# Loop Mining in the Encyclopedia of World Problems

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## Abstract

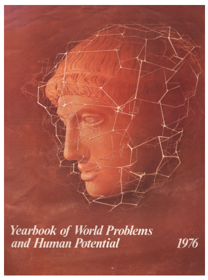
Any effort to tackle one problem has to take into account its relations to others. For a deeper understanding of a problem's context, we also need to study the nature of the relations. One relation type is *aggravation*; the systemic notion of one problem worsening, or being made worse by, another.

This paper focuses on the intricate web of aggravating relations emerging from almost 57,000 issues collected in the databases of the *Encyclopedia of World Problems and Human Potential*. The data is based on research started in 1972.

Several deep samples and a relatively shallow but full scan of the whole database show that most of the aggravating relation chains form straight strands. Some are short, other amazingly long. A very small subset of the chains loop back to their own initial or intermediate nodes. In such positive feedback loops, problems aggravate each other in a closed circuit, reinforcing each other *ad infinitum* — constituting structures familiarly known as *vicious cycles*.

A substantial amount of algorithmic optimization and sheer computer power is required to identify the rare circular chains. The effort and time needed to extract each subsequent layer increases steeply. Hence the name: "loop mining".

Due to the computation speed barrier we struggle to uncover the complete landscape of loops in the database. Nevertheless, we can report some interesting initial results, and there are troves of intriguing questions inspiring further research. This paper explores both.



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# 1. Introduction

Problems are sociable: none exist in isolation. Any effort to tackle one has to take into account its relationship to others. For a deeper understanding of a problem's context, it is important to also study the nature of the relationships. One of the possible “relationship types” is *aggravation*; the systemic notion of one problem worsening, or being made worse by, another.

This work examines the intricate web of aggravating relations emerging from the *Encyclopedia of World Problems and Human Potential*[1]. The Encyclopedia is an outcome of a long-term research project born more than four decades ago from the partnership of two international NGOs in Brussels. Over time, the Encyclopedia project has hand-picked and refined profiles of tens of thousands of problems occurring around the world: from notorious global issues all the way down to very specific and peculiar ones. Many of the problems fit the definition of intractable, wicked problems[4].

It is the intricate web of relations between the listed world problems, rather than just their descriptions, that makes the Encyclopedia’s body of work — notably, its database resources — particularly interesting. The reason is that (thanks to computer analysis) some relationships appear to form distinct systemic patterns that can be understood intuitively. Knowledge of such patterns may empower researchers and decision-makers to devise more efficient strategies aiming to tackle problems from a multidimensional perspective.

Several deep samples and relatively shallow but full scans of the whole World Problems database show that most of the aggravating problem chains form straight strands. Some are short, other amazingly long. A very small subset of the aggravating chains loop back to their own beginnings or to intermediate nodes. In such positive feedback[5] loops, problems aggravate each other in a closed circuit, reinforcing each other *ad infinitum,* thus constituting structures familiarly known as vicious cycles[6].

Due to the computation speed barrier and complexity involved, we so far struggle to uncover the complete landscape of loops in the database. We are, however, already able to shed some light on these peculiar patterns and outline the plausibly pertinent questions worth researching during the further course of the renewed project.

# 2. Encyclopedia as a data source

## 2.1 Project history

The *Encyclopedia of World Problems and Human Potential* is an outcome of a long-term research project initiated by the Union of International Associations (UIA)[2] and Mankind 2000[3] in Brussels in 1972. Both of the organizations are international non-profit associations. Whilst Mankind 2000 has been dormant since the end of the 1980s, further work has been carried forward under the auspices of the UIA.

The Encyclopedia is a set of databases. Most notable are World Problems, Global Strategies, Human Values, and Human Development. The databases are heavily interlinked both within and between them. The Encyclopedia is to some degree also interlinked with other major databases maintained by the UIA, notably the *Yearbook of International Organizations* and the *International Congress Calendar*.

For the greater part of its long history, the Encyclopedia was published in book form. Initially as a single tome under the title *Yearbook of World Problems and Human Potential* in 1976, then under the surviving title in 1986 and 1991. The final book publication in 1994 was spread over 3 volumes and included a CD-ROM.

The first online publication followed in 1999 thanks to a set of pioneering software tools (Advanced Revelation, Open Insight, S/Web) and boundless enthusiasm. In 2003 the online interface was completely rebuilt using open-source systems (PHP, MySQL), adding search and commenting possibilities as well as several types of dynamic network visualizations.

Since the end of 2012, the Encyclopedia is undergoing another major redevelopment. It is being ported into a modern open-source content-management system (Drupal)[12]. This means that the databases will be easily accessible on any device as well as instantly editable online, paving the way for future content updates using crowdsourcing techniques. There is a possibility of automatic data augmentation using complementary Internet sources. The project also brings creative changes in terms of governance, financing, and strategy. A strategic decision has been made to allow Encyclopedia data to be available, under an open-source licence (Creative Commons), for use by third parties. For this reason, the editing interface is built separately, allowing publication on any other platform or device using a platform-independent data exchange (API). The database of World Problems is already fully ported; the others are scheduled to follow.

The Encyclopedia is a long-term and open-ended project. The information it offers is always evolving and there is no notion of stable releases. It prides itself on being fiercely unbiased and free of censorship.

## 2.2 Web of aggravations

This paper is based on a study of the database of World Problems and its internal interrelations. Aggravation is just one type of relationship identified in the database. Others are the notion of *reduction* (one problem diminishes or is diminished by another), *hierarchy* (one problem being broader or narrower than another one), *simple, undefined relatedness*, and relations based on problem-specific typology, Encyclopedia-wide subject categorization, flat tagging, etc.

The World Problems database currently contains about 34,000 unique aggravating relationships. This may not seem much, but examining the network of these relations is not a small computational feat.

Earliest studies analyzing feedback loops in the database of World Problems date back to 1995 (Judge & McLaren, 2000[7]). In the early days they ran DOS, Windows 95 and Windows 98 computers for days on end.

## 2.3 Data eligibility and collection

Up to recently, the Encyclopedia databases have been populated with content based on information and activities reported by international organizations monitored by the UIA, complemented by information stemming from other sources, such as newspaper reports, scientific studies, books, etc. There was a focus on variety of perspectives rather than on the perceived importance of particular problems. Entries were edited by trained UIA editors.

In the anticipated future, the variety of information sources is likely to increase steeply with the number of different contributors. Additionally, some complementary data is now being automatically added from compatible databases, e.g. Wikipedia, WorldCat, Google Trends, etc. This is especially useful for data that is either secondary (e.g. illustrative images) or subject to frequent changes or evolution (e.g. statistics, trends, etc.)

The database of World Problems contains hand-picked and well-refined profiles of almost 57,000 problems occurring around the world: starting with notorious global issues and ending with very specific and rare ones — from famine and child labour all the way to nail biting and abduction by aliens. The Encyclopedia tries hard not to make judgement about what is or is not a problem. If an issue is perceived and reported as a problem by individuals or groups around the world, then it is likely to be included in the database.

## 2.4 Limitations

The Encyclopedia is a resource attempting to represent the world problems as perceived by humans. Whilst it may be of little use to even try to imagine viewpoints of problems perceived by other parts of nature, this is still an inherent limitation worth noting.

At the current stage, most of the data selected for inclusion in the Encyclopedia is a work of precious few individuals. While these editors are supposed to be strictly non-judgemental and follow specific editorial guidelines, it cannot be ruled out that their personalities have shaped the dataset in some ways. In other words, the content, and therefore also structures, that emerge from it are likely to be subject to some degree of systemic bias[8], the inherent tendency of a process to favor particular outcomes. It is expected that such any individual effects will be balanced out once the resource becomes the work of a much larger pool of unrelated editors (crowdsourcing mode).

The network of aggravating relationships, whether in straight or looping chains, is inherently fragile. Any addition or removal of a link means a sudden shift that may pervade a large subset of the database; new loops or interlocks (whether desired or not) may be added or disappear instantly. Each change, therefore, requires a lot of “whole-of-body” experience and surgical data skills on the part of the editor. Up to now, editors were blind to the database-wide consequences of such changes. For the future, there are plans to equip the editors with a specific loop-editing toolset and processes that will allow them to examine any such knock-on effects in advance.

# 3. Basic structures and terminology

In mathematics and computer science, graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects. A "graph" in this context is made up of "vertices" or "nodes" and lines called edges that connect them. A graph may be undirected, meaning that there is no distinction between the two vertices associated with each edge, or its edges may be directed from one vertex to another[9]. Whilst our analysis of the aggravating network does in fact make use of graph theory approaches, in this work we will most of the time keep referring to problems and aggravating links rather than vertices and edges.

Aggravation is a directed relationship. Unlike in generic relations, swapping the related end points changes the meaning of the situation. In other words, if problem A aggravates problem B, it does not mean that problem B aggravates problem A.

Let us use notation A → B to indicate a relationship between problem A and B, where problem A is aggravating problem B and problem B is being aggravated by problem A. We can then rewrite the above observation as: A → B ≠ B ← A.

If problem A aggravates problem B then problem B indicates that it is aggravated by problem A, and *vice versa*. As these two notions mirror each other (A → B means both), it is enough to follow one of them to get a full picture of all involved problems in the database.

If A → B and B → C, then these form an aggravation path A → B → C. Thanks to the chaining, we see that while problem A directly aggravates problem B, it also indirectly aggravates problem C.

Several deep samples and a relatively shallow but full scan of the whole World Problems database show that most of the aggravating relation chains form straight strands. Some are short, other amazingly long.

A very small subset of the aggravating chains loop back to their own beginnings or to intermediate nodes. An example could be A → B → C (→ A). In such positive feedback loops, problems aggravate each other in a closed circuit, reinforcing each other *ad infinitum* — constituting structures familiarly known as vicious cycles.

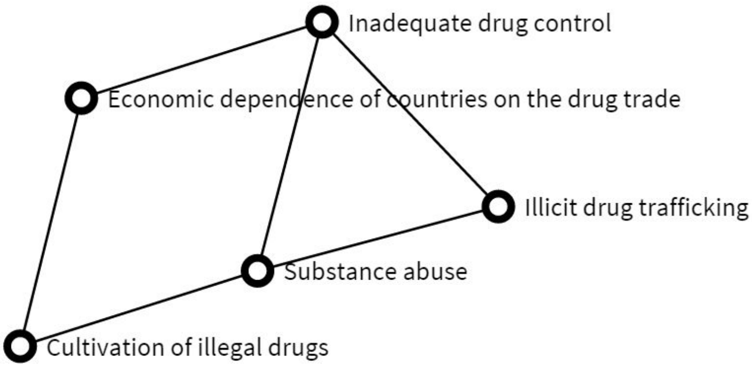
Many of these chains are known to interlock. That happens whenever a problem aggravates more than one other problem. A simple example could be loop C → E → F (→ C) which intersects with loop A → B → C (→ A) in node "C". There are several interlock possibilities — between straight chains, looping chains, or both. Loops can interlock in more than one node. Terms "intersection", "interlock" and "nexus" are all equivalent for the purposes of this work.

Let's define "loop level" as the number of nodes involved in a loop. For example, A → B would be a level 2 loop.

A real-world example of a 4-level loop:

Substance abuse > Cultivation of illegal drugs > Economic dependence of countries on the drug trade > Inadequate drug control > Substance abuse

In reality this loop shares 4 nodes and 3 edges with a larger loop involving “Illegal drug trafficking”; the result can be represented visually like this:



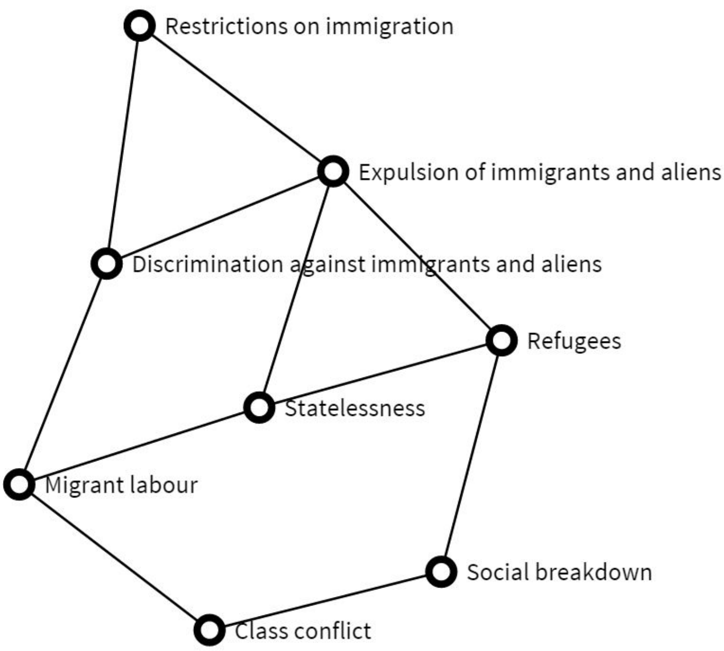

Another simple example:

Obesity > Abnormal blood fats > Diseases of metabolism > Obesity

An example of a 5-node loop:

Statelessness > Migrant labour > Discrimination against immigrants and aliens > Expulsion of immigrants and aliens > Refugees > Statelessness

and how it interlocks with related loops:



# 4. Loop mining algorithm implementation

Looping chains are much less common than the straight ones. In fact, a substantial amount of algorithmic optimization and sheer computer power is required to identify the rare circular chains. The effort and time needed to extract each subsequent layer increases steeply. Hence the name: "loop mining".

The basic decision for a loop mining algorithm is whether to search depth-first (DFS)[10] or breadth-first (BFS)[11]. DFS starts with a node and explores as far as possible long the branching relations before it backtracks. BFS explores the neighbour nodes first, before moving to the next level neighbours. Both eventually deliver the same results, though one tends to be more efficient than the other one. It is not trivial to determine which approach is more efficient for a given data set. After numerous tests we opted for breadth-first search, which appeared to be less memory-intensive for the server than DFS (which involved great many levels of recursion).

Thanks to BFS we can quickly discover low-level loops across the whole database — first the self-loops, then pair loops, triangle loops, square loops, etc. However, it remains a challenge, in terms of computing complexity / time, to mine deeper into the data set. BFS brings us shallow-depth loop analysis results but deep mines remain very hard to reach.

In the process of aggravating network analysis, our application of BFS algorithm returns four kinds of paths: a) straight terminal chains (those that we know cannot grow any longer because they end with a node that does not aggravate any other one), b) straight unresolved chains (those where we do not have that certainty), c) dirty loops (straight chain(s) intersecting with one or more loops), and finally d) pure loops (the resource we are mining).

Terminal paths (a) are retained as interesting in their own right. Unresolved paths (b) are thrown back into the process until they resolve to (a), (c), or (d). Dirty loops are discarded because they are in fact composed of chains that can be found back in (a) and (d) (we are indeed assuming that every interlocking structure is in fact made of pure loops).

The algorithm runs only as long as there are any unresolved paths. This is very useful, since it means that a loop mining, once started, will stop only after it has found all loops and terminal paths.

However, detection of all loops that exist in the data set is still an elusive goal because of the sharply increasing time it takes to process wider portion of the source data. For example, computation of database-wide loops up to level 6 (still very shallow) found almost 2200 loops, but the process took 92 hours and 16 minutes.

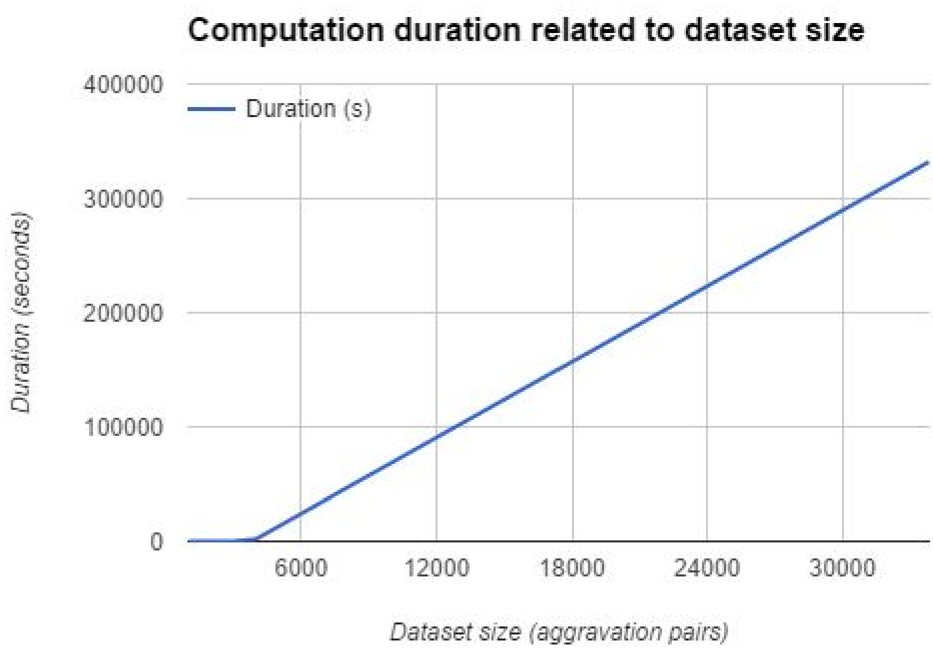
It is evident that we have to improve the algorithm drastically in order to be able to examine the full depth of the loop mine in any reasonable time.

## 5. Findings and questions

Given the enormous computational complexity, most of the long loops present in the database still remain undetected. Some of the findings described below may have to be revised appropriately once we are able to examine whole network at full depth.

### 5.1 Peeking deep

Thanks to the algorithm employed (breadth first), all short cycles ones are known. However, computation resources / mining time needed with each next loop level increase sharply.




Below is a table of a complete excavation of several partial sets of increasing size and with a shallow but complete dataset examination in the last column.

| | Partial dataset excavated fully | | | | | Whole dataset limited to depth 6 |
|---|---|---|---|---|---|---|
| Aggravating units | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 33,844 |
| Chain variations | 4,111 | 13,964 | 34,430 | 2,134,792 | | 53,030,422 |
| Mine depth | 9 | 14 | 16 | 33 | 32+ | 6 |
| Terminal chains | 556 | 775 | 1,019 | 1,217 | | 7,820,025 |

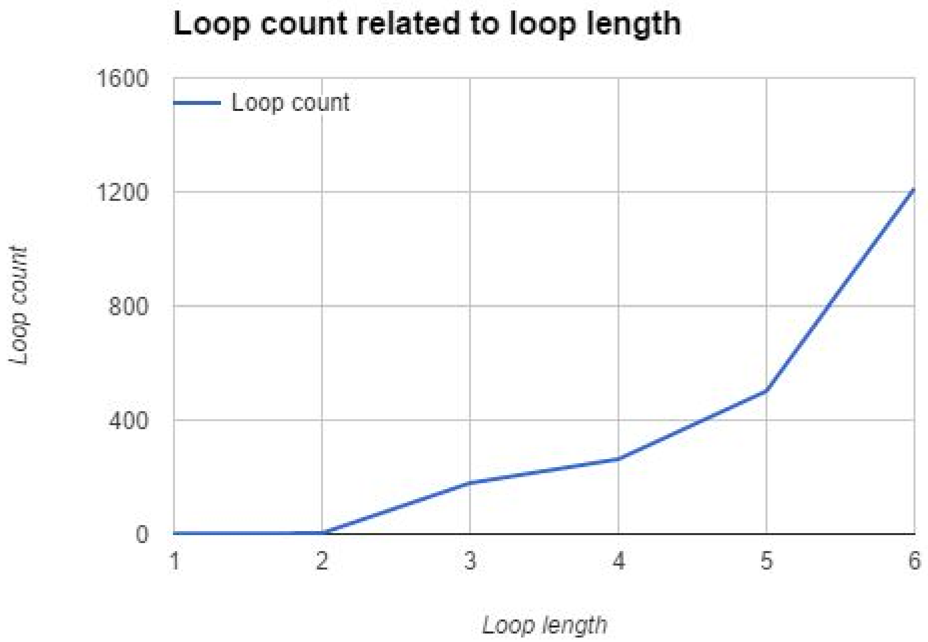
| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum chain length | 10 | 15 | 17 | 35 | ? | 7 |
| Pure loops | 1 | 1 | 9 | 25 | 32+ | 2,160 |
| Maximum loop length | 3 | 3 | 6 | 9 | ? | 6 |
| Duration | 00:00:02 | 00:00:09 | 00:00:25 | 00:37:33 | 32:00:00+ | 92:16:15 |

In the following table we see a distribution of loops of various lengths detected in the same datasets.

| | Partial dataset excavated fully | | | | | Whole dataset limited to depth 6 |
|---|---|---|---|---|---|---|
| Aggravating units | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 33,844 |
| Length 1 | - | - | 1 | 2 | 2 | 1 |
| Length 2 | - | - | 1 | 1 | 1 | 3 |
| Length 3 | 1 | 1 | 4 | 6 | 7 | 179 |
| Length 4 | - | - | 1 | 1 | 2 | 263 |
| Length 5 | - | - | 1 | 3 | 5 | 502 |
| Length 6 | - | - | 1 | 4 | 4 | 1212 |
| Length 7 | - | - | - | - | - | ? |
| Length 8 | - | - | - | 4 | 4 | ? |
| Length 9 | - | - | - | 4 | 4 | ? |
| Length 10 | - | - | - | - | - | ? |
| Length 11 | - | - | - | - | - | ? |
| Length 12 | - | - | - | - | - | ? |
| Length 15 | - | - | - | - | 1 | ? |
| Length 14 | - | - | - | - | 2 | ? |
| Length 15 | - | - | - | - | 1 | ? |
| ... | - | - | - | - | ? | ? |

We notice that the number of loops sharply increases with their length.
There are 179 loops of level 3, 263 loops of level 4, 502 loops of level 5, and finally 1212 of level 6. We see that the number of loops roughly doubles with every loop level. This seems to be natural: while considering longer and longer chains the chances of some of them looping back increase as well.

Here's a diagram of the loop count increase in relation to the loop length from the shallow dataset.




Loops have been proven to frequently interlock. Statistics are pending, but it seems that it is in fact harder to find a loose loop than an interlocking one. This is of course due to the fact that most problems aggravate more than one other problem.

## 5.2 Meaning waning

Some feedback cycles, especially the shorter ones, may be obvious. Others, having been mined using intensive algorithms that were previously not available, may come as a surprise even to experts in the respective fields. Provision of the latter is one of the main inspirations powering the mining and research of loops in the network of world problem relationships.

It appears that meaningfulness of the detected loops varies with their level (i.e. length of chain). Let us have a closer look at various groups of levels.

We know that single-level loops are definitely meaningless (a problem aggravating itself). They are only useful for signalling a linking error to the editors.

Loops of level 2 are most unlikely to be valid, although we cannot rule them out. A loop of level 2 would need to mean that those two problems exist in a strangely small universe of their own.

Loops of levels 3-5 are much more interesting. They are short enough to be either immediately known to researchers, or they can be relatively easily verified using thought experiments.

Loops of level 6 and more (approximately) tend to be too long for most people to grasp immediately. Besides, we can relatively easily notice a chain link that looks questionable (it might be valid, but it's difficult to prove quickly), thereby casting a shadow of doubt on the whole loop. In general, the longer loops feel less plausible.
However, we should ask whether they are intrinsically feeble, or whether they just appear that way.

- One possibility is that due to their length, the chance of them containing an inappropriate chain link grows higher, but that does not mean an absence of absolutely valid, plausible vicious cycles of level 10, 20, 50, or more.
- Another possibility is that they are for some reason intrinsically weak due to the yet unknown aggravation force distribution and dynamics (see later in this article). Is the dataset too small for "quality" long loops? For example, longer loops may be formed between problems of very different hierarchical types: usually an indication of an editorial mistake in forming links that is more easily detected in short loops, but far from evident in longer ones. Again, very long loops might be forming just because long chains naturally have a higher statistical chance to form a loop, even in absence of any discernible vicious qualities. Or, is there some kind of property limiting further aggravation?

## 5.3 Force distribution

We could say that in a straight chain of aggravating relationships each problem is aggravated with a "force" related to all problems that aggravate it. What the relation is remains unclear. If A → B → C, to what degree does A aggravate C? Is it a combined force of A and B? Or does the force from A diminish with its distance from C? Or is there some other formula, perhaps involving other properties, determining the force felt by C?

How is that situation different in a simple loop A → B → C (→ A)? Does the force on C grow infinite because the aggravation has no ending point and therefore runs in a closed circuit, or does it run down due to a type of unknown friction? Does an aggravating loop have other force distribution properties (which could perhaps be modelled on basis of problem typology, hierarchical position, etc.)? Can it even be stable over time, and if so, does it require some kind of external influence for that?

The situation is even more complex in a network with interlocking straight and looping chains. In visual spring/tension maps, nodes with more interlocks tend to become rigid, while loose strands and non-interlocking loop nodes are far easier to move around without disturbing the network. How do interlocks change complex tension balance and geometry and what does it mean for the nodes involved?

Does the force cause the original problems to splinter into new problems and aggravating pathways (consider how a problem often "creates" other problems). Could a force analysis help to assess the "tensile strength" of any node in a graph to see if it's running the risk of rupturing under the pressure?

What can actually be considered a real-world manifestation of an aggravation force: The frequency of its mentions in (social) media? The relative speed at which it causes its target(s) down the line to deteriorate?

These are not just academic questions. Knowing the distribution and dynamics of forces in aggravation chains, and particularly in aggravation loops, would allow us to be able to determine possible weak points or links. It is a consolation stemming from the very definition of a feedback loop that even the most vicious cycles can be disarmed by cutting out just one single link/point. Information of this kind could provide solid, informed tools for researchers and decision-makers attempting to tackle world problems.

But cutting out the weak link is not the only plausible strategy to mitigate the ill effects of vicious loops. Especially in loops involving wicked problems, which are by definition too vague or shifty to be effectively solved, the solution could lie in attenuation of the crucial points. Such attenuation could be realized, for example, by designing a virtuous (rather than vicious) cycle running through an appropriate problem node. Attenuation would not solve the problem or break a loop, but it would make the problem, and by definition all problems it aggravates, less intense.

# 6. Conclusions

Better understanding of the nature of vicious cycles emerging from a network of aggravating relationships between problems is promising to be a useful approach for systemic understanding of any problem's context. It may have the potential to equip researchers and decision-makers with powerful analytical tools and strategies to minimize or completely solve problems they set out to deal with.

Thanks to an implementation of the BFS algorithms we have successfully mined all low-level feedback loops from the World Problems dataset of the Encyclopedia. We have also succeeded with several full-depth excavations, but — due to the computational complexity / speed barrier — so far only of narrower segments of the database[13].

Apart from two transient chain types we have been able to retrieve straight terminal paths and pure loops. We have observed that interlocking loops and chains are by far more common than isolated ones.

Whilst there are much less loops than straight chains, only the short ones are really rare. We have seen that the number of loops increases sharply with the loop lengths.

It appears that meaning or usefulness of detected loops depends on their length. Loops of level 1 and 2 tend to be meaningless, then there is a short range of typically clear and useful looping structures, followed by a long tail of ever longer loops with decreasing perceived meaning. It remains a question whether that is an inherent property of long loops, or simply a result of lower comprehensibility and higher chance of systematic error.
It is possible that the longer loops, if properly validated, can surprise us with unexpected connections and dynamics which are otherwise hidden from us in too much complexity.

We have looked into force distribution and dynamics of aggravating paths. Problem nodes are subjected to exertions related to their position in the network. The distribution and dynamics of such forces is far from clear.

More than once we have employed the metaphor of mining to the retrieval of vicious cycles. That metaphor is fitting in many ways — just like mining minerals there is need for powerful machines, good maps, and a lot of patience. The algorithmic approach taken (BFS) is akin to surface mining, excavating layer by layer of waste to get to the prized rare ore. Vicious loops are intrinsically negative: our only chance at solving the problems they weave together is to break them free from the loops. This is where the metaphor stumbles a bit; we search for a treasure in order to be able to shatter it.

# 7. Acknowledgments

This work would have been incomplete and impossible without giving credit to a number of Encyclopedia gurus and other present and former colleagues, including Tony Judge, James Wellesley-Wesley, Nadia McLaren, Jacques de Mévius, Sinead Mowlds, Clara Fernández López, Rachele Dahle, Ryan Brubaker, Tim Casswell, and many others.

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## About the author

A temporarily conscious speck of dust harvesting our star's light...

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Born in Czechoslovakia in 1971, graduated from Technical University of Košice (Slovakia) in 1994 and from Catholic University of Leuven (Belgium) in 1998. Worked as a researcher and web developer at the Union of International Associations in Brussels between 2000-2012. Since February 2012 took up a position of Project Technical Lead for Hewlett-Packard at the Flemish Authority in Brussels. Also active with his own company, Vacilando, since 2003.

Slovak by birth, Belgian by law, European at heart. Loves travel, philosophy, creative writing, natural sciences (physics and astronomy in particular), the Web (Drupal and the open-source world in particular), and pretty much anything intriguing. He is a member of WFSF.

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