Survival of the Fittest – Utilization of Natural Selection Mechanisms for Improving PLE

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ABSTRACT
In the current ongoing work we propose the use of tracking and feedback mechanisms in order to improve our Personal Learning Environment (PLE), officially launched in October 2010. The approach can be seen as a necessary prerequisite similar to the darwinistic model of evolution. This means the implemented widgets will be improved (variation) and removed (selection) according to the observations. This paper will describe the backgrounds, methods and some details of the technical implementation.

Categories and Subject Descriptors
H.5.2 (D.2.2, H.1.2) **[User Interfaces],** D.2.4 [**Software/Program Verification**].

General Terms
Measurement, Design, Experimentation.

Keywords
PLE, Widget, User Experience, HCI.

1. INTRODUCTION
Variation and selection are important mechanisms in the evolutionary development of organismal life forms. These mechanisms were extensively examined and described by Charles Darwin in his famous book on the topic [6]. He argues that there is an advantage in the probability to survive for these individuals and populations which are able to adapt better to their environment. This is described as fitness or 'Survival of the fittest'. Darwin's theory was later used as base for the so called evolutionary algorithms (EA), which represent a certain class of optimization algorithms, able to solve nonlinear, discontinuous and even multimodal problems. Evolution itself is a very efficient optimization process, which is able to adapt even pretty complex organisms to a changing environment in a very short time.
Ernst Mayr, who developed the synthetic theory of evolution, states that the natural selection is rather a selection process but an elimination process. Thereby less adapted individuals of every generation are terminated, while better adapted ones will have a higher probability to survive [7].
The interesting question is how evolution theory can help us in the development of a Personal Learning Environment (PLE). First of all the concept of PLE is still a new and vaguely explored concept. From an evolutionary point of view it could be considered as a new species conquering a still undetermined territory in an eLearning environment. There is no guarantee of success resp. survival of the species. More technical it could be considered as optimization process with undefined specifications how to solve the problem of helping the learner to overcome the challenge of managing distributed and potentially unknown but useful Web resources and Web applications.

The biological evolution would approach this problem by choosing the r-strategy, which succeeds by a high (r)eproduction rate. This strategy can usually be found when a species conquers new space. In case of the PLE we need two different views on the evolution metaphor, in order to fully apply this strategy. The first view is **macro evolutional**, concerning the development of PLEs as a 'species'. The question here is about finding the most appropriate form, which includes the programming language, deployment, user interface metaphors and value within eLearning environments (e.g. is it just a link list in an iPhone app or a full grown web desktop). Therefore a long-time 'survival' of the concept PLE would imply the development of many different individual solutions in a short period time. The second view to adopt is the **micro evolutional** view. In this view the functional elements of a single PLE solution are considered be individuals, struggling to 'survive' within the PLE. This view solves the question of adaptation to the user's needs on a functional level. Which resources are really needed, which functions are necessary, which are rarely used and which are never used?

A first prototype of a Personal Learning Environment (PLE) has been developed and launched in October 2010 at Graz University of Technology (TU Graz) [1]. Following the main PLE concept it aims to provide different learning and teaching resources, which can be personalized by each learner. Learners can decide if they like to use an application or not and build their own individual learning environment. This paper will outline our current research and development of a PLE.

2. Theoretical foundations

2.1 Evolutional considerations applied

In order to apply evolutional thinking, it will be necessary to establish the metaphorical links to the development of the PLE. The links will be mostly done on afore mentioned micro evolutional level, as this is more important to the specific development, however they can be adapted to the macro evolutional view easily. Evolution theory of natural selection uses the following relevant factors: reproduction rate and mortality (cycle for update, replacement and new widgets), population size (# of widgets), environmental capacity (max. # of widgets in the system and # of users using the widget).

In order to produce an evolutional pressure upon a population of individuals, it is necessary to have a limited resource. In our case there are actually two such resources driving the selection: a) the limited space within the PLE UI and b) the limited number of potential users. The first factor can also be described as growth regulated and limited by **population density**, which is depicted in fig.1. A population can't grow unlimited, as there are limited resources. The environment has a capacity, which is in our PLE case represented by the maximum number of widgets.

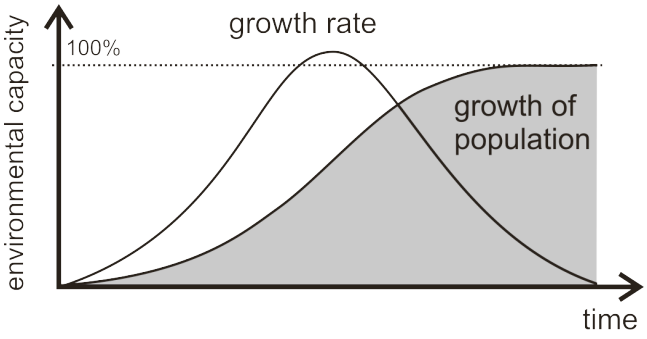

Figure 1. Growth regulation by population density

The second factor b) can be operationalized as selection criteria by asking the questions: 'Which widget draws the attention of the most users?' and 'Which widget has the biggest frequency of usage?' [8].

2.2 Selection

So the individuals of a population are forced into a constant competition for a certain resource against each other and against potential harmful conditions of the environment, producing variations for better adaptation. The different probabilities for survival are the base of the selection mechanism. Indeed selection is the main controller for the search direction within the evolutional optimization process. In biological systems it would determine which phenotypes reproduce at a higher rate. Phenotype describes the amount of all observable characteristics of an individual, expressed by its genes and influence from its environment at a certain point of time. The natural selection is a non-deterministic process, as it's disturbed and interrupted by random events. Individuals can die, thereby the evolution loses information which could have represented an optimum solution (e.g. the Wikipedia widget is dismissed because the company offering the service wasn't able to raise enough funds). Environment and other contextual conditions are ever changing. According to Solbrig [9][10] there are three different modes of selection 1) stabilizing selection 2) disruptive selection and 3) directed selection. All these selection modes and evolutionary pressures aim at increasing the fitness of a population.

1) The stabilizing selection mode (as can be seen in fig.2) describes that the evolutionary pressure of the environmental factors is directed at outliers, thus this mode favorites the average, which will result in a decrease of variability within the population.

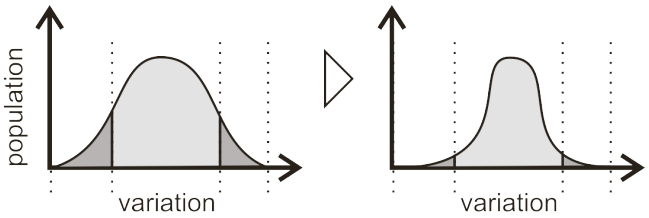

Figure 2. Stabilizing selection on the distribution of population

Stabilizing selection on micro evolutional level can be done by analyzing which functions, respectively widgets in the system are hardly or never used. On a macro evolutional level it would mean to discontinue 'excotic' PLE solutions.

2) The disruptive selection mode (as can be seen in fig.3) is directed against the average, reinforcing the extremes, thus splitting a population into two new species. Since our population (on micro evolutional level) is the quantity of widgets, the development path would split and result in two new different solutions for a PLE. On the macro evolutional level this would mean to dismiss the core idea of a PLE, while generating new concepts.

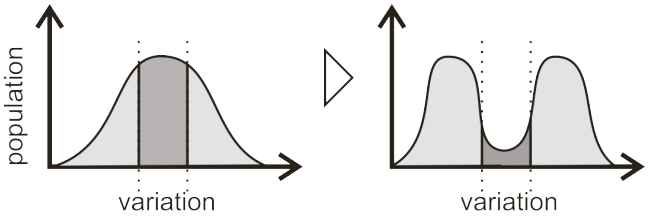

Figure 3. Disruptive selection on the distribution of population

3) The directed selection mode (as can be seen in fig.4) can be found in natural populations quite often. Thereby the selection works only against individuals on one side of the distribution, moving the curve to a new optimum. This mode can also be found when the PLE developers define new functions and user requirements, resp. conceptual decisions (e.g. we will only support intranet applications).

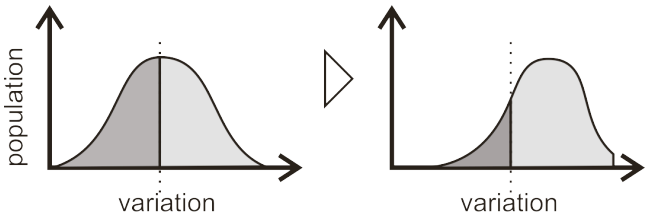

Figure 4. Directed selection on the distribution of population

2.3 r/K selection theory

The terminology of r/K-selection was defined by the ecologists Robert MacArthur and E. O. Wilson [11][12]. The r/K selection theory states that in the evolution of ecology two major strategic approaches for reproduction can be found, aiming to increase the fitness of a species. The strategies are basically a tradeoff between **quality and quantity of the offspring**.
Thereby increased quality come with a corresponding increase in parental nurture, while a focus on quantity would decrease the amount of parental investment. Each of the strategies is designed for specific environmental constraints. It is also possible that a species changes the strategy due to a change in the environment (e.g. the ecosystem becoming stable for period of time). However in nature many different mixed forms of these strategies can be found. In long terms the k-strategy will always be superior, which means that quality succeeds in the long run over quantity.

The r-selection strategy (also referred to as r-strategy) succeeds in unpredictable, unstable environments. It is especially useful when it comes to conquer a new unknown ecosystem. It would be a waste of energy and time to adapt to circumstances which are still unknown and will most likely change again. Therefore the r-strategy is characterized by a high reproduction rate and short lifespan (see fig.5). Transporting this to the PLE would mean to provide a mass of functions (in our case widgets) without looking for quality in the first instance.

The K-selection strategy (also referred to a K-strategy) succeeds in stable, predictable environments and describes a growth which is ruled by population density, usually constant and close to the maximum capacity of the environment. The adaption process is slower but the lifespan is longer and it fills more effective the environmental niche. In case of a PLE the application of this strategy could mean the increase of quality of a single widget, due to several update cycles, thus adapting optimal to the user's needs.

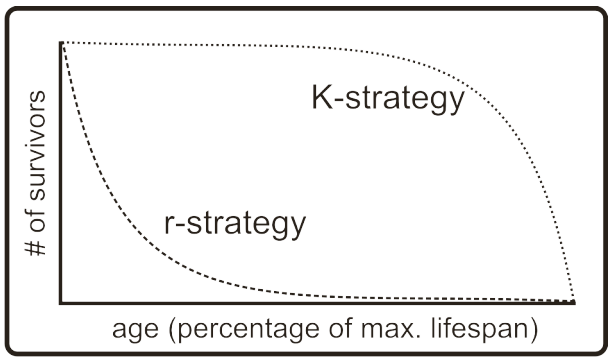

Figure 5. Depicting the relation between fitness and age for r/k

In the example of our PLE we also use a mixed approach. With the beta 'generation' of the PLE a bunch of widgets was provided. These widgets were then tested for usability issues, corrected and deployed in the first generation. Last semester a class of students programmed additional widgets in order to produce a certain quantity of functions for the users. So the first and the second generation can be seen as mostly r-strategic. The update process will be repeated on an annual basis. Most of the students last semester chose to produce new widgets, while some reused and optimized existing code (which in turn can be considered K-strategic).

2.4 Variation

The term variation in the evolutional context is usually described as shift in the genotype or genomic sequence. These shifts occur through a) mutation and b) recombination and generate new phenotypes with different probabilities for survival.

a) Mutation is a random process, aiming only at the generation of new alternatives. Mutation can result in different types of change in DNA sequences. It can have either no effect, altering the product of a gene, or prevent the gene from functioning properly or completely [13]. According to the optimization theory, mutation would be considered as a mechanism to overcome local optima. Which means the evolution doesn't stop if everything seems to be nicely adapted. There is still potential to explore new variants. In case of PLE development mutation can be considered as slight updates of existing code or UI elements.

b) Recombination
Recombination is also referred to as cross-over. The process is working somewhere between mutation and selection, thereby combining and distributing genetic material (DNA, RNA) in a new way. There's a random process determining the points where crossovers occur, however recombination is not a random process like mutation, as the recombination itself is not random. This means that the probability is low to separate genes that are close together or functional linked.

The code to all widgets in our PLE is open source and so far all widgets are open for variations by future developers. An open source policy and continuous development, resp. variation are a necessity for the 'species' PLE to finally succeed.

2.5 Technical Implementation

The basic architecture of the PLE is a mashup [4] of widgets. For each service a widget is provided that follows an extension of the W3C widget specifications [5]. The PLE, its requirements and its technological concept are described in detail in MUPPLE09 workshop [3]. Fig. 6 shows the general concept of the PLE as it is used at Graz University of Technology. The concept follows the idea to bring together university wide services with applications on the World Wide Web.

The implemented first prototype of PLE offers centralized access to various University services [1], like administration system: TUGraz online, LMS: TU Graz TeachCenter (TUGTC) or blogospheres: TU Graz LearnLand (TUGLL) [14] in one overview. The users can personalize the PLE to their individual information and learning needs. In addition, public services on

WWW are also offered in the PLE. For each of these services, a widget has been developed that can be integrated into the PLE.

Widgets are small embeddable applications that can be included in an HTML-based web page or executed on the desktop. This client side code can be a simple JavaScript, Java-applets or what ever can be embedded in a valid HTML or XHTML document. It contains the functionality to build the GUI of the widget dynamically and the logic to retrieve or update data from services provided by the PLE server as well as remote servers. The mashup of widgets used in PLE can be classified to end-user mashups as described in [15]. The PLE contains a widget engine, implemented in Palette project [16] to load and handle the widgets according to the W3C widget specifications. While the data extraction is carried out on the server side, the data flow and presentation components are handled by the widget engine on the client side.

Fig.6 shows a conceptual view of the PLE first prototype that integrates university portals and some other Internet services.

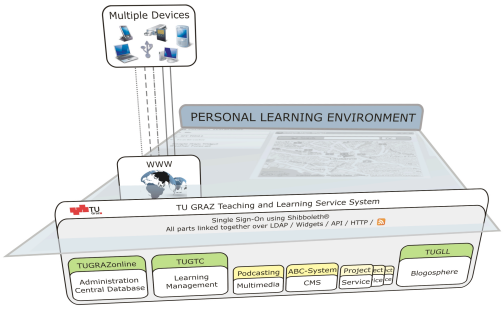

Figure 6. PLE concept at TU Graz. Mashup of distributed applications and resources from the university and the WWW.

2.6 User Interface Structure

There are many e-Learning services that are already provided by the TU Graz, including course administrations in TUGraz online, course learning materials such as e-books, podcasts etc. in TUGTC and user generated contents as well as user contributions such as blogs, bookmarks and files posts in TUGLL.
All these services are going to be integrated in the PLE as widgets. Therefore it was necessary to design a coherent GUI to avoid the possible usability and consistency problems that may occur [3]. The PLE GUI (see fig.7) is a combination of a traditional UI with a sidebar element and banner for orientation and navigation. In addition, it offers a widget-based UI with the so-called ”widget zones”, which require an adjustment by the user.

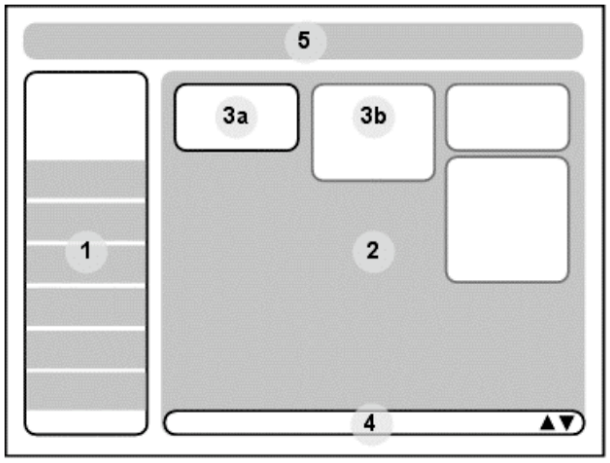

Figure 7. User Interface Structure

The PLE User Interface contains the following elements: 1) Sidebar elements contain widget topics. 2) Widget zone contains the widgets that belong to a widget topic. 3a and 3b) Widgets within the corresponding widget zone. 4) Hidden personal desktop containing a mash-up of widgets from different widget zones selected by the user. 5) Banner displays information in context of the active widget zone from the network.

2.6.1 Sidebar elements

Widgets are categorized according to pre-defined topics. Each widget topic (category) has its own widget zones. The sidebar elements contain the main widget topics and help the user to switch between widget zones. The topics are easily extendible if the number of widgets is increasing. Furthermore, it is planned that the sidebar also updates the user on the status of the widgets by means of color and numerical indicators. The sidebar can be switched off in favor of the unfamiliar widget-based UI and replaced by another navigation element, which resembles the Mac Dock menu on the bottom, left, top or right part of widget zones.

2.6.2 Widget Zone

The widget topics include different areas related to formal and informal learning, i.e. ”Communication Center” for emails, chats and news groups, ”TeachCenter” for all services related to the TU Graz LMS system TUGTC, such as course materials, podcasts etc., ”LearnLand” for services related to the TU Graz blogosphere system TUGLL social bookmarking, file sharing, etc. and ”Help and Support” for the help desk as well as Frequently Asked Questions (FAQ). These areas are called widget zones. Widget zones contain widgets and are structured in columns. The users can switch between widget zones, add, open, close, customize, position and arrange the widgets in different columns according to their personal learning preferences.

2.6.3 Widgets

The widgets consist of a front side and a rear side, where the rear side contains the widget preferences that can be modified by the user. If preferences must be changed, the desired widget can be flipped. By this applied flip-animation the users spatial perception is undisturbed and makes the GUI more understandable. There are two kinds of widgets a) system widgets and b) standard widgets.

2.6.4 Personal Desktop

The users are able to create a mash-up of the most frequently used interesting widgets from different widget zones in a special interface called ”personal desktop”. The personal desktop is always available to the user and can be activated at any time. When the user activates the personal desktop it overlays the whole screen from the bottom of the page upwards (see figure 4.2 part 4). The user can add or remove widgets from all widget zones to his personal desktop and arrange them in columns according to his personal taste.

From the very beginning, an appropriate and good usability of the TU Graz PLE interface was one of the main objectives in the development process. Therefore during the implementation of the first prototype several usability tests were conducted, including heuristic evaluation and thinking aloud tests. The results were integrated and deployed in the current version.

3. Hypothesis

Tracking user behavior, respectively the usage of individual widgets in combination with a feedback mechanism will provide empirical evidence for adaptive development.

Following an evolutional model of developing the PLE, this will mean a stepwise improvement and rejection of individual widgets in further iterations of the development cycle.

4. Methods and Materials

In order to improve the PLE we needed to consider different parameters that influence the attractiveness and effectiveness of the whole system in general as well as individual widgets. To meet this goal a tracking module was implemented to measure quantitatively how often the widgets are used and by how many users. The measurement was operationalized by the means of tracking individual and overall usage of widgets. In order to measure the usage of widgets a hidden module in the background tracked the users' active widgets.

The widgets that are used in PLE can be classified to three categories depending on how they interact with other services and applications on World Wide Web (WWW).

- Widgets that have no interactions with WWW such as widgets representing learning objects.
- Widgets that have a server side component to preprocess the data on PLE server such as widgets that integrate university services in PLE.
- Widgets that use the PLE built-in proxy to request data from remote services such as RSS FEED reader widget.

The client-side tracking module is added to the PLE widget engine to provide widgets including the possibility to offer information about user behavior on the client side. In periodic intervals the information (if any) is captured from all activated widgets in PLE and sent to the server-side tracking module for further processing. The server-side tracking module is used also for second and third widget types to capture information related to the user behavior in widgets depending on the data traffic on the server side.

At the current state of the PLE development there are 912 users in the system, whereof almost 30% can be said to use the PLE. In the last semester a group of students developed new widgets, in order to provide additional functionality as well as improving widgets from the previous beta stage. The system was introduced to the students in October 2010. The Tracking module was active since 1st of November 2010. At the current date this is 102 days.

5. Discussion

First the acquired data seem not sufficient to draw any clean conclusions for improvement. As the feedback module wasn’t implemented yet, there is no chance of getting qualitative feedback, without performing another usability test. The analyzed data are purely quantitative. Nevertheless from the number of users, who have installed a certain widget, we are able to determine to top 5 used widgets out of the 30 provided. Actually theses top 5 are about the universities eLearning services, a mail widget and a system widget for changing the color styles of the interface (tugWidget, tccourses, tugllBlogs, mail, changeThemecolor). Within the top10 we find further a newsgroup reader, a game, google maps, facebook and the leo dictionary. From an educational point of view these choices make perfectly sense as these services are well known and frequently used even without the PLE.

Interestingly the most installed widgets are not necessarily the most used ones. The top 5 with the highest usage rate include weather forecast, rss reader, twitter, TUG library widget and again the leo dictionary. Within the top 10 we find here again google maps, Facebook and tugllBlogs, beside another dictionary and a currency converter.

Within the last update cycle, resp. the time when the students course developed new widgets, the weather widget was replaced by a new version. Actually this can be seen our current update strategy. If the outcome of the variation is a widget that fulfills a function better, then the old one will be replaced.

6. Conclusion and future works

According to the hypothesis we expected to get more knowledge about user behavior, user preferences and derive data, which would help us to differentiate user behaviors, for instance between students of first and last semesters or students of different major of studies, and finally to improve the system in a natural way by variation and selection. However due to lacking qualitative data we are not able to falsify the hypothesis.

In order to gather qualitative measures of the user experience (UX) in future versions, a rating system will be implemented. This will be done either by a 5 star rating system or alternatively by a small feedback questionnaire contained in every widget, which consists of less than ten items of semantic differentials inspecting the UX quality of the widget, respectively important variables of evolvability. These would be attractiveness, dependability and perceived effectiveness. The semantic differentials will be taken from the reliable UEQ inventor constructed by [2]. The fig. 2 depicts the questionnaire integrated into the widgets backside.

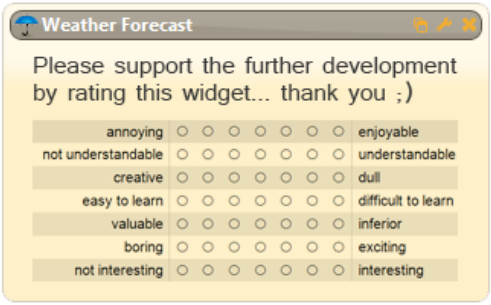

Figure 2. Mockup of questionnaire integrated into the widget GUI for qualitative measures of the user experience.

In our PLE users can select some widgets from a widget pool and activate them for personal use. However if the user activates some widgets it does not necessarily mean that these widgets are actively used. In future versions the tracking module might be able to detect an active widget usage und track the usage in detail as deeply as possible.

In future works it would also be interesting to classify users according to their individual needs, for instance users who use more often only widgets with a strong focus on communication or users who use PLE more for learning issues, etc.

In order to meet data privacy considerations, we will implement a disclaimer, or terms of service (TOS) which needs to be agreed by the users once in order to use the PLE.

The tracking module provides sufficient quantitative data about the usage of the widgets. Bearing in mind that more knowledge about the learner will help in designing didactical models for providing learning courses, data gathering must be seen as a first valuable step. Furthermore these data combined with user profiles will be a precondition for building a recommender system on learning objects within PLE.

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