xPERT-O, a collaborative tool to enlighten key challenges in a complex situation

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Abstract. Situations experienced by companies are complex, with lots of interconnected challenges. Rushing straight into solution usually leads to failure by lacking to identify key issues to solve.

Therefore, we developed xPERT-O, an interactive web tool to analyze situations on a collaborative frame. Principle is simple: challenges harvested during the analysis are introduced by participants in the form of documented nodes logically linked in cause-and-effect relationships. 2017-award winning xPERT-O allows more than 40 people, not necessary located at same place, to simultaneously collaborate on case studies and build directed networks by applying simple heuristics. Centrality algorithms help to determine which nodes have the greatest impact. By using multiple filtering /sorting possibilities, the network is made clearly understandable by human eye. A 3D Virtual Reality mode is also developed to better explore complex situations and pin up key issues.

Applications are numerous as modeling of complex processes, FMEA, innovation development, etc.

Keywords: Complexity, Situation Analysis, Interactive web tool, Co-construction, Directed Network, Centrality Algorithm, Virtual Reality

1 Our motivation: necessity of collaborative analysis

1.1 Real situations are complex

The situations that are experienced by companies are complex. The second principle of thermodynamics illustrates it: diversity is a generator of life. However, this diversity also implies the multiplication of issues, problems, challenges, divergences, complexities and difficulties. And rushing straight into the path of the solution usually leads to failure (see for instance different papers of Harvard Business Review on the subject as [17]). Indeed, most failures are related, not to unsuitable solutions (such as "we gave the wrong solution to the right problem") but exist because we have not addressed the real problems (such as "we found a good solution, but to the wrong problem"). And even more so, almost all innovations come from the fact that we pro-

vide a response that suits a key problem that matters, a frustration of the market, a pain / gain of the targeted user. Innovation comes by solving the key challenge and simplifying the user' life.

There are many situations in life wherein challenges and problems have chain consequences and are interconnected. Often so much that we don't know from which angle to approach the problematic. That is why we settle first the most urgent, or most obvious, while knowing that we maybe don't address the root causes, far too complex to discover.

An exhaustive analysis of situation is by definition complex: problems and challenges have a self-generating behavior and once you solve them, others are popping up. So we just have to live with them. And to quote Nikolaï Khomenko [1], problems present a fractal behavior [2]. The characteristic self-replicating aspect of fractal forms appears.

For example, in figure 1, the upper box (P0) represents the initial problem. In order to solve this problem, we have a solution (S0), but at the same time appears a sub-problem (P1). In this very simplified case, when P0 is processed, we can delete from our graph both P0 and S0. We then find ourselves with a new scheme, in which P0 and S0 have disappeared, and are replaced by P1 and S1.

At the end of the problem-solving step P1, the new system is a model analogous to the initial model. As illustrated on fig.1, this configuration is found on each of the following stages, which allows to call it a fractal (we recognize there a nesting structure, which extends to infinity).

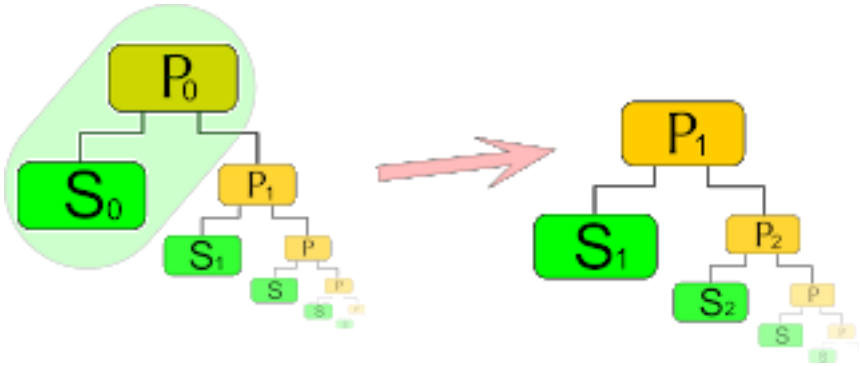

Fig. 1. Schematic representation of fractal dimension of problems.

This very basic model is only there for understanding a simple structure of successively interconnected problems & solutions. In general, a given problem is connected to several new problems, and the solutions that solve this given problem also generate new problems. The representation of these relations between problems and solutions becomes rapidly intricate and complex [3] (see fig. 2).

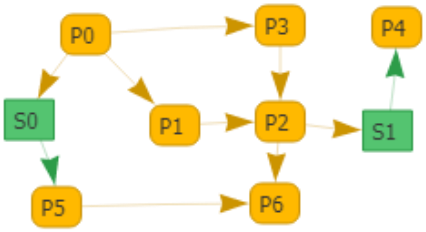

Fig. 2. Complexity of network of problems.

1.2 **Problems are a never-ending story**

Other models do exist to represent problems. For instance, a Pareto diagram highlights the same structure, and is used extensively in continuous improvement operations (see fig. 3).

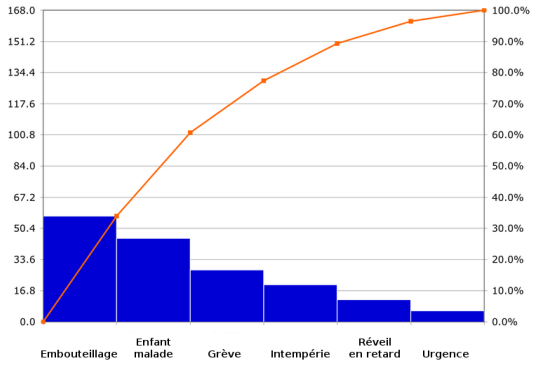

Fig. 3. Pareto diagram.

Just like in the model of fig.1, if we remove the left-most column of the Pareto diagram (because we have addressed the cause of this problem), the data set keeps the same shape and we then focus on the resolution of the second column which becomes a priority.

This vision of the problems leads us to observe the following elements:

- Any problem solving brings new problems. And thus, one could choose to use the new solution by evaluating the weight of the new problems which are due to this problem solving compared to the initial problem.
- Some of the new issues are not necessarily identified in the initial resolution and only appear much later. This is because quite often some of the operating pa-

rameters of the system are not directly known. The situation is evolutive, and anticipation of problems can be a tough job.
- Solutions to a problem depend also on the particular conditions of the problem. It generates an entropy of problems.

As shown here above, representations of a set of problems in the form of a Pareto diagram or a problem graph do present similarities. In fact, several methodologies can also be applied to analyze initial situations for generating problem-solving activities, as analyzed by Akashdeep Howladar and Denis Cavallucci [4].

These problem-solving methodologies are sometimes rather dedicated to optimization-type resolutions (as lean or 6sigma…), sometimes more prone to disruption and breakthrough invention (as TRIZ or OTSM-TRIZ). Depending of the intention of the problem-solver, he will use the most appropriate tool for his goal. Nevertheless, without identification of the key problems, problem-solving will be unsatisfactory. But how to do it?

This implies that, in solving a problem, one must expect to have to solve many sub-problems. Our culture does not shape us with this approach, so that many good ideas are abandoned before a real evaluation. The observation is simple: to evaluate complex situations, without tools allowing to have a synthetic vision, is complex.

Let's take a simple example in an industrial environment: the maintenance of a machine. If it breaks down, the first action will hold "How": how to put the machine back into operation, because each stop time immobilizes the production tool. It is then a curative maintenance, an operation carried out in urgency. If nothing more is done after the resolution of the failure, we cannot ensure that it is permanently eliminated. If, on the other hand, after this action "How" necessary to restart the machine, we take the time to ask the question of the "Why" of the failure, we enter a preventive maintenance procedure. The answers to this "Why" will generate solutions that will tend to eradicate the problem...

The same is true for innovation as well as other areas. The "How" brings immediate solutions, often essential (even vital) but without significant improvement. The "Why", in turn, can significantly improve the situation, and bring innovative solutions. The “How” is a "reflex" question. The Why is a "thoughtful" question.

That is the reason why, among other techniques to explore the problematic in its broad sense, the “5 Whys” procedure [5] is so interesting, especially in the initial stages because it literally "plunges" into the heart of the problem. For each level of why, we come closer and closer to the root cause of the problem, and therefore to the underlying contradiction.

1.3 **How to visualize?**

Collecting problems is quite an uneasy task in our culture which so dedicated to provide as soon as possible an answer to any question. We have to put ourselves in a mindset that forces us to not to plunge into solution but to surf on the wave of problems.

In order to be systemic when you analyze a situation, you have to take into account many dimensions in collecting problems and challenges inside & outside the organization that is concerned. For instance, internally one speaks about customer care, marketing, sales, research & development, technology, production, logistics, processing, HR, legal, HSE, etc. And externally about different stakeholder's points of view: competitors, partners, subcontractors, prescribers, influencers, knowledge partners, politics, etc.

A simple case can become quite rapidly a real mess if you collect the different angles proposed by all actors. A typical collection system is the "post-it board". Everyone is entitled to write down the problems he considers as important on post-it and these post-its are then organized by pattern and categories in subsets (see fig. 4).

Fig. 4. Collecting Problems

This process can deliver in a short period of time a huge number of problems, expressed in many different ways. But there are several drawbacks behind this process as:

- Communication bias and problems: everyone express his problems with his own perception, and own writing. So, after a while it becomes nearly impossible to understand what was written, without having explanation of the concerned person.
- No interactions between problems: it is very complex to make links between post-its and when you move them to another place you lose the connections.
- Quickly frozen interpretation: as it is difficult to move post-its several times without impairing their ability to stay in position, one fix quite early the global frame in the collection process, and this will guide all the rest of the analysis.

- Limited ability to retain everything: the normal human mind is not usually able to hold more than 10 problems, especially if they are interlinked. To overcome this disadvantage, people brings together problems and frames them in macro-problem that are more encompassing and vague. And this leads to misunderstandings because nobody has the same way of aggregating problems or the same representation.

So, we rapidly lose the overview on the problematic and there is no clear vision on key problems: after a certain amount of post-its, it becomes impossible to get an objective view on what's important. A workaround of this is made by asking the participants of the exercise to identify their own top three of items to tackle, which provides at end of the process a list of items ranked subjectively.
Different systems have been settled to eliminate these drawbacks. The visual approach is essential at this stage, because it allows a shared understanding of the issues. A general frame for building problem graph has been developed in INSA Strasbourg [3][4].

It is a good step forward, but we were looking for something more flexible regarding collaborative work, more visual regarding graph exploration and more powerful regarding relationships interpretation.

2 Our development: xPERT-O (http://www.xpert-o.com)

2.1 Analysis of the situation is a crucial step in our innovation methodology

xFIVE has developed an innovation methodology called 2A2CI (Awareness - Analysis - Concept development - Concretization - Impact) which has been already presented in ETRIA conferences [6][7]. A very crucial step in our methodological approach is Analysis: a preliminary analysis of the situation before going directly to action. Indeed, it is important to think before acting, and to define the important challenges / critical issues / key issues to be solved. Problem and opportunity are two sides of the same concept, namely a question to be solved in any field, which presents itself with a number of difficulties, obstacles.

To analyze a situation is to study an unfinished event. What is targeted is not "good" identification but rather the integration of information from all members of the group. This group should ideally include all stakeholders in the business ecosystem of the project under study. What is targeted by this step is to share the maximum knowledge, expertise and vision of the issues between the participants. Of course, the more one spends time in analysis, the more robust is the modeling of the global problem. But it consumes precious resource: time of participants. So it is essential to capture at least 80% of issues of the situation to examine: the effort to be deployed beyond generally does not bring much more richness of interpretation.

The objective of the analysis exercise is to identify and put the finger on the key problems of a complex situation, in other words the fundamental opportunities, in a collaborative way with all important stakeholders of the problematic which is studied.

This is a very demanding work wherein expertise in reformulation and synthesis are critical.

2.2 **Solutions do exist**

As written before, manual procedures do exist to collect and consolidate lists of problems and challenges: post-it on flipboard, excel sheets, word tables, etc. These systems are made by hand, are time consuming, quickly unreadable and vague, and because there are manual, they become rapidly unable to integrate change.

Mind Mapping [8] is a way to balance some of the drawbacks: it helps to structure the data collection, it is easily adaptable. But one start from a central node and it is not suitable to build complex representations, intricate networks. And there is a huge bias in identification of key issues: what's central gets all attention.

Other software solutions do offer a way to illustrate complex graphs of problems, as YeD [9], Gephi [10] or Microsoft Visio [11]. But as they are generic systems to visualize all kinds of data, there are lacking focus on the process of collecting problems, there are not so user friendly, collaboration and co-construction are quite complex to organize within their frame.

As mentioned above, INSA Strasbourg had developed a software tool to automate the ideation process (STEPS), with a part of it dedicated to the construction of problem graphs [3][4]. But this problem graph software shows also limitations when used in non-technical areas or when several dimensions other than sole technology are important: limited co-creation mode (only one editor at a time, thus requiring a centralized building process), limited visualization possibilities, especially when looking at different metadata of the problems, only one heuristic to calculate importance of different problems. These limitations are quite understandable as main goal of STEPS' problem graph is to collect parameters of the problem, and not to visualize the key issues of the situation.

2.3 **Principles behind xPERT-O development**

So we have decided beginning of 2017 to build our own visualization software. In six months, with the support of students working for their thesis within the frame of the SoftLab program of the Microsoft Innovation Center [12], xPERT-O has been developed in asp.net technology as a collaborative SaaS web tool. A SaaS web tool means that it is accessible through internet, by paying a fee proportional to its use. It is constructed with 5 guiding principles in mind.

- **Focus on ergonomics and user-friendliness**: xPERT-O allows an ergonomic encoding & visualization experience adapted to different and intuitive uses (self-explaining action modes for text processing, live encoding, alone or with others, on a site or several sites, with its PC, tablet or smartphone, etc.).
- **Online collaboration and universal accessibility**: xPERT-O is a SaaS solution which is always up to date, wherever it is used, on all devices. It allows more than 40 people to interact together on the same network of problems, at the same time and not necessarily on the same site. It makes possible to co-build a complex network, while managing interactions between all participants.
- **Powerful visualization capabilities:** xPERT-O do offer many visualization possibilities with sorting, filtering and searching tools to explore the networks and easily find the information that is needed.
- **Powerful heuristics to identify key issues**: xPERT-O has a library of algorithms (that can be extended) to adapt to different situations and different objectives of identifying key issues: identify the most influential nodes, identify weak signals, identify critical paths, etc.
- **Documentation of the information which is introduced**: thanks to its lexicon, xPERT-O makes it easy to illustrate the concepts in order to share with the participants a clear understanding of the concepts. xPERT-O offers also different possibilities for data exploitation (image export for insertion in presentations, export in Excel for further processing, export in xml for integration into other applications, export in xPERT-O format for archiving at different times of the project).

The general philosophy of xPERT-O is summarized in the figure 5: transforming a confused mass of rough data into a clear overview of key issues to tackle.

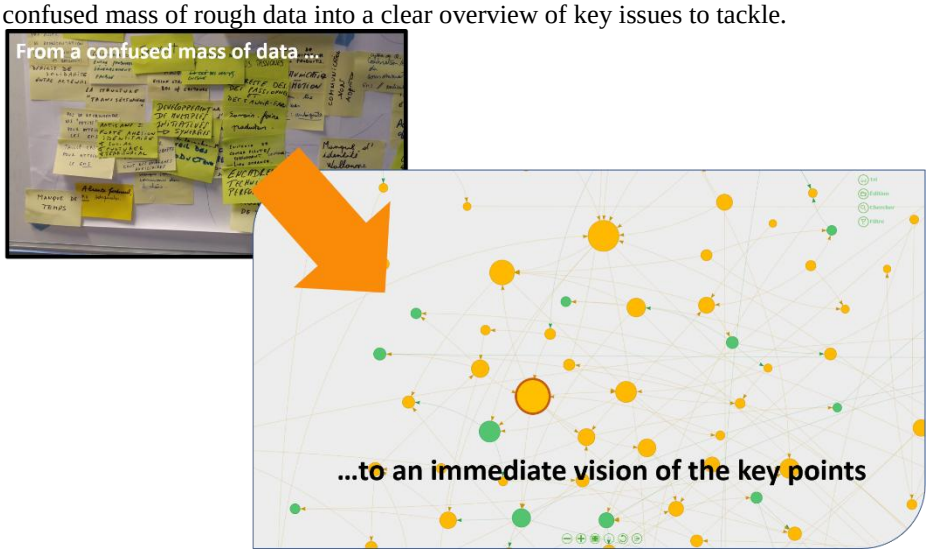

Fig. 5. Philosophy of xPERT-O

2.4 Using xPERT-O in several applications

In a matter of minutes, several users can simultaneously create and connect simple elements (NODES) with oriented links (LINKS) to create a complex network. Using graph theory algorithms, xPERT-O then highlights the most influential nodes within this network of nodes and links.

The applications of xPERT-O are numerous for all sectors (energy, environment, materials, e-health, technology industry, chemistry and biotech, etc.). It can be used for instance to identify the key opportunities for an Innovation Project, identify critical risks and major issues in a Risk Analysis or focus on the essential parameters of a Process Improvement, etc.

The main benefits come from the software's ability to highlight the key issues of the situation that is modelized with xPERT-O. On the other hand, xPERT-O offers indirect benefits from the facts of its mode of operation:

- Develop together the same understanding of a problem by sharing the working method, on a collaborative way, in the same room or remotely;
- Overwhelming the debates by objectifying the situation, especially when problems are intricate;
- Make the priorities clearer and more shared, because they are better objectified;
- Increase understanding of interactions in a complex situation, and improve the systemic view of this situation;
- Improve the concentration of the teams on the subject to be treated, limiting the digressions and expressions of feelings that are not related to the subject;
- Reduce time for organizing information: as measured on several projects, one can expect a time gain in a factor 2, especially when it comes to interpretation of information.
- Etc.

This has been experienced in more than 30 projects realized with the support of xPERT-O since mid-2017. This software has received in October 2017 the Sésames2017 prize from the Federation of Technology Companies AGORIA (very active in raising awareness in Industry 4.0 in Belgium).

3 Key points behind xPERT-O

3.1 Collaborative Data Introduction

Objects which are manipulated in xPERT-O are NODES and LINKS. A NODE is an item that corresponds to a simple concept. When one speaks about problems, one can use the formalism developed by Cavallucci [4] wherein a NODE can take two forms: problem or partial solution. Problems and Partial Solutions are described by simple sentences (problem = subject-verb-complement, partial solution = verb in infinitive form-complement). Other types of NODES are possible within xPERT-O under development). LINKS are oriented cause-effect relationships between NODES.

NODES and LINKS do have several additional characteristics (as importance, categories, validity, editor, etc.) that are used in visualization modes.

Once connected to xPERT-O, each user has the possibility to create NODES and LINKS by using classical editing tools (see fig. 6). More than 40 people can work together on the same network, with as working constraint that each NODE that is already edited by some editor has to be released by this editor before being modified by someone else. Fusion of NODES allows to create a collaborative frame to build together a network of nodes, and to minimize redundancy. Human interpretation is still critical in this version of xPERT-O to review the network which has been built in order to frame it adequately. This is clearly an improvement path of the software: building best practices and typical template networks that can help the user in his definition of the problematic.

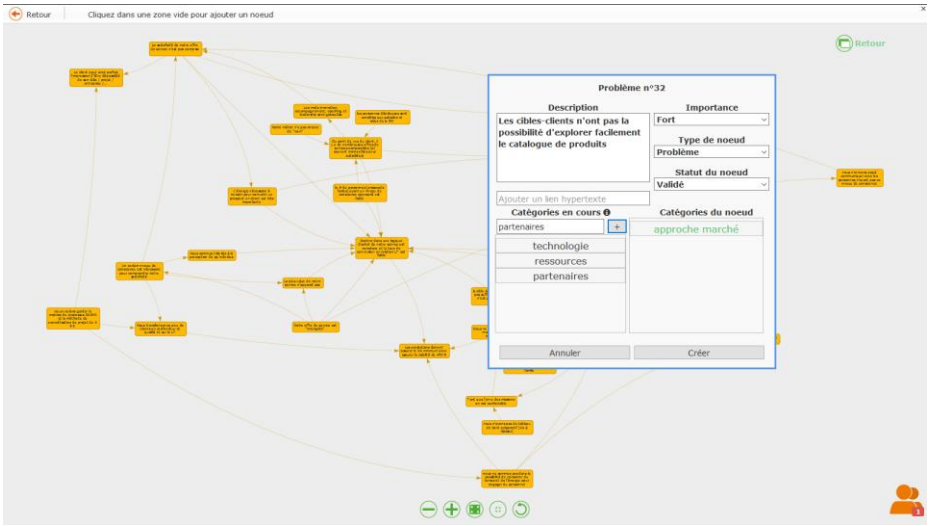

Fig. 6. Editing mode of xPERT-O

3.2 **Interpretation of networks of NODES and LINKS**

The main advantage of xPERT-O is that once you have built the network of NODES and LINKS, it is possible to easily highlight the key issues (key NODES), those whose resolution will have the maximum impact.

An orientated network of NODES and LINKS can be assimilated to a graph, and graph theory do offer several tools for analysis [13][14]. In graph theory and network analysis, indicators of centrality identify the most important items within a

graph [15][16]. This is a way of detecting the most influential NODES, those that have the greatest impact, those whose resolution makes it possible to eliminate the greatest number of related NODES (in the manner of these dominoes that, when they fall, entail a large chain of other dominoes in their fall).

Different centrality algorithms have been introduced in xPERT-O (eigenvector, degree, clique, etc.) The calculated influence which is normalized between 0.0 and 10.0 is illustrated by the following figure 7, where the most influential NODES have the largest diameter.

The choice of the centrality algorithm is up to now left to the user of xPERT-O, but this is clearly an improvement path of the software: building best practices and typical template networks that can help the user in his definition of the problematic.

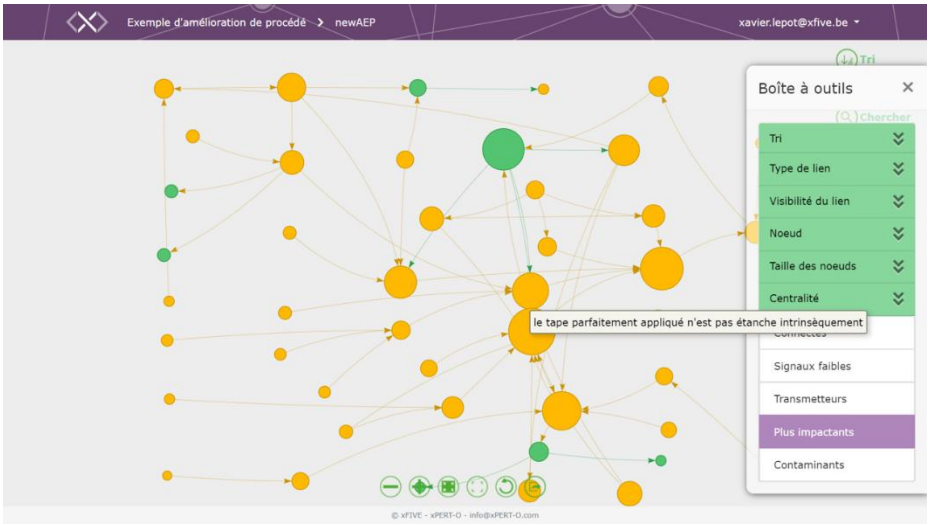

Fig. 7. Calculated Influence of NODES

In one look, we better understand the key issues of the complex situation that we are diagnosing. This then allows to choose the issues to be addressed to support the strategic recommendations.

3.3 **New ways of thinking**

xPERT-O as such forces us into new ways of thinking. For instance, the more time we spend consolidating the network, the more the links are becoming intermingled. This makes the result unclear. So, and it is still under development, there is an advantage to "untangle" the network. It means to arrange NODES in a position so that crossing of LINKS are minimized. It generates in fact also some indications to possible solutions. Our intention is to get a better understanding of networks established

by untangling connections. This untangling operation could be done on the complete network, but also on subnets and filtered networks. The objective is, as previously mentioned, to give a better understanding of the problematic to the users.

Other possibilities also linked to graph theory are the search of deadlocks (circular connections of NODES) that could be also the sign of unsatisfactory description of NODES. This hypothesis has not been implemented till now, and thus a fortiori is not validated.

xPERT-O is a perfect platform to develop network exploration tools.

4 Virtual Reality Mode

4.1 How it works…

When 2D networks become complex, it arrives a moment where it is impossible to avoid crossing of links. This is making the graphical representation of the network more difficult to understand.

So we have developed in 2018, once more with the support of the Microsoft Innovation Center [12] an exploration mode in 3D Virtual Reality. With a VR helmet, you plunge literally into the network and you can explore it from the inside, which provides great overview capabilities (see figure 8). By changing dimension (TRIZ principle 17), we avoid crossing of links and a network can be organized using untangling algorithms.

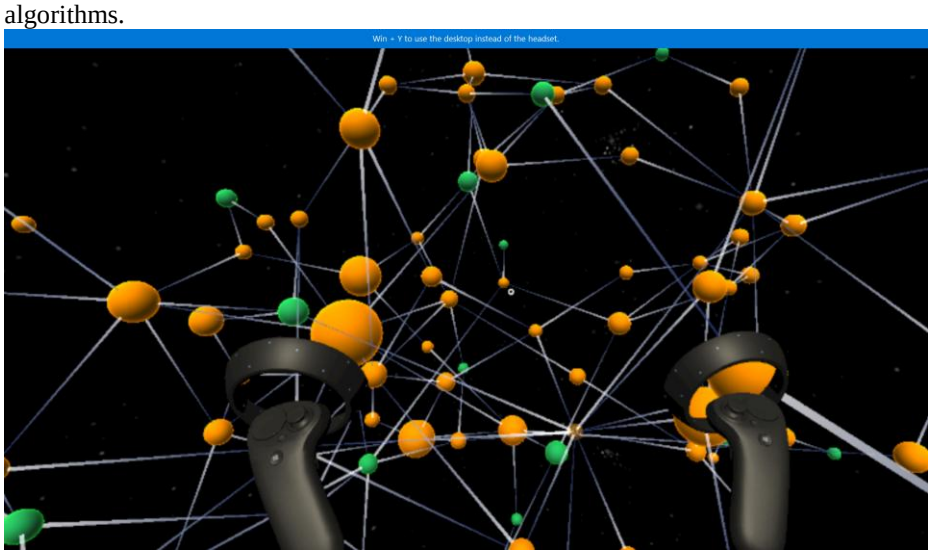

Fig. 8. 3D representation of a network

In addition to this possibility, one can for instance place a 3D model of the problematic that is studied, in the middle of the 3D universe. The NODES (problems or solutions) can then be placed on the most suitable places. We are at the beginning of VR possibilities and the perspectives are very promising.

5 Case Study

To illustrate the benefits of using xPERT-O in analysis of situation, we will discuss briefly the case of a manufacturer of basalt fibers. Basalt is a very difficult material to process. It requires very high temperatures (around 1.600°C), and is very abrasive. Our customer had to modify his lab' processing line in order to develop a new industrial line. We have collected all the problems and partial solutions that were related to the processing of basalt on this lab line. This has been done in collaboration with workers in the plant, process engineer's, representative of equipment suppliers, researchers from research centers, etc. About 200 NODES have been collected. The biggest difficulty was to identify the key issues to tackle in order to optimize the process. The calculated centrality of NODES has put in evidence some candidates of problems to solve in priority (see fig 9). The most influential one was related to the ability of the molten state to mix itself spontaneously.

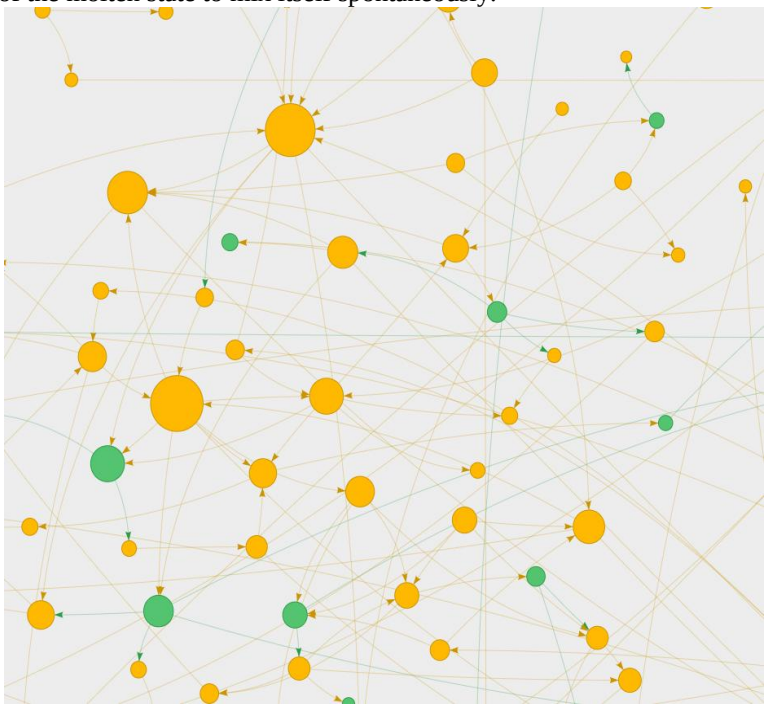

Fig.9. Influence of nodes

We have thus developed an inventive solution to this problem (by using some TRIZ principles, as playing on phase transition). And the results were quite impressive: reduction of scraps by 20%, increase in productivity by 20%, etc. Why? Because we did address the root cause. It is interesting to note that nobody before this exercise was convinced that this could be the problem to tackle. When we proceeded to a manual selection of key problems, it has never been selected.

6 Future work

xPERT-O, as it exists today is a first version of a visualization tool with already several possibilities but offers also lots of perspectives for improvement. Future works could include for instance:

- Constructing different contextual views for NODES (as for instance Functions & Constraints, Risks & Countermeasures, etc.);
- Constructing multiple LINKS (with Boolean operators);
- Constructing Heuristics to build networks of NODES and LINKS;
- Constructing multilayered structure of networks (with super system network and system networks);
- Multiplying centrality measures;
- Building templates of network based on best practices;
- Etc.

VR exploration is a study subject in itself. Today possibilities are making network exploration quite fascinating, but collaborative construction in VR mode is still difficult to organize, because there is no multi-user mode in VR.

7 Conclusion

When analyzing problems, we often look at the most urgent, or the most obvious, while knowing that we do not tackle root causes, far too complex to discover. The xPERT-O software provides a solution to this: it is an interactive web application, simple and user-friendly, that allows to easily model complex situations presenting a large number of interconnected challenges and opportunities. With xPERT-O, one can visualize easily the problematic and highlight the key issues that need to be addressed.

Since the launching of xPERT-O mid-2017, we have already completed more than 30 projects for many interested customers and some (including big names such as Engie, Besix, AGC) are using it in their projects. In a few minutes, several users can simultaneously create and connect simple elements (NODES) with oriented LINKS to create a complex network. Thanks to algorithms of graph theory, xPERT-O then highlights the most influential nodes.

The applications of xPERT-O are numerous for all sectors (energy, environment, materials, e-health, technology industry, chemistry and biotech, etc.): modeling and optimization of complex processes, analysis of dangerous and / or conflict situations, improvement of organization, innovation development, knowledge consolidation, etc.

We are currently expanding the possibilities of xPERT-O, mainly in visualization possibilities in 3D Virtual Reality mode. This could lead to new ways of making analysis of situation.

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