Chapter

Artificial Intelligence Assisted Innovation

Gideon Samid

Abstract

Artificial Intelligence Assisted Innovation (AIAI) is a technology designed to improve innovation productivity by helping human innovators with all the support tasks that kindle the creative spark, and also with sorting out innovative propositions for their merit. Innovation activity is mushrooming and hence innovative history is an ever growing data accumulation. AIAI identified a universal innovation map, which is processed like the tape in a Turing machine, only here in the Innovation Turing machine, marking an innovation pathway. By mapping innovative history onto these maps, one enables the growing record of innovation history to guide current innovation as to merit, expected cost, estimated duration, etc. Using Monte Carlo and Discriminant Analysis, an Artificial Innovation Assistant runs a dialog with the human innovator with a net effect of accelerated innovation. Users of AIAI are expected to exhibit a commanding lead over innovators guided only by their creativity.

Keywords: innovation, AI, innovation challenge, innovation solution protocol, Monte Carlo

1. Introduction

AI -- artificial intelligence -- per se is human innovation, all its achievements should then be credited to its human creators, therefore, by Gödelian reasoning, in a very deep level, the artificial entity is subservient to the natural entity, however more efficient AI is in countless specific tasks. One would then wish to combine the in-depth human superiority to the avalanche of superficial superiority exhibited by intelligence that is computational and artificial, and speaks in binary and no more.

We propose a framework for natural and artificial intelligence collaboration in pursuit of an innovative (R&D) objective. We envision a human innovator (HI), interacting with a computerized entity: Artificial Innovation Assistant (AIA). The HI (i) poses questions, (ii) submits information to the AIA, and the AIA in return (i) poses questions, (ii) replies to questions. The AIA is comprised of (i) a dialog part (D), a processor part (P), and an environmental part, (E). The dialog part uses modern AI technique to appear as human-like as possible for its human operator, the processor part is running the powerful AI search and discover algorithms, and operates the underlying innovation framework (the Innovation Solution Protocol -- Innovation^{SP}), while the environmental part (E) interacts with (i) innovation partners, (ii) propriety innovation sources, and (iii) public domain sources.

In addition to the AIA running a dialog with the human innovator, HI, it also runs a dialog with the other innovation stakeholders: (i) the financial investors, (ii) the beneficiaries, and with anyone impacted by the project.

This AIA configuration is geared towards a single innovator working alone, or to a team of small or large size. It applies to local, or global effort, to cases of one private investor, or to many socially minded investors, and to any number of beneficiaries or impacted parties.

This chapter first describes the underlying innovation solution protocol, ($Innovation^{SP}$), then depicts the AIA configuration, followed by a description of the various AIA parts, concluded with an outlook and a prospective view of the future of artificial intelligence assisted innovation.

For a good review of established innovation thinking see [1–10].

2. The innovation solution protocol

The Innovation Solution Protocol refers to an innovative challenge for which one has no apparent direct solution. The procedure identifies three possible routes of action:

1. **Divide the challenge to components** -- solve, or generate insight about the components, then return to the original challenge.

2. **Re-define the challenge in a more abstract fashion** -- solve, or generate insight about the abstract version, then revisit the original challenge.

3. **Extend the challenge to a larger one including related challenges** -- solve or generate insight about the extended challenge, then revisit the original challenge.

Whichever road the innovator takes, they end up with one or more new challenges. These new ones may be solved in a direct manner, but if not -- and here comes the iterative aspect -- each of these challenges can be likewise tackled through the same three-way solution procedure. Doing so would create a third generation (now front and center) of challenges, which again can each be treated the way the original challenge was -- applying the three-way solution. See **Figure 1**: B-A-X.

This ongoing procedure would keep generating new challenges, until such time that the new ones can be resolved in a direct manner. And if not completely resolved, then partially resolved. When this happens the attention backtracks to the parent challenge, and if that challenge is resolved (completely or partially) then it would point to its parent challenge, and so on, until the backtracking process would

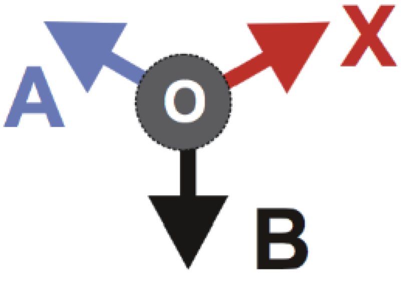

Figure 1.
B-a-x.

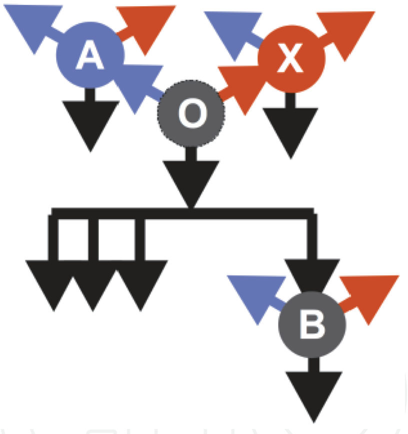

Figure 2.
The innovation solution map.

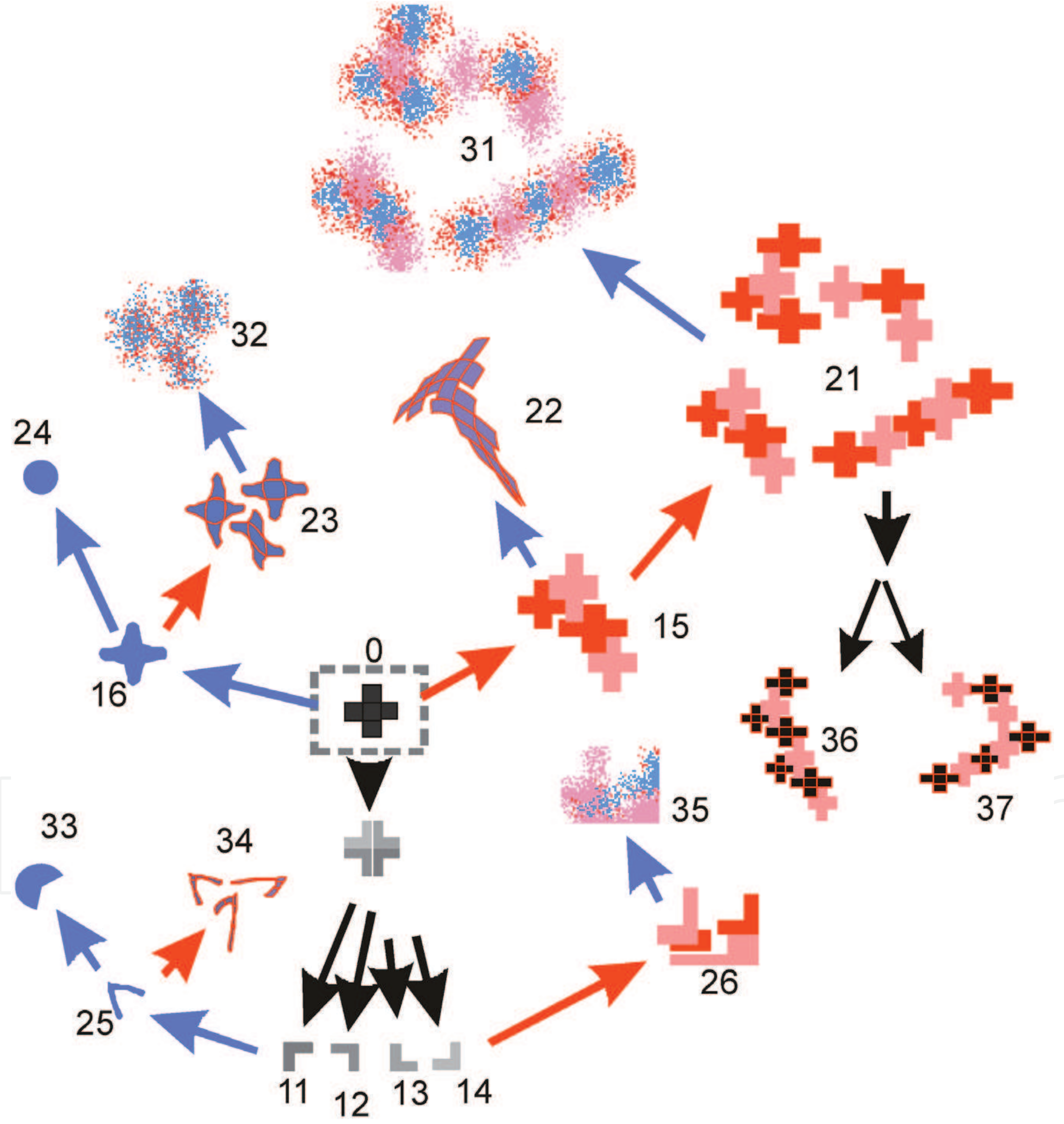

Figure 3.
An evolved ISP map.

refocus on the original challenge. The solution seeker has always something concrete to do. There is always a next step. See **Figure 2**: The Innovation Solution Map.

This procedure is captured as the Innovation Turing Machine (ITM). Its operation moves the innovator's attention from one innovation challenge to the next. It is iterative, open-ended; it spreads further and further until it hits a negotiable innovation challenge. Once this challenge is negotiated (resolved), the innovator's attention shifts back to its parent challenge. Applied repetitively, this "Innovation Machine" ends up with a resolved original challenge. Check out an evolved map in **Figure 3**.

3. The innovation Turing Machine

The innovation process can be described via a generic machine. Its operation is designed to express any innovation sequence. The machine is dubbed The Innovation Turing machine, citing its analogy to the famous Turing Machine that became the generic framework for all computers (up to the emerging quantum computers). The Innovation Turing Machine, ITM, operates on the fundamental innovation object: the innovation challenge, IC. The innovation challenge may be viewed as the gap between two states: a desired state, and an existing state. The states define a technological situation. The fundamental dilemma of innovation is the mystery of that gap, the difficulty to measure it, and to eliminate it. Measuring the gap constitutes a quantitative definition of the effort to close it, where effort is measured in time, cost or any individual or combinations of resources. To resolve, or to solve an IC is to eliminate its gap. The fundamental rhythm of the ITM is a combination of foretracking and backtracking, defined as follows: If an IC is too difficult to resolve, then advance (foretrack) to another, —- hopefully, but not necessarily -- simpler IC, and when it is resolved, backtrack to the former IC, and try again. Repeat and re-apply the sequence of foretracking-backtracking. By re-applying the foretracking-backtracking sequence to each IC that was defined to help out with a former IC, one generates an indefinite sequence of ICs -- an IC track. And since every IC may have more than one simpler IC associated with it, these tracks expand into a tree structure. And, since some of the ICs so defined may be identical, the tree structure transforms into a network, referred to as the ITM-WEB.

According to the ITM model there are only three types of "simpler ICs": those that may be defined as components of the IC, those that may be defined as an abstraction of the IC, and those that may be defined as an extension of the IC. By way of convention, the number of components may be two or more, while all possible extensions are summarized into a single "master extension challenge," and similarly all possible abstractions are summarized into a single "master abstraction challenge". Hence, every innovation challenge gives rise to m + 2 next generation of challenges, where m is the number of components.

One's attention is focused on a single challenge. If that challenge is not the very original one then, following the attempt to resolve it, one's attention moves to another; either to the "next" challenge or to the "before" challenge. This is analogous to the motion of the tape under the read/write head in the original Turing machine. This process continues until the original challenge is resolved, or the system halts. Like with the original Turing machine the single read/write head may be expanded to two or more heads working in parallel. This expansion will reflect the work of a large R&D team working in parallel. See ahead a sample of the IC map:

THE TRIANGULAR OPTIONS: The three triangular options B-X-A (Breakdown, Extension, and Abstraction), along with the nominal (direct solution) option, represent the full spectrum available for the innovator wrestling with an innovation challenge. This is essentially a dialectic range: If you cannot solve a problem directly, you can opt downward -- breaking the problem down to smaller parts, or upward -- considering a 'higher' problem where insight may be easier to come by. The 'higher' option divides to abstraction and extension, while the 'lower option' divides to at least two parts. The nature of these options is explained below.

BREAKDOWN CONFIGURATION: We distinguish between three types of configurations, which can be pieced together to form a complex configuration:

- serial breakdown configuration
- parallel breakdown configuration
- concentric breakdown configuration

SERIAL BREAKDOWN CONFIGURATION: An innovation challenge (problem), IC, may be broken into n serial breakdown units: S_1, S_2, S_3, ...S_n, such that a sequential solution of these units, constitutes a solution to the former challenge, IC.

$$IC = \{S_1 \rightarrow S_2 \rightarrow S_3 \rightarrow .....S_n\} \quad (1)$$

If any one of the n serial units remained unsolved, then IC remains unsolved. **Figure 4**.

PARALLEL BREAKDOWN CONFIGURATION: An innovation challenge (problem) IC, may be broken down into n distinct parallel breakdown units: L_1, L_2, L_3, ...L_n, such that solution to any one of the parallel breakdown units would constitute a solution to the former problem, P. In order to insure completeness, one of the n solution options (solution scenarios) would have to be: "a solution different from the other (n-1) scenarios". This implicit scenario would be associated with a probability rating, and treated computationally as the others. **Figure 5**.

CONCENTRIC BREAKDOWN CONFIGURATION: An innovation challenge (problem), IC, may be broken down to n concentric breakdown units: C_1, C_2, C_3, ...C_n, such that the first unit provides a solution to IC_1 a simplified model of IC, the second unit provides a solution to IC_2, a bit less simplified solution to IC, and in general C_i provides a solution to IC_i, a simplified model of IC. For all j > i IC_i is more simplified than IC_j and IC_n = IC. For each IC, it may be that C_i i = 1,2,...(n-1) would be practically sufficient for the purpose at hand. There are several typical formats for concentric breakdown. For instance: theory-practice sequence, shedding constricting assumptions.

It's quite common to formulate an IC as 'build contraption X'. One could then define the following children challenges: (1) prove or disprove theoretical feasibility; (2) find a practical feasibility. (If the IC is not zero-generation then the first and second consecutive steps may be sufficient); (3) develop a construction option. There are circumstances when an innovation objective cannot be carried out under a set of some constricting assumptions. In that case, one might break down that challenge into concentric components. The first component is comprised of parallel

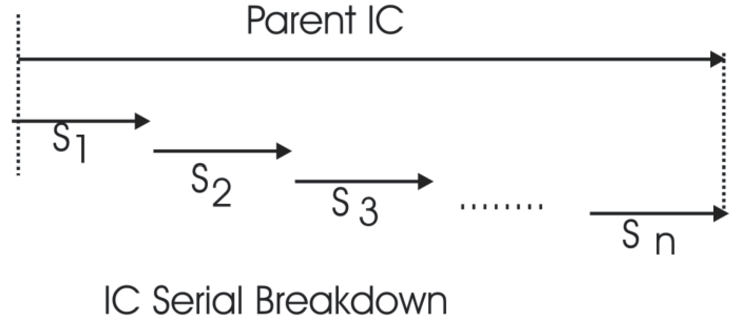

Figure 4.
IC serial breakdown.

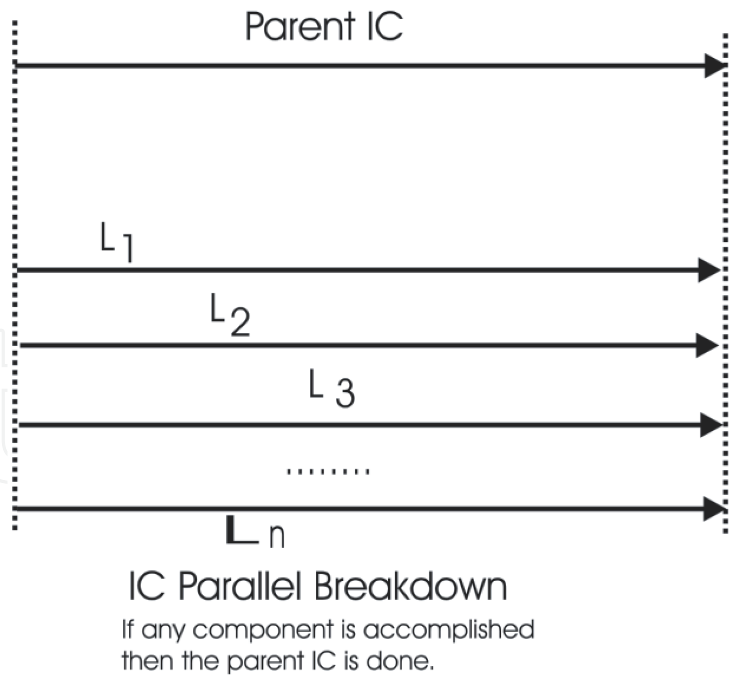

Figure 5.
IC parallel breakdown.

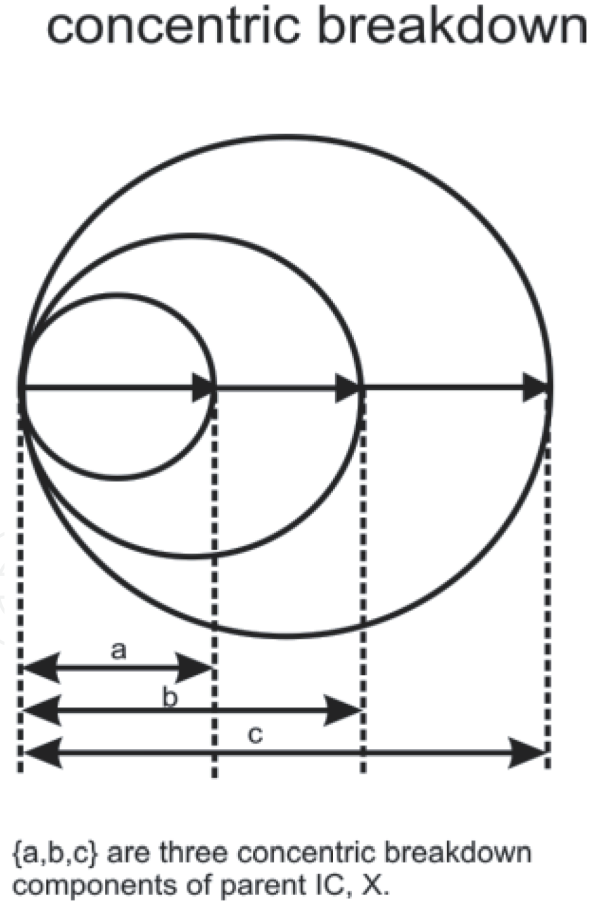

Figure 6.
Concentric breakdown.

ICs, each defined as accomplishing the parent IC by circumventing one assumption. The second concentric component would be to accomplish the same circumventing two assumptions, etc. It would be the same if the assumptions are worded to alleviate the construction: the first component would assume all these relaxing assumptions; the second would assume the same minus one assumption, then minus two assumptions, etc. **Figure 6.**

ABSTRACTION: This R&D route amounts to an effort to redefine the challenge at hand with fewer confusing details, and more fundamental principles, with the hope that the new view would bring to the fore some insight that was hidden when the issue was presented with all its "gory details". Filtering out less important particulars might be helpful by reducing the emotional impact of those details.

ENLARGING THE CIRCLE OF PROBLEM SOLVERS: Abstraction has the inherent benefit of allowing for a larger number of people to think of a solution to the R&D challenge. By stripping the former challenge to its essence, its difficulty can be appreciated by intelligent people who are not necessarily versed with the particular discipline of knowledge of the formal R&D. They may offer a solution that escapes the narrow professional. The more readily communicated abstracted version of the problem, also allows for the challenge to be considered by people who are not cleared to know the details of the original problem. It's a confidentiality issue. For so many cases this aspect severely limits the number of potential problem solvers.

EXTENSION: This option amounts to identifying related challenges, and defining a master challenge that would encompass them all. The underlying idea is that every challenge at hand has some "neighbors" -- challenges that bear certain similarities with it. Some of these challenges are associated with a solution or a partial solution, and this can inspire or suggest a solution to the former problem. The pioneer of the extension approach to innovation practice is the Russian scientists Altshuller [10–12].

IDENTIFYING RELATED CHALLENGES: The quality of this step determines the prospects of the extension route. Some similar challenges are obvious, and readily listed. Others need a more formal effort to be flushed out.

SEARCH STATUS: The search parameters are generally:

- Any-Fit/Best-Fit
- Needle in a Haystack
- Grouping
- Bayesian

A search may be conducted to find one fit instance among many, and it matters not which. Alternatively, the case may be where one is searching for the best fit, and second best will not do. This is a critical search parameter. When a search is characterized as a needle in a haystack, it implies that both the needle and the haystack are well defined. Once the needle is found, there is no confusion about it being the needle and not a strand of hay. The challenge here is simply the size of the stack compared to the size of the needle. Some search cases may be conducted by grouping individual instances into a single group and somehow concluding whether the target is, or is not, in that group. Such searches share a strategy for how to define the most efficient groups. Some searches develop new information as the search goes on. Even failed searches are thus helpful. This is expressed through the revised probability profile for the unchecked instances based on the search so far (Bayesian probabilities). In attempting to diagnose a disease, generally the results from failed tests help reshape the probabilities for the remaining options. By contrast, searching for the right cryptographic key is a case where all the futile searches are probably unhelpful in terms of better searching the remaining options. These search parameters will help identify similar ICs to exercise the extension step with the IC at hand.

SYMMETRY: Symmetry refers to the relationship of an innovation challenge towards its counter-challenge (a precise definition of counter challenge is given ahead). In the symmetric case both challenges are difficult, in the a-symmetric case the counter-challenge is easy, or no challenge at all. To suppress some gene expression may be as difficult as it would be to express the same (symmetry), but to construct a gene sequence from inorganic building blocks is infinitely more difficult than the opposite job (a-symmetry). A-symmetric challenges enjoy some similarities that may be exploited in the extension step. Generally the counter-challenge of an a-symmetric challenge represents a verification metrics for performance or even progress of the original challenge. Also, a-symmetric challenges may allow for incremental R&D work. Trying to cure an ailment, one may wonder if some measures taken have been helpful or not. Since it is generally easy to induce a disease, it opens the possibility for some animal trials where infected specimens are compared (statistically) as to any distinction between treated and untreated cases. It is therefore that the symmetry status of an IC is an important factor in trying to round up similar challenges for the extension step.

METRIC DEVELOPMENT: Challenges can be sorted out based on how easy it would be to measure success and progress towards success. Consider a researcher trying to develop a dye that would not be shaded or faded for one hundred years. How would one measure a successful accomplishment of that challenge (without waiting one hundred years)? Challenges that face such metric difficulty have some attributes in common. They all have to come up with some metric-substitute. Such substitutes have innate similarities. They may be mathematical models, some indirect metric, or extrapolated incremental measurements. By reviewing such similar challenges together, these similarities are likely to generate resolution ideas for the challenge at hand. Progress metric is also an important parameter. In a search challenge suppose one tries to find a single target within a field of search candidates. If the number of candidates is not known, then one lacks any measure of progress after having checked (and not found) m candidates. However if the number of search candidates, n, is known, then the ratio m/n represents progress rating [0:1]. If the search is also Bayesian, then the information skimmed from the m tests would change the probability profile for the remaining (n-m) candidates, and potentially accelerate the R&D progress. For that reason, it is generally helpful to identify the metric status of the IC at hand, and to identify similar ones to help develop solution ideas.

COUNTER-RESEARCH: Generally, an IC may be matched with a counter-IC, IC*, such that the two ICs in a series void each other:

$$IC + IC^* = 0 \text{ [the null IC]}. \tag{2}$$

If the IC under consideration is to find something, then IC* is to lose the same. Configured in a series, they pose no challenge at all. Same for reduction and increase, mixing, and separation, etc. Recalling the symmetry attribute, an IC would be either a "one way" or a "zero way" case where the former is defined as an IC where the counter-IC is an easy one, not really much of a challenge, while a zero-way challenge is one where the counter challenge is also intractable. While it may be difficult to separate two similar liquids, it's rather easy to mix them (one-way). While it is difficult to increase the amount of rain in a given area, it is also difficult to decrease the same (zero-way). In either way it may be very helpful to define the counter-IC for the IC at hand, and handle the two challenges together, learning from each other. It is therefore a recommended extension option to match a given challenge with its counter.

TRIANGULAR CHAINING: Any challenge that is not resolved directly is eventually being replaced by one or more different (but related) challenges, taking one of the three routes: breakdown, extension, or abstraction. The new challenge or challenges may be solved in a direct manner or may opt again to one of the three replacement routes, and so on. An innovator unable to find a direct solution to the problem at hand may choose to bet all his time and resources on one of the three replacement options. The new challenge may be solved directly, or branch out again in one and only one direction. In the simplest version the innovator would branch out n times, and face (n + 1) challenges. When the (n + 1)-th challenge is eventually resolved in a direct manner, the process returns, and after n back-branching (backtracking) the innovator is facing the original challenge. If one of the branching is a breakdown, then the number of challenges is larger. If the innovator, considering a given challenge is unsure about which is the best branching option, and thus he divides his resources to two or three options in parallel, then the number of challenges becomes much larger yet. If we assume that every breakdown step produces m subdivision challenges, then a single branch option would lead to (m + 2) new challenges, and n steps would lead to $(m + 2)^n$ challenges. Even for modest values of n, the number of challenges to consider becomes astronomical and impractical. It is necessary then, at some point, to rank-order the three branching options to limit the number of attacked challenges. An innovator may pick one of the three options at a given challenge, and proceed accordingly, chaining more triangles to the web. At some point, the innovator would conclude that this route is futile, and s\he might return to the original challenge and pick a different branching option. Since this can happen at every challenge, the actual "travel route" of the innovator over this so called Turing Web may be quite complicated. Complicated or not,

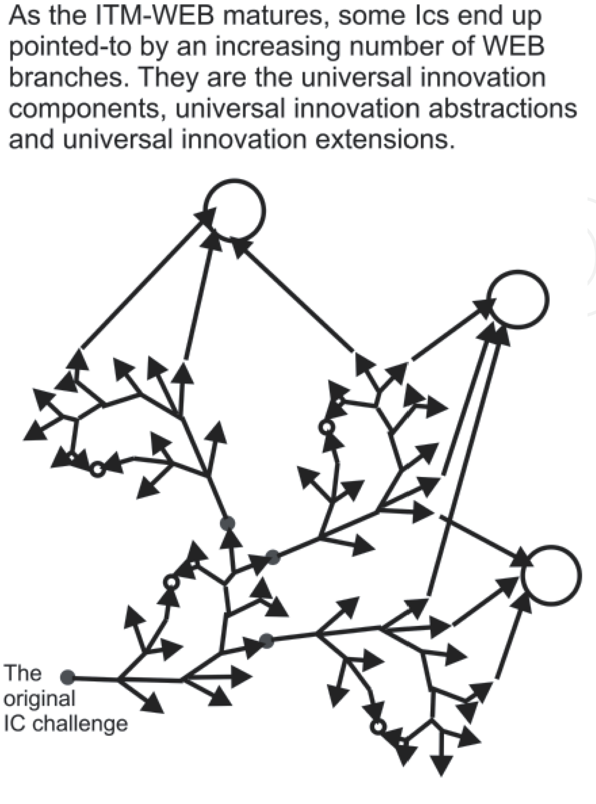

Figure 7.
ITM-web.

the travel route of the innovation process over the Turing web of triangles is a formal codification of the innovation process. It can be documented, analyzed, compared, and learned-from for the benefit of future innovative processes. The accumulating history of innovation processes mapped on the Turing web leads to the identification of innovation invariants that would be helpful for future R&D.

UNIVERSALITY: Is the Innovation Turing Machine universal? That is, is it possible to map every innovation process onto the Turing web? Historic innovation processes, to the extent they were tested, could all be mapped onto the web. It serves as no proof with respect to future innovation tasks, but at least this is a positive indication. The generality of the model can be argued from the following analysis: The three triangular options to handle a challenge that cannot be solved directly are well defined, distinct and thus valid. However, these options may not be complete. In other words, a technological challenge may be faced with the three options: A (abstraction), B (breakdown), and X (extension), plus a forth one, Y, not recognized by the model. To be distinct, Y must not be a component of the current challenge, and may not be an abstraction thereto. It may not be some reverse-abstraction challenge, which means it is a breakdown component. It may be a different description of the current problem, at the same level of abstraction. In such case, the Y option would qualify as a challenge to be listed abreast of the current one by selecting the extension option. See **Figure 7**.

4. AIA configuration

The Artificial Innovation Assistant is comprised of:

1. The Dialog Element, D

2. The Processor Element, P

3. The Environmental Element, E

This configuration is emerging from prior configurations, see [1].

The Dialog element communicates primarily with the human innovator, (HI), but also with the Innovation Underwriter (IU), and with the Innovation Beneficiary (IB). It employs the most advanced man–machine interface techniques to maximize communication efficiency. The Processor element is running the innovation related databases (AI-DB), the innovation processing procedures, and the respective calculations. The environmental part, (E), reaches out to parties in cyber space: innovation partners, paid data and information services, as well as to public domain sources. See **Figure 8**: AIA Configuration.

4.1. State of the innovation challenge

The state of the innovation challenge is comprised of:

1. Current definition of the R&D objective

2. Assessment of cost-to-complete and time-to-finish

3. Credibility Measure of (2)

4. Time since Kick-off

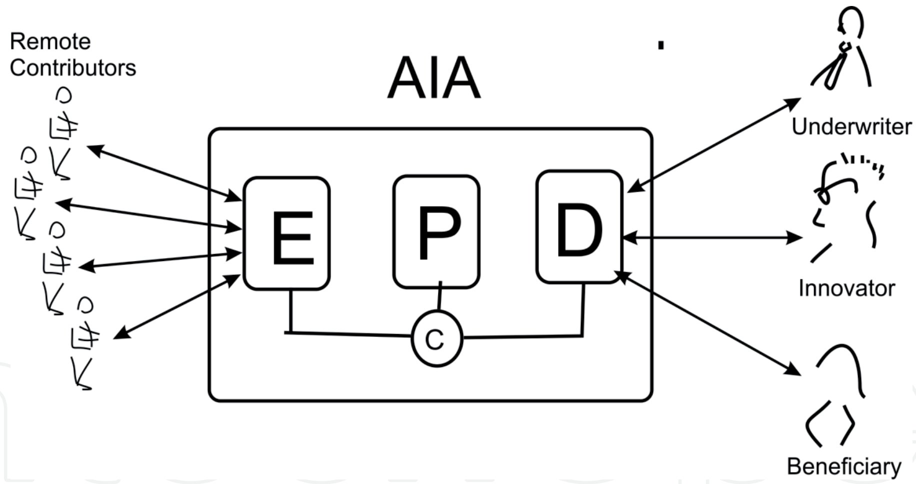

Figure 8.
AIA configuration.

5. Expenditure since Kick-off

6. List of Key Documents

7. List of the R&D team

8. Competing Models and Theories

9. Display of the Innovation^{SP} map

10. Brief history of the innovation project

At any moment the Innovation^{SP} map is comprised of some t specified innovation challenges (IC) configured as tree structures where the original IC is the root. Upon user request the map may be marked by the innovation pathway: how attention shifted from one IC to another.

If the map is comprised of a large number of ICs then the map will be displayed with the standard dynamic focus technology where the default is the full map with small IC indicators, and upon touch screen, or mouse-click the clicked or touched area swells into the center of the screen.

Upon further clicking on a given IC, a side screen displays the important information regarding that IC.

4.2 Next steps suggestions

Next steps suggestions are comprised of:

1. Strategic pathways to achieving the current R&D objective

2. Assessment of (1)

3. Specific next step suggestion

4. Assessments of (3)

4.3 The dialog module

The conversation with the human innovator (HI) will range from pre-defined forms in which the HI just enters specific parameters, up to full free conversational mode emulating human to human innovation discussion.

Emulating Human to Human Innovation Discussion: For this module one applies the current technology for human conversation emulation, complete with colorful words and expressions familiar to the HI. The conversation will be replete with "Hmm....", "I am not sure", and "How about that?" etc. The add-on of the AIA is to deploy randomness options; accordingly the AIA will suggest randomized ideas, emulating 'brain storming'.

The AIA may be programmed to participate in a conversation where more than one HI speak together, and even to accommodate other AIA modules.

An important part of this conversational module is to imprint warnings and alarms, and do so in a perfectly conversational manner.

4.4 The processor element

This module will include the AI computation power, mainly:

1. The AI engine

2. Monte Carlo State Evaluation

3. BiPSA operation

4. multi-variate analysis

5. The AI database

6. Innovation^{SP} map processing

See **Figure 9**.

Challenge Based Process Overview: The human innovator will query the AIA with a particular innovation challenge (The innovation challenge of reference,

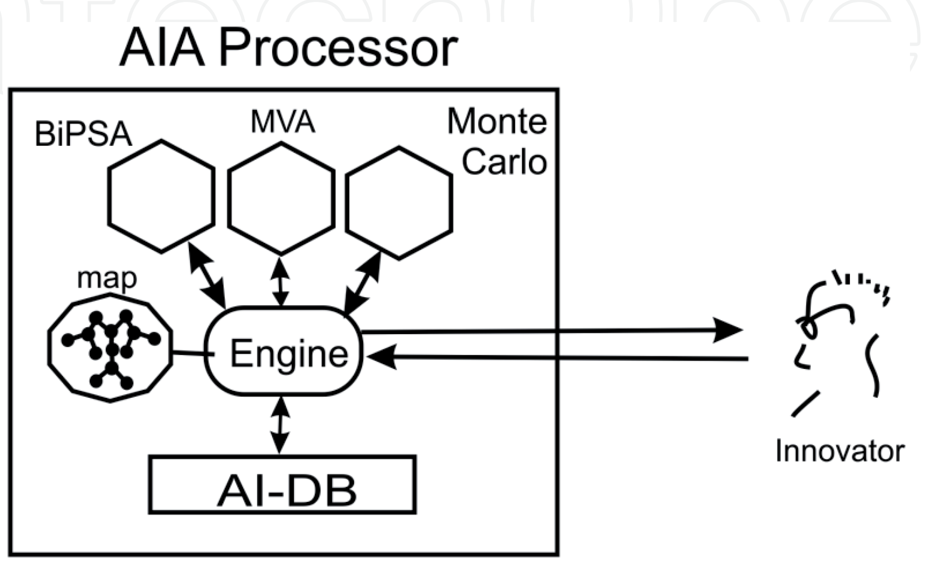

Figure 9.
AIA processor.

ICR). The AIA engine will evaluate the ICR and issue (i) a probability statement for the ICR to be solved directly within a preset time and within preset resources; (ii) resource requirements (time, budget) for identifying (B) breakdown ICs, (X) extension IC, and (A) abstraction IC. Each estimated resource requirement will be accompanied by a credibility metrics of that estimate. Each of the resultant 'switched IC' (ICS) will be estimated per its chance to be resolved directly, and the chance to resolve the ICR given the ICS was resolved, will also be estimated, along with a credibility assignment. This AIA report will be evaluated by the innovator who will decide on the next step based on the following conditions:

1. **Nominal Situation:** the option with the highest estimate credibility will be selected, regardless of its resource consumption.

2. **Stressed Situation:** the option estimated for minimum requirement of resources (time, budget) will be selected.

3. **Exploratory Innovation:** the option with the lowest credibility assessment will be selected, since it is expected to present more productive innovation load.

Following his or her decision, the innovator will do one of the following:

1. Address the ICR directly.

2. Address the most promising ICS directly.

3. Re-Query the AIA over the most promising ICS.

If option 1 is successful, the process terminates. If option 2 is successful, the innovator backs off to the ICR. The dynamics is depicted in **Figure 10**: (map pathway dynamics).

The figure shows the ICR on the left, branching out to a set of switch ICs as the AIA indicates. One of the pointed ICs, is selected for another AIA round, identifying a second set of switched (2nd generation) ICs, and so on until the switched IC can be directly solved. Once so, the process backs up, all the way to the ICR.

When drawn on the map, the process may look as follows (**Figure 11**).

The figures depict a path forward on the Innovation Map leading from the ICR to the last IC (ICL), which is easy enough to resolve directly. This terminates the initial forward path (see the left side of the figure). On the right side the backwards path is depicted where the innovator climbs back from the ICL, tracing the forward path. Upon arriving at a particular IC (ICB), the innovator runs into difficulties. ICB cannot be solved directly (although all the ICs from ICL to ICB were properly solved). In that case the innovator branches off from ICB, and starts another

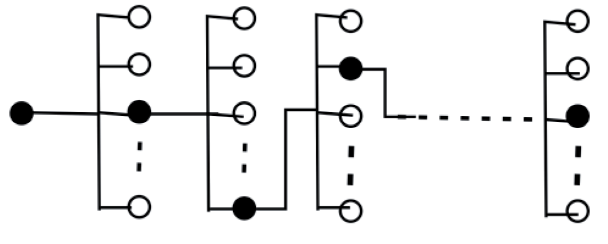

Figure 10.
Map pathway dynamics.

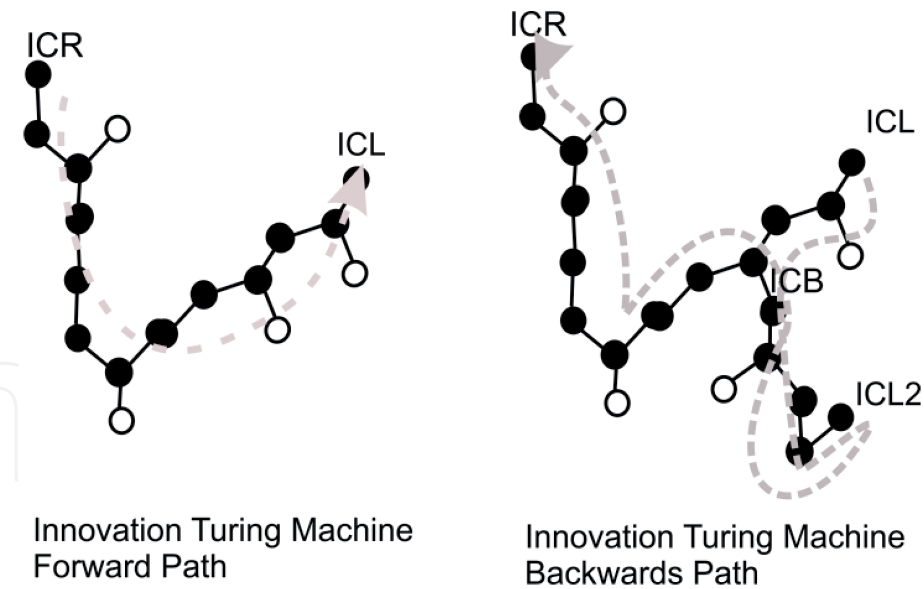

Figure 11.
Innovation Turing machine forward and backwards path.

forward path. As depicted the new forward path progresses to a second last IC: ICL2. From there it regresses to ICR where the process terminates.

Monte Carlo State Evaluation: The Monte Carlo Procedure is the central activity of the AIA processor. It is used to estimate cost-to-complete and time-to-finish, and its credibility. Its results are used to judge 'next steps' options.

In describing the Monte Carlo method for this purpose we adopt the integral sign over the cost probability function. We regard f(x) as the cost probability function of cost-bearing entity x, where the chance for x to cost between a low level, L, and a high level, H is given by:

$$C(L \le X \le H) = \int_L^H f(X)\,dx \tag{3}$$

Thereby f reflects both the estimated cost and the credibility of the estimate. We also 'steal' the integral sign to denote Monte Carlo integration of two or more probability functions:

$$\mathrm{f}(x+y) = \int_0^\infty MC\big(f(x)+f(y)\big)\,dc \tag{4}$$

where the integration in special cases can be taken over different boundaries across the cost parameter, c. In this Monte Carlo context the limit of the integral sign will reflect the interval of values from where a randomized selection is made. Given a query regarding the ICR = "o", the AIA will respond with a cost probability function f'(o). If f'(o) is too high for the innovator, then the innovator will prompt the AIA to estimate the cost probability functions for the three derived IC: $O \to x$, $O \to b$, $O \to a$: $f(x), f(b), f(a)$, and the corresponding cost probability functions for the resolution of o, given the respective derived IC was resolved: f(o|x), f(o|b), f(o|a). x, b, o designates extension, breakdown, abstraction respectively. The derived estimate for o will then be computed based on f(o||x), f(o||b) and f(o||a) where:

$$f(o \,\|\, e) = \int_0^\infty MC\big(f(e) + f(o|e)\big)\,dc \tag{5}$$

where e stands for x, a, or b, and the derived cost for o will be:

$$f(o) = \int_{0}^{\infty} MC\big(f(o\|x) + f(o\|b) + f(o\|a)\big)\,dc \tag{6}$$

The innovator will choose among the x,b,a options according to the innovation mode, as described above (nominal, stressed, exploratory). More on R&D cost estimation in [13–16].

BiPSA Operation: BiPSA (Binary Polling Scenario Analysis) is a discriminant analysis tool engineering to accommodate large number of discrimination factors. The BiPSA processor is working both for human respondents and for functional respondents. It is responsible for "Bipsizing" all questions to a series of binary options, the results for which progress into the answer for the original question. This is readily proven through Gödel numbers. A solution to any complex problem can be expressed via some set of elements and their relationships. Gödel has shown that such set can be represented arithmetically by an integer, G. One can then construct a series of binary questions: is G smaller or larger than some arbitrary value R. The answer limits the interval for G. The next question will ask whether G is located in the lower half of that interval or the higher half thereto. And the resultant half can again be halved again with a binary question, until G is pin pointed, and the answer to the complex question is given. Based on this premise AIA will use a BiPSA network to answer complex innovation questions. Because each question is binary, it will be readily possible to integrate the various answers coming from different knowledge sources in the system. Questions regarding path choices, cost to complete, time to finish, etc., are readily answered through progressive binary questions where each question is answered by any element of relevant knowledge in the system. As the binary questions progress the detailed answer surfaces.

The BiPSA processor includes the randomized sub processor to devise new innovation scenarios to be BiPSA processed. BiPSA is an adaptive network comprised of BiPSA elements. A BiPSA element is an operation that accepts n inputs, x_1, x_2, ... x_n, all in a form of integers in the range {-N:+N}, where N is an arbitrary integer. The BiPSA element responds to such input tuple with a single integer y in the same range: $-N \leq y \leq +N$. The BiPSA operator is symmetrical for change of signs. Its prime output is the sign of y. Its secondary output is the absolute value of y, which is regarded as the confidence measure of the prime answer. The prime answer is binary (positive or negative), or 'no answer' (y = 0).

BiPSA output can be threaded as an input to a next BiPSA element, and thereby a given set of BiPSA inputs may be processed through a network of BiPSA elements.

The BiPSA network is adaptive, and can be constructed as any adaptive algorithm. It reflects the growing wisdom of the system based on its expanding innovation database. **Figure 12** "BiPSA Network" depicts a network comprised of 6 BiPSA elements: B1, B2, B3, B4, B5, B6 processing n BiPSA inputs: x_1, x_2, ... x_n into a BiPSA output, y. The network can be defined algebraically as (x_{ij}, B_k), to indicate that input x_i is threaded through element B_k at position j. In **Figure 12** if x_1 is the top input then we write: (x_{11},B1), (x_{12},B4), (x_{13},B6) and the same for all the inputs. This algebraic definition can be adapted to best reflect the accumulated knowledge. Also note that for any value of n, there can be infinite number of BiPSA elements to "play with". **Figure 12**: "BiPSA Network".

BiPSA lends itself to genetic adaptation with increasing network complexity. One common expansion for BiPSA is to break the input tuple to confidence levels, to be subsequently integrated, as illustrated in **Figure 13**: "BiPSA Confidence Mapping":

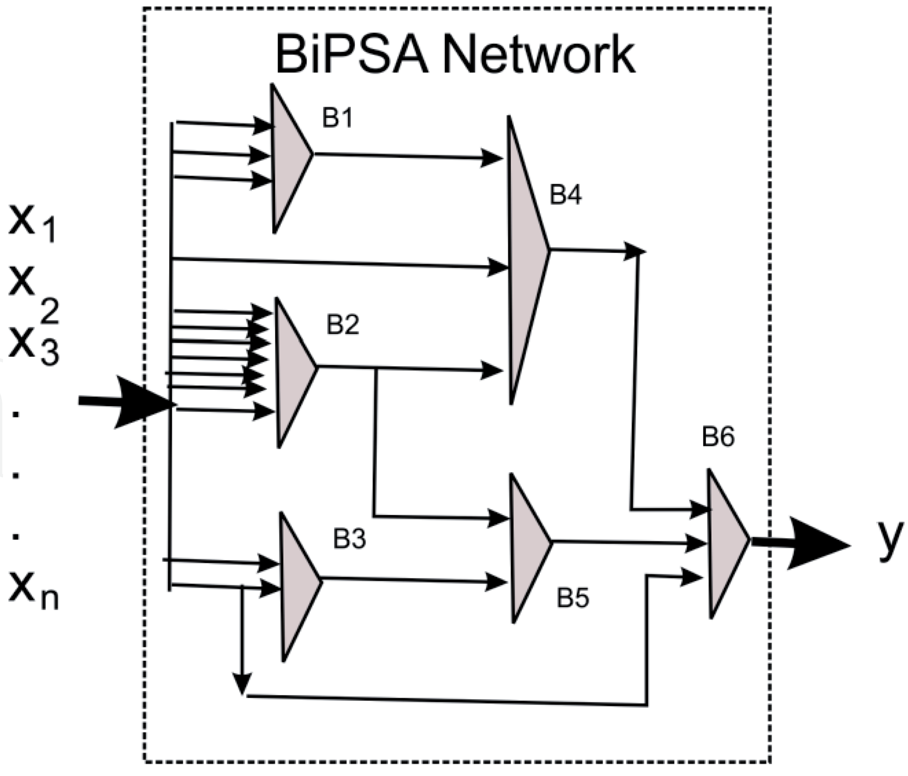

Figure 12.
BiPSA network.

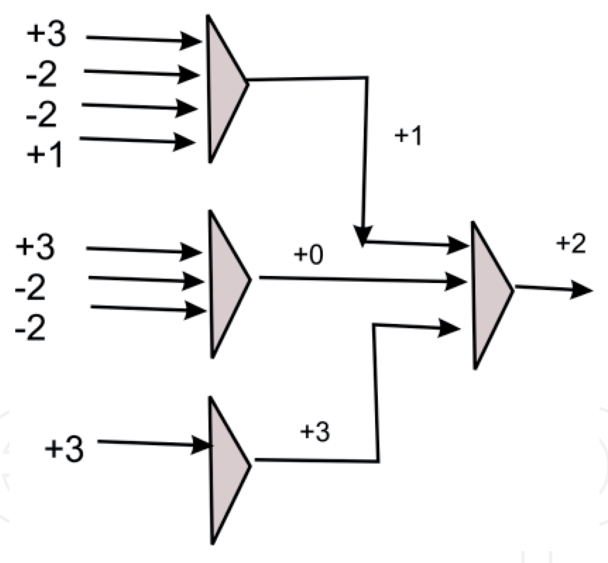

Figure 13.
BiPSA confidence mapping.

The input tuple {+3, −2, −2, +1} is processed as is in the upper element with an output of +1. A second element is processing only input values of confidence level 2 or above, resulting with an output of +0, and the third BiPSA element is processing only input values of confidence level 3. All the three respective output values are further BiPSA integrated to an outcome of +2.

Note: the BiPSA methodology is documented in various references [17].

Multivariate Analysis: Innovation is an ever growing practice, millions of innovation effort hours are being recorded worldwide. Every innovation effort can be mapped onto a pathway on the innovation map. Innovation challenges may be characterized by a very large number of parameters. This ever-increasing database is the raw material for a potent multivariate analysis (or rather maga-variate analysis). This worldwide database is not openly shared, and thus large organizations that can assemble the entire innovation history into a database will have a distinct advantage. However, there is a considerable amount available on the public domain. Technical papers may be used to map a solution on the innovation map. Every published patent can be matched with an innovation challenge it solves. One may envision future service companies that would map public domain and some private innovation pathways onto a standard data platform (the innovation map). This database will serve as a guide for any current innovation challenge. This approach is inspired by the surprising success achieved by language translators that rely not on complex man-elucidated rules of linguistics, but on an ever larger database of properly translated text between the two languages of reference. The very large number of analyzed parameters suggest the BiPSA methodology as an effective multivariate analysis tool. We consider some n arguments x_1, x_2, ... x_n which are used as input to determine the value of an output variable y.

$$y = f(x_1, x_2, \ldots . x_n) \tag{7}$$

Typically f is not known. What is given is some k data points where in case i = 1,2...k the values of the arguments is x_{1i}, x_{2i},..... x_{ni} and the respective output is known as y_i:

$$y_i = f(x_{1i}, x_{2i}, \ldots . x_{ni}) \tag{8}$$

The function f can be approximated through one of the many techniques developed for the purpose. However, most of the common solutions are based on high dimensional metric spaces and complex cluster analysis. These are methods that get prohibitive when the value of n increases. Not so with BiPSA.

Interval Based Operation: let the k y values be organized by increasing order, so that $y_i \le y_{i+1}$ for i = 1,2,...(k-1). Let y_0 be the median, or the average of the k y values, or sufficiently close to it, and let $y_0 \ne y_i$ for i = 1,2,...,k then the k data points are divided between those pointing to y values above the median and data points pointing to y values below the median. Given any new set of n input parameters, not listed in the k points database, then the binary question would be, is the corresponding y value above or below the median. Once answered the roughly k/2 points in the section of the y range pointed to by the first BiPSA question, will be used for in the same way to further pinpoint y in the upper or lower half of the established y range, and so on, pinpointing y as needed. The credibility of the answers will decrease as each successive BiPSA question uses about half of the data points used before. The larger y intervals will be stated with greater confidence.

Fuzzy logic neural network tools are a good alternative to BiPSA, as discussed in [18].

4.5 The environment element E

The environment element will connect to the environment comprised of:

1. Collaborating Teams
2. Proprietary Sources
3. Public Sources

Collaborating Teams: The given AIA will benefit from exchange with AIA machines operated by collaborating teams. The various AIA will agree on a sharing protocol that may be based on free updating of a shared access database, or on a push or pull configuration. Issues of cyber security will play a role in the selection of the right sharing solution.

A sophisticated AIA will use Homomorphic encryption to handle the division of confidentiality within the team members. This will account for collaborating teams who keep some proprietary information confidential while sharing the rest of the material.

Proprietary Sources: Companies like R. S. Means are selling innovation related data for a price. Mostly they are subscription based, but some international purveyors offer pay-as-you-go, requiring the AIA to use digital money to pay per services rendered real time.

Public Sources: The share of global information freely available to the public is growing exponentially. The efficiency of the major search engines like Google and Bing is improving daily. Yet, the utility of these search engines depends largely on the selected search keywords. It is the responsibility of the AIA software to translate the need for information into proper key words string.

A critical source of innovation related information is government. By law most democratic governments publish a wealth of data regarding public projects. This data is very useful for an effective AIA. One important government source is the patent office which publishes new patents in very searchable forms.

5. Outlook

Thomas Edison, Bill Gates, Alexander Graham Bell are examples of top tier innovators who changed our lives in a fundamental way. However societal progress is taking place via a myriad of non-famous innovators, each making a small innovative step forward. These run of the mill innovators are the target beneficiaries of AIAI. The Steve Jobs and the James Watts among us do not need the help offered by AIAI, but most of us are better served by advanced guidance to channel our creativity into a productive pathway.

We see AIAI making great progress in the dialog part with the innovator, and the other innovation stakeholders, in the interaction with innovation contributors from the outside.

The profound contribution of AIAI to the innovation process is in (i) a comprehensive exploitation of rich innovation history, and (ii) in advanced Monte Carlo computation of credible estimates of cost to complete and time to finish the innovation process. We witness a world with a "global library" as exemplified via Google, Bing, Yahoo, and Baidu and proprietary systems like R. S. Means offer a rich "digging ground" for sophisticated AIAI systems. Also, innovation is an ever-growing enterprise and invariably there are more research ideas than there are resources for them all. A competition ensues. The AIAI methodology centered around credible cost estimates leads to rational allocation of these scarce resources, all for the benefit of society at large.

The solution to most of the pressing and universal problems of humanity is to be found in the promise of innovation, and hence a tool to make the innovation effort more productive, is a welcome addition to the tool-box we use to meet our future.

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Author details

Gideon Samid
Case Western Reserve University, Cleveland, OH, USA

*Address all correspondence to: gideon.samid@case.edu

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