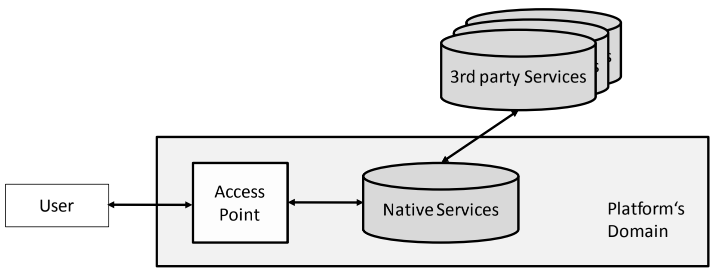
address checking	1	2	3
	Postal Address	Validation (output: correct address or error info)	International
	Email Address	verification (output: message correct / not correct)	USA
	…		UK
			…

Assume a platform operator decides to improve the general availability of its address checking services to 99.6%, for example. The vector element of the set value to be considered is $G_{AddCheck,\ avail.} = \{ S_{Target} \mid Availability \geq 99{,}6\% \}$. S_{Target} describes all elements in the set S, where the requirement $Availability \geq 99{,}6\%$ shall be true at the end of the control process. As the goal is imposed on the whole set S, the value $G_{AddCheck,\ avail.}$ = S with the cardinality #S = 8 (meaning all elements of the set). The initial value $Y°_{AddCheck,\ avail.} = \{ S_{actual} \mid Availability \geq 99{,}6\% \}$ embraces all services, which initially conform to the requirement $Availability \geq 99{,}6\%$, i.e. s3, s4, s6, s7 and s8. The offset $G_{AddCheck,\ avail} - Y°_{AddCheck,\ avail} = \{s1, s2, s5\}$ is inserted into the regulator with the objective to reduce the offset to {}. This takes place in an iterative line-up process.

In a second example, we use clustering and service descriptions: Assume the platform has many customers with an international e-Commerce background. In our scenario, the extended analysis component discovers that the biggest cluster chose "international postal address verification". A hypothetical explanation for this phenomenon (which can of course not be measured) could be that in the case of an erratic entry, the e-Commerce customers are requested to correct their inserted data; hence address validation is not required. As the set value requests to optimize service provision on actual consumption, the following feedback would be suitable: Services s2, s4, should get the feedback that internationalizing their services would enhance the opportunity to enter the e-Commerce cluster with scope for increasing pricing. S7 could in addition downsize from validation to verification to increase probability to conform the cluster's preferences. What could be the driving force of a platform provider to tune his service portfolio on important (or strategic) consumption clusters? Increasing the amount of substitutable services in highly demanded segments leads to a higher variety of choice and increased competition. This, in sequence, leads according to Schumpeter (1926) to improved service quality that is oriented towards consumers' requirements. For this second scenario, the set value is more difficult to grasp. Let us assume the platform's goal of profitable growth (Schumpeter, 1926). In this current case, we use a set value that is not externally given by the platform provider, but by the consumers (through the consumption clusters). We hence set the platform provider's set value{ }. For each individual service $Y°_{si} = \{-\Delta Q_{cluster1}, -\Delta Q_{cluster2}, \dots, -\Delta Q_{cluster\ n}\}$ for all n clusters of financial importance bigger than a defined minimum value. The offset will be $0 - Y°_{si} = \{\Delta Q_{cluster1}, \Delta Q_{cluster2}, \dots, \Delta Q_{cluster\ n}\}$.

A third scenario reflects the platform's goal pursuits. Assume a provider wants to gain share in the European e-Commerce market. Therefore, $G_{EuropVer.} = \{\#S_{EuropVer} \mid AddressChecking; PostalAddress; Verification; Europe\} = 20$. As currently only s5 conforms to this requirement, the offset is 19. The offset needs to initiate a suitable control mechanism to motivate additional providers to supply European postal address verification services. We will further proceed with the following scenario: Assumed the set value expects a minimum availability of 99.60%. Assumed further, tier-1 services are deployed as native services in the platform's domain and invoke tier-2 services, which are off-site (see fig. 8). Then the platform provider can provide hints on possible reasons of underperformance to the tier-1 service providers, which can be solved through system transition (meaning through the replacement of a possible 3rd party provider). In an alternative case where the 3rd party services are also deployed on the platform's domain, the tier-2 providers can be influenced through control mechanisms.

Figure 8: *Native services on the platform's domain invoking external 3rd party services*

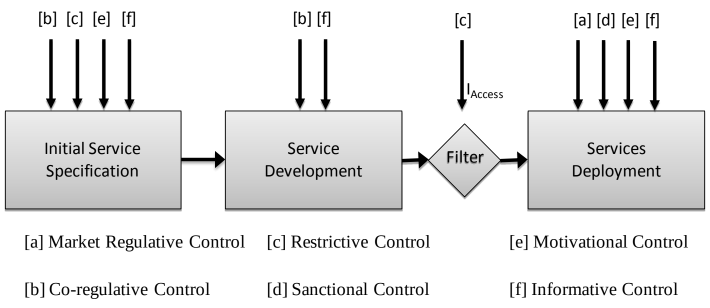


Limitations to this approach are that preference patterns can only be approximated to a certain granularity, but never captured in their entirety. This is actually similar to any other control process, especially those that follow non-linear patterns. The regulative process has been characterized with its decentralized control and respectively decentralized decision-making process. Available control mechanisms for the platform provider will be introduced in the next section.

4 Control Mechanisms

The regulator depicted in fig. 5 has to steer the service ecosystem respectively its services towards goal congruence with respect to service quality and service portfolio. To do so, it is equipped with a toolset of six control mechanisms for Service Life-cycle Management (SLM) in ecosystems. They have been formulated as a result of explorative studies on successful platforms (Scholten et al., 2009; Scholten et al., 2010; Scholten & Scholten, 2010). Figure 9 illustrates where the mechanisms leverage the services. The three toeholds of service leverage are the initial specification phase, the service development phase and the deployment phase. The first mechanism, market regulative control (a) describes consumer-based service verification and auditing; it finds broad application in service platforms through reputation systems and triggers self-optimization of the ecosystem through publicly displaying (perceived) service quality. Co-regulative control (b) comprises guiding principles of service development, providing development rules or tools for coherent service supply and observability of quality parameters. Conjointly with restrictive control (c), platform access regulations depicted as a filter in fig. 9) and sanctional control (d), coercive action up the exclusion of services or service providers), it creates a sequence of regulative and subsequent enforcement mechanisms. Also market regulative control is sequenced with the described enforcement mechanisms, e.g. in cases where quality ratings do not meet the platform's quality standards. These mechanisms can be classified in the group of service quality management tools. The remaining two mechanisms, motivational control (e) and informative control (f) indirectly steer the ecosystem. Whereas information control leverages service quality and service portfolio, motivational control focuses on the service portfolio. Market regulative control (a), which was mentioned earlier, also belongs to the group of indirect steering mechanisms.

Figure 9: *The regulator's control mechanisms and their toeholds*



4.1 Direct Control: Co-regulative Control

Through the provision of development rules and tools, coherent and observable service quality is ensured throughout the whole life-cycle of a service. In all of the successful platforms analyzed (e.g. Facebook, Salesforce, Netsuite), service providers are required to develop products with proprietary tools, interfaces and/or according to development guidelines that allow the platform operator to observe the service's function and performance in detail. In all stated cases, it also includes the mandatory hosting of tier-1 services on the platform provider's own infrastructure. This enables the platform provider to guarantee the transactional qualities like availability, sufficient replication or computing performance as it is in their own scope of influence. It further simplifies the monitoring of services.

Co-regulative control is to be understood as a set of rules, which have to be fulfilled. Starting from Junghans & Agarwal (2010a; 2010b), we consider a service as a finite set of property types $\Pi = \{P_1, P_2, \ldots, P_n\}$. Rules and regulations consider only a defined subset $\Pi_{CO} \subseteq \Pi$ with a permitted set of values V_{coi} per property type P_i. Property types that are not actively addressed by the platform provider are in consequence not regulated or restricted. An example for a rule could be that the property type 'availability' has a restricted permitted value set ranging from 99.6% to 100%. Service availability of 98% would hence not be compliant to the rules and regulations.

As Co-regulative control is purely informative, it needs to be sequenced with an enforcing mechanism. After the upload process, new services are automatically screened w.r.t. rules compliance by the restrictive control mechanism (see fig. 10). If for a service S, all value sets of the property types Π_{CO} fulfill $\{V_{P1}, V_{P2}, \ldots, V_{Pn}\} \subseteq \{V_{co1}, V_{co2}, \ldots, V_{con}\}$, the service will be deployed. If not, the service is rejected, along with feedback to the respective service provider.

4.2 Direct Control: Restrictive Control

Restrictive control is applied pro-actively prior to the deployment of a new service or an update. Most of the platform operators regulate platform access in accordance with rules set in co-regulative control (see section 4.1). This way, initial coherence with the platform provider's goals is ensured. In our research, we experienced (semi-) automated entrance assessment methods for all leading platforms. Therein, each service provider has to run through automated link-in procedures and is only published on the platform, once the assessment has been successfully accomplished. In general, basic quality and interoperability-features, but also conformity to rules and policies are verified. We can formalize the composite control mechanism of co-regulative control and restrictive control as a proportional element, specific for each service and its individual set of values V_{PSI}.

$$u_{si}(t) = k_{restr} = \begin{cases} 1 \mid V_{P_{SI}} \subseteq V_{CO} \\ 0 \mid V_{P_{SI}} \not\subset V_{CO} \end{cases} \quad (2)$$

As we work with a direct control element here, there is no ecosystem specific response function of the system. In other words: h(t) = 1. This leads to

$$y_{Si}(t) = u_{Si}(t) * h(t) = u_{Si}(t) \quad (3)$$

This control sequence is applied per individual service S_i at a given point in time t_i. The service-upload-time T_i is individual, depending on each specific service provider SP_i. Formalizing system behavior of restrictive control on an ecosystem level is therefore not meaningful.

4.3 Direct Control: Sanctional Control

Similarly to restrictive control, sanctional control acts directly on services and their providers. Many platform operators apply sanctional procedures, including the removal of an offering from the platform, if specific rules or guidelines are not met.

In analogy to the control value in the case of restrictive control we can formulate:

$$u_{si}(t) = k_{sanct} = \begin{cases} 1 \mid (V_{P_{SI}} \subseteq V_{CO}\ ) \vee (V_{P_{SI}} \not\subset V_{CO}\ ;\ t_1 \in [t_0\ ,\ t_{end}]) \\ 0 \mid V_{P_{SI}} \not\subset V_{CO}\ ;\ t_1 \geq t_{end} \end{cases} \quad (4)$$

The formula deviates from that of restrictive control in the disjunction '∨'for the case k_{sanct} = 1. To clarify this, we work through the possible outputs now: As long as the deployment condition $V_{P_{SI}} \subseteq V_{CO}$ is fulfilled, k_{sanct} = 1. Any change is triggered by the event: $V_{P_{SI}} \not\subset V_{CO}$. Once the event occurs, an escalation routine starts. During the time period $[t_0\ ,\ t_{end}]$, the service will remain deployed. If at the end of the escalation routine (t_{end} = t_0 + T), the deployment condition is still not fulfilled, the service will be undeployed, hence k_{sanct} will turn zero. The escalation routine is formulated in a way that a service will be already undeployed in the beginning of the escalation routine. This may be meaningful in safety or security relevant applications, where a proactive undeployment is preferred to potential damage or casualty. Examples are payment transaction services or services controlling a production unit, for instance a gas turbine. In such a case, we would reformulate $u_{si}(t)$ as:

$$u_{si}(t) = k_{sanct} = \begin{cases} 1 \mid V_{P_{SI}} \subseteq V_{CO} \\ 0 \mid V_{P_{SI}} \not\subset V_{CO} \end{cases} \quad (5)$$

4.4 Indirect Control Mechanisms: Informative Control

Informative control counteracts information asymmetry. Each service provider is supplied with information on consumption clusters (gained through automated consumption cluster analysis) such as clusters' economic relevance or the service provider's (non-)involvement in services compositions (retrieved through structural analysis). Based on consumption cluster analysis, automated feedback provides guidance on which of the functional and non-functional parameters a service needs to be improved to better compete in a successful service value net. The advantage of informative control from an economic point of view stems from its resource neutrality to the platform provider. The handling of consumer data and the respective feedback to service providers is very low in costs, while the growth of those proportional costs with growing amounts of consumers and providers is limited. The approach promises improved service quality and better aptness of the overall service portfolio on the consumers' preferences. From an epistemic system-theoretic view, supplying feedback in a customized way to each service provider promises to accelerate the emergent self-organizing process, as all service providers get a clear picture on consumer preferences and potential steps towards profit maximization. The platform and its service portfolio can thus rapidly adjust to new market conditions. Ruling out the option of manipulation through feedback of biased, filtered or incorrect information, this approach however does not allow for steering the service ecosystem towards strategic goal congruence w.r.t. platform providers' service portfolios. In other words, guiding the ecosystem towards a currently non-existing, but targeted consumption segment does not adhere to much incentive to the service providers, unless he is differently motivated (see 4.5).

With the objective to verify the findings in a field experiment, let us now grasp reactivity on information feedback through an epistemic approach. First, each set of information, e.g. consumption of address checking services, is only of interest for a subset of all service providers, i.e. service providers that offer services falling into a candidate pool $\hat{S}_{CP} \subseteq S$. As an example, we have another look at the taxonomy presented in fig. 7. Let us assume that $\hat{S}_{CP}$ is a candidate pool of services, offering postal address verification for at least one, but not all European counties. The platform provider transmits the information of an insufficiently serviced consumption segment of a total size of 100.000 € revenue per month, requesting address verification on a European level. We can state that the number of service providers reacting on this information will be smaller than the total group of service providers addressed, hence $\#\hat{S}_{CP\text{-react}} \leq \#\hat{S}_{CP}$. Also, service providers will react with a minimum reaction time that is not shorter than T_T, describing the time required by the fastest service provider to supply an upgraded service. In the cases of direct control (see 4.2 and 4.3) the service ecosystem had no degrees of freedom. Therefore the system response curve was $h(t) = 1$. In the current case however, indirect control is applied. This implies that the control value $u(t)$ only incites a reaction onto the autonomous ecosystem. The response function $h(t)$ is time dependent. It also depends on system-immanent parameters that we will discuss later in this section. The actual value y(t) can be read as the response on the control value u(t), accomplished through the response function h(t) with y(t) = u(t) * h(t).

What makes u(t) efficient? We defined that informative control leverages selected feedback to service providers within candidate pools. The better the selection, the better is the amplification on the system's response curve. We hence design the informative regulator as a proportional element k_{th} that reflects the magnitude of a specific consumption cluster. Informative control should only report on consumption clusters of a certain threshold, e.g. a cluster of address verification service consumption with more than 50.000 € revenue per month. The control value u(t) will only be addressed to those service providers that are part of the candidate pool.

Moreover, there is a second significant deviation from the direct control approach in sections 4.2 and 4.3. In the current case, at a given point in time t_i, we stimulate a whole set of service providers, i.e. those that offer services that fall into a candidate pool $\hat{S}_{CP}$. Therefore, in the case of informative control, we formalize the ecosystem's response on a macroscopic level. Third, once a critical mass of service providers has reacted, the motivation to react on a specific information abates, as the expected benefits are perceived to be creamed off already. This leads to an attenuation of the initial growth of the response.

Based on the reflections above, we approximate the system behavior to a first order delay element, lagged by a dead time element, describing the minimum reaction time T_T. This first order delay element takes effect at the candidate pool CP and is described by the response function:

$$h_{CP}(t) = K * (1 - e^{-\frac{t}{T}}) \quad (6)$$

where K is the amplification and T is the time where h(t) reaches 63% of K.

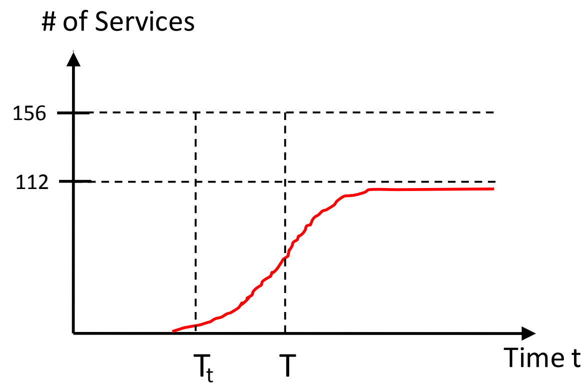
Adding the delay $h_T(t) = h(t-T_t)$ leads to:

$$h_T(t) = K * (1 - e^{-\frac{t-T_t}{T-T_t}}) \text{ for } t > T_t \quad (7)$$

With $K = \#\hat{S}_{CP\text{-react}} / \#\hat{S}_{CP}$ we can derive:

$$h_T(t) = \frac{\#\hat{S}_{CP-react}}{\#\hat{S}_{CP}} * (1 - e^{-\frac{t-T_t}{T-T_t}}). \quad (8)$$

Figure 11: *The response behavior on informative control, $u(t) = 1$, time period smaller T_{iv}*



By the example in fig. 11, we see that 112 out of 156 services are updated after a time delay $T_t + 3(T-T_t)$. In control literature, this point characterizes the 'response rate' as $h_T(T_t+3(T-T_t)) = K^*(1 - e^{-3}) \approx 95\%^*K$. The amplification K can be read as relative attractiveness of feedback information. The system behavior described in fig. 11 starts at the time $t = 0$ and ends before the T_{iv}, where the validity of the information abates. Information can be read as a special form of incentive, leading to specific behavior of service providers in the ecosystem. The system's reaction after T_{iv} will be similar to a response behavior in cases where motivational incentives are diminished. Further discussions on this subject are made in section 4.6.

What will be the benefit of these formulas? Knowing by approximation relevant factors of a platform's specific ecosystem like T_t, T, and an average of $\#\hat{S}_{CP\text{-non react}}$ will help the platform provider to better control the system, e.g. if reaction by the ecosystem is strategically required within a time period shorter than $T_{t\,+}$ T. The platform provider needs to complement this control approach with a mechanism that accelerates intrinsically motivated optimization (see 4.6). Although T_t and T depend on factors such as availability of resources, we assume that, when considering the whole candidate pool with a sufficiently high number of providers, macroscopic reaction patterns will be comparable for similarly complex services.

Informative control by itself cannot be considered as a closed loop control process yet. It incites a system response, building on the emergent and self-organizing behavior of the ecosystem. The system (i.e. the service providers) reacts in function of the information's relative attractiveness, but informative control does not steer the system towards a target value through a process of continuous comparison of actual and set value (as described in fig. 5). For that informative control needs to be placed into a feedback loop with other indirect mechanisms such as motivational control.

We conclude our formalization of informative control by briefly reflecting the limitations of the epistemically derived framework: When ramping up the system, the standard deviation from the real values (e.g., T or T_t) will be high. Also, we expect various T_t, depending on the services complexity. Furthermore, variables will vary within subsets of candidate pools. We assume, like in typical controlled systems, that these values will evolve and optimize over time. In a controlled system, this is called the parameterization process.

4.5 Indirect Control: Market Regulative Control

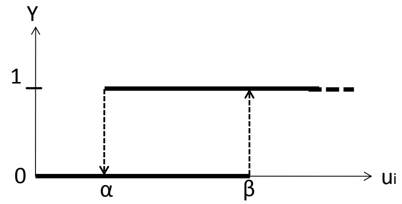
Market regulative control resembles informative control through self-organization of the service providers. The main differences lie in consumer-based gathering of information (e.g., reputation systems) and the visibility of the results to other consumers. Through publishing consumer-based service verification and auditing, aspects of a service providers' performance are made publicly visible. This provides 'an incentive for good behavior and therefore tends to have a positive effect on market quality' (Audun et al., 2007). Many platform operators apply reputation systems. In these systems, aggregated ratings about a given entity are used to derive a trust or reputation score. The response function resembles to one of the informative control. The strength of the control value could be enhanced by providing information on the respective consumption cluster's relevance. However, this will evoke counter-effects: If only a small consumption cluster consumes a certain service type, the feedback will be of negligible relevance for service providers.

4.6 Indirect Control: Motivational Control

Motivational Control can be accomplished though development support, community building, subsidized access to the service ecosystem, open license models for specific code, but also through monetary motivation such as seed funding. Facebook or the Apple App Store for instance co-finance best performers in specific segments in a spotlighted way and with the intention of attracting a spate of followers towards underdeveloped subject areas. With regard to the 'increase in order' (Holvoet & de Wolf, 2005), we assume a non-linear reactivity of the ecosystem on motivational control. Being an indirectly controlled system, we expect the same response behavior as is the case of informative control and market regulative control. However, the key questions differs: how strong must the stimulus given by u(t) be to achieve the desired effect? From a platform provider's perspective, the goal is to apply the minimal required input to achieve the desired effect. We will now focus our interest on this stimulus–reaction behavior of systems.

To explain this effect, we start with one service provider SP_1 and one service S_1. Based on Schumpeter's (1926) postulate on the entrepreneurial goal of profitable growth, we assume that incited with a specific stimulus u = β (threshold value), the service provider SP_1 will deploy a desired service S_1. The quantity Y of deployed services in the system rises to 1. If the stimulus further sustains or increases, S_1 will remain active. However, assuming certain maintenance and deployment costs α, the service provider will only keep the service deployed as long as the lower threshold α is not undercut. The resulting behavior is that of a non-ideal relay, also called thermostat non-linearity (Krasnosel'skii & Pokrovskii, 1989) (see fig. 12).

Figure 12: *Non-ideal relay of a service provider's response on stimulus (x = level of stimulus, y = number of respective services deployed)*



The service provider's behavior thus be formulated through the Preisach model:

$$y(t) = R_{\alpha,\beta}\,(t_0, \eta_0, u(t)),\quad t \geq t_o \tag{9}$$

In this model, $R_{\alpha,\beta}$ is a transducer, taking the values 0 or 1, meaning at any moment, the relay is either switched on or off. The transducer's state depends on the control value u(t) and on the initial state η_0. Alike the transducer, η_0 can either have the value 0 or 1.

According to Preisach's model of non-linearity, the system response y(t) can be described by the following formula:

$$y(t) = R_{\alpha,\beta}\,(t_0, \eta_0, u(t)) = \begin{cases} \eta_0 \mid & (\,a < u(\tau) < \beta) & : \forall\tau \in [t_0, t] \\ 1 \mid & \big((u(t_1) \geq \beta) \wedge (u(\tau) > \alpha)\big) & : t_1 \in [t_0, t] \wedge \forall\tau \in [t_1, t] \\ 0 \mid & \big((u(t_1) \leq \alpha) \wedge (u(\tau) < \beta)\big) & : \forall\tau \in [t_1, t] \end{cases} \tag{10}$$

If we now consider a finite number of service providers in an ecosystem, the constellation can be formalized as a weighted parallel connection of non-ideal relays. The constellation is visualized in fig. 6. Mathematically, it can be described as:

$$y(t) = \sum_{j=1}^{N} \mu_j\, R_j(t_0, \eta_0(j), u(t)) \quad : \quad t \geq t_o \tag{11}$$

with $R_j = R_{\alpha,\beta}$, $1 \leq j \leq N$ *and a weighting of* $\mu_j = \mu(j) > 0$ *for* R_j.

In our consideration, we rule out a potentially prioritization of specific service providers in comparison to others (fig.13). Under this prerequisite, all services can be considered of equal weight μ_j (simplifying assumption). In consequence, formula (11) can be reduced to:

$$y(t) = \sum_{j=1}^{N} R_j(t_0, \eta_0(j), u(t)) \quad : \ t \geq t_0 \tag{12}$$

Figure 13: *Parallel connection of a service providers' response on stimulus*

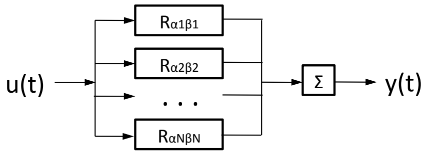
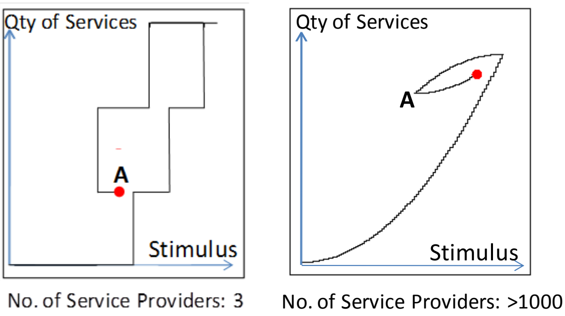


Fig. 14 shows possible reaction patterns of platform-based ecosystems. In the case of three service providers, the form of a non-ideal relay from fig. 12 can be still detected. For higher numbers (see fig. 14b), the system response converges towards a hysteresis-like curve. The simulation results based on the Preisach model (Krasnosel'skii & Pokrovskii, 1989) in fig. 14 b) show a response curve of service providers, deploying new services in reaction of the platform's financial stimulus. When a stimulus reaches a critical level (breakthrough-level, e.g. sufficient seed capital for specific service ideas paired with accentuated visibility), the ecosystem will react and emerge towards a new level of order. Being a non-linear process, the new level of order will sustain or only slowly decrease, even though the stimulus is reduced, until a second critical level (break-down level) is reached. If the consumers adopt the new services, the fading stimulus of capital injection will be replaced by a second stimulus. This effect can be observed at point 'A', where the decreasing stimulus of capital injection is super-imposed by capital reflux from the consumers, purchasing the new services.

Figure 14: *Hysteresis-like system response of services offered on stimulus; the initial stimulus is capital injection, at point 'A' super-imposed by service consumption.*



5 Implementation and State of Research

We designed and implemented a feedback control platform that allows running tests on important aspects of our conceptual architecture. The implementation of the feedback control platform is based on service-oriented computing (SOC), thus can be integrated into existing SOC-based platforms (for technical details see Fischer et al., 2010). So far, we accomplished the monitoring functionality during service execution (runtime) to collect the data basis needed for successive structural and preference analysis. Our initial results indicate that the generation of structural feedback w.r.t. value net composition and to preference behavior is possible in an automated way. However, further efforts will be required to improve the applicability of the solution as well as the quality of data. We also developed and successfully-tested clustering algorithms to weight groups of similar consumption patterns among service consumers. This is necessary to optimize the platform ecosystem in function of (evolving) market demand. We therefore reviewed clustering algorithms that handle various scales of measure (e.g., security aspects are scaled at the ordinal scale while response time is at the ratio level) to generate clusters of similar service consumption. As a major next step, we will concentrate on tying these results into the above described architecture to complement feedback information with data required by – for instance – informative control.

All control mechanisms have been integrated into SAP Research's e-market 'Agora'[5], however still with a low level of automation. Within Agora, restrictive and sanctional control are implemented in multiple ways: General access to the marketplace requires authentication. Thus providing user accounts is regulated by Agora as the intermediary. Providers can enter, modify, or undeploy services as they wish. However, changes are performed in a staging area and versioned, and thus the intermediary has full control on changes of the service portfolio including the removal of service offers. Market regulative control is accomplished through a reputation system, allowing the consumer to score the offered service. Informative and motivational control are made possible, but are still fully manually accomplished. To allow for scalability, the degree of automation, as suggested in the conceptual architecture will now require to be implemented. Furthermore, the consumption cluster analysis needs to be incorporated.

The formalizations given in sections 4.4 - 4.7 have been derived in an epistemic way on the grounds of information gained in the described market analyses. In order to gain further understanding on parameterization w.r.t. sections 4.4 and 4.6, the team is currently launching a field research initiative, as well as a parallel simulation.

[5] Available at http://marketplace.sap.com/

6 Conclusion

This paper extends state of the art w.r.t. control mechanisms applied to manage service quality and portfolio in platform-based ecosystems. Its focus is placed on direct and indirect mechanisms embedded within feedback-controlled systems. The paper explained the various toeholds to leverage control and explicated possible sequences for control mechanisms. Thus, allowing optimization and building on the ecosystem's own emergent characteristics, monitored as system response to information and incentive. Informative and motivational control mechanisms act on a macro level influencing a whole system or subsystem towards a specific target. Market regulative control, sanctional and restrictive control in conjunction with co-regulative control act on a micro level allowing to directly influence specific services.

The ecosystem's non-linear system response on inputs from the platform provider can be approximated with a first order delay element together with the Preisach hysteresis model. Knowing that, platform providers can better respond to ecosystem-behavior and are put in a position to proactively apply a suitable control mechanism.

In a next step the ongoing field study and simulation are expected to provide valuable data w.r.t. optimization of such controlled systems. As a prerequisite to serve the information needs of feedback control mechanisms for platform ecosystems, we will furthermore research software architectures, service choreography protocols and related data mining algorithms to monitor distributed value generation in service ecosystems.

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