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Visual Techniques for Problem Solving and Debugging

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ABSTRACT

No matter how well we plan, issues and bugs inevitably occur. Some are easily solved, but others are far more difficult and complex. This paper presents a range of largely visual techniques for understanding, investigating, solving, and monitoring your most difficult problems. Whether you have an intractable SAS® coding bug or a repeatedly failing SAS server, this paper offers practical advice and concrete steps to get you to the bottom of the problem. Tools and techniques discussed in this paper include Ishikawa (fishbone) diagrams, sequence diagrams, tabular matrices, and mind maps.

INTRODUCTION

Puzzling problems occur in every facet of our lives – at work and at home. Some are easy to solve, others less so. Either way, we're all extremely well versed in problem solving techniques, aren't we? Perhaps not. In my experience, a lot of people's approach to problem solving is intuitive - based on gut feel and past experiences. Applying a structured approach to problem solving (or, a *number of* structured approaches) is not always the default approach.

Viewed another way, I've observed many colleagues following an established problem solving approach yet, when I talk to them, they are not conscious of doing so and we realize that they are not optimizing their use of the technique because they haven't studied it and understood the concepts and details.

The more complex the issue, the more people are involved. Often times the problem solving process becomes an exercise in getting the right people in a room and sharing their knowledge – a number of people have different parts of the solution, and we need to facilitate the process of revealing those parts and joining them together.

Problem solving is a human activity. This paper focuses on processes, not tools. Creation of the diagrams in this paper is assumed to occur within a facilitated meeting of subject matter experts. The greatest contribution made to the solving of complex problems is the interaction between the humans involved. The approach is secondary; it's simply a facilitator to get people talking, sharing ideas, and sparking new ideas in a constructive, structured manner. The use of a tool to facilitate the process is often counter-productive and just gets in the way.

However, the visual techniques described in this paper can form useful means of communication to the wider team. Tools can be useful for recording the outputs of a meeting, on an after-the-fact basis. I will list some tools that are useful for recording specific types of problem, solving techniques, but it should be remembered that they are best used as a repository for transcribing meeting outputs, not for guiding or influencing the interactions within the meeting.

The techniques and diagrams discussed are:

- DMAIC
- 5 Whys
- Ishikawa
- Mind Map
- Affinity
- Table / Matrix
- SIPOC
- Windows Problem Steps Recorder

END-TO-END PROBLEM SOLVING WITH SIX SIGMA DMAIC

Six Sigma is an approach to end-to-end process improvement and problem resolution. A key process within Six Sigma is DMAIC (pronounced Duh-May-Ick). DMAIC is an abbreviation for Define, Measure, Analyse, Improve, and Control. Used in combination, the five steps in the DMAIC process can be used to identify and resolve your most complex issues. As part of the Six Sigma approach, DMAIC can be used to improve existing programs and applications (pro-actively fixing them before they break!).

DMAIC has no explicitly visual elements, but the discipline of its steps is crucial for breaking-down your problem-solving efforts into controlled and managed phases. The five steps lead a team logically through the process by defining the problem clearly, implementing solutions linked to root causes, and taking steps to ensure the solutions remain in place. You can try skipping some of the steps, but in my experience they each contribute a valuable part of the lasting solution. The basics of each step are:

DEFINE - First of all, make sure you have a clear and precise definition of the issue. This might include a list of symptoms, plus some information about the negative impact on users and/or the system. Make sure you understand priorities and objectives. All-in-all, this is an exercise in pulling together what the team already knows, and making sure that each member of the team is heading off to solve the same issue

MEASURE - Use the measurement phase to gather additional information about the issue and the impact of the issue. The aim is to gather as much information as is practical, for the purpose of exposing the root cause or causes of the issue. It may be appropriate to capture temporary/intermediate files or network traffic, or to look for patterns in the surrounding activity in the system. Remember that this is a data capture phase, you're not trying to solve the issue at this point

ANALYSE - In the analysis phase, we want to pinpoint and verify root causes in line with our priorities and objectives. Always be prepared to distrust the evidence or the means by which it was collected. Be careful to avoid "analysis paralysis", i.e. wasting time by reviewing data that isn't moving the investigation forward. Remember that the aim is to identify the root cause (or causes), not to define one or more solutions

IMPROVE - This phase identifies solutions, prioritises and selects them. It may be appropriate to implement a pilot of one or two solutions prior to finalising your decision and implementing the definitive solution. Your choice of solution may be influenced by impact analysis that shows the full knock-on effect of implementing each potential solution. Be sure to gain proper confirmation of success from appropriate stakeholders before implementing the definitive solution

CONTROL - Often overlooked, the control phase is post implementation of the fix or improvement. Use the control phase to make sure that lessons were learned and that the problem doesn't re-occur (nor problems of a similar nature). Add additional test steps to your regression testing suite and put additional control & validation steps in your application. If it's not practical to stop all potential re-occurrences give thought to how the issue could have picked-up sooner and dealt with more quickly

The five steps seem like common sense, but in the heat of a high priority, complex issue it is easy to forget some of these basics. I find it helps me a great deal to have the five steps at the back of my mind as my team and I investigate issues. I mentally tick-off each phase and makes sure that we've got all the information we need to proceed to the next step.

FIVE WHYS: GETTING TO THE ROOT

When investigating problems and issues we need to overcome or bypass them, but we also need to be sure they don't happen again, so we need to be sure we get to the root cause and fix that.

One of the Six Sigma techniques offered in the analysis phase is "5 whys". Somewhat reminiscent of conversations with my kids when they were younger, 5 Whys teaches us that by repeatedly asking "why" we can peel away layers of the problem until we get to the root cause. Asking "why" 5 times is usually sufficient, but the general rule is to keep asking until the root cause is identified.

Note that the technique is intended to offer a structured route to help teams establish root cause. It doesn't work well when wrongly used to emphasise the person or blame, turning the 5 Whys into the Five Whos!

Here's an example I encountered a few years ago. Our daily production review revealed that one of our input files had failed to load last night. Why? Because it didn't match the data structure expected by our data loader (an extra column had been added to the right-side of the file). Why? Because the group that regularly supplies the data file had changed the structure. At this point the knee-jerk reaction was to assume we had some unexpected emergency coding to do in order to get our data loader to accept the new structure, but we continued with 5 Whys. Why was the data structure changed, and why were we not told? Because (the supplying group told us) the change had been tested with all systems that used the file and they weren't aware that we used the file. Why weren't they aware we used the file? We'd informed them, but there had been staff changes and they didn't keep formal records.

The negotiated resolution was for the data-supplier to a) temporarily supply two files (the old structure and the new structure) until we had time to plan and schedule a change to our data loader, and b) create a more formal process for recording consumers of the data file. Whilst we clearly needed to make a change to our data loader, the more crucial part of the analysis and diagnosis was the revelation that the data-supply team didn’t know that we were using their data; hence, the problem would have been repeated every time they changed their data structure. By following the 5 Whys to its full conclusion we managed to prevent a reoccurrence of the issue.

The purpose of 5 Whys is to find the root cause and to avoid assuming that a symptom is the cause. The objective is to find THE problem rather the problem. Used thoughtfully, 5 Whys can be tremendously powerful in helping you identify and resolve production problems (and problems during testing and development phases too).

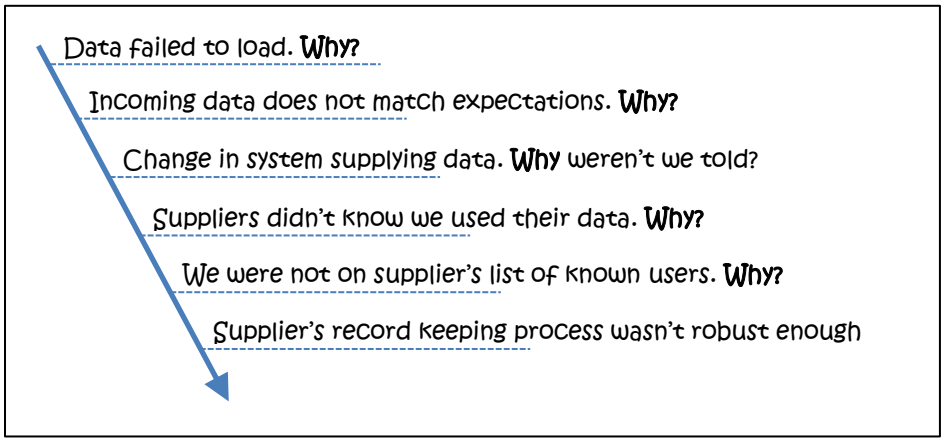

Figure 1. A Basic 5 Whys Diagram

Whilst not explicitly a visual approach, 5 Whys is the basic building block for the next technique: Ishikawa Diagrams. However, there's nothing to stop you drawing a basic diagram such as is shown in Figure 1 (above).

DEBUGGING WITH SIX SIGMA ISHIKAWA

5 Whys can be represented as a trivial/obvious technique, but this is to miss the point somewhat - sometimes we overlook the obvious and need reminding of it, and sometimes the simplest techniques can provide the most valuable results.

That said, no one technique is guaranteed to work in all circumstances. Ishikawa Diagrams, another part of the Six Sigma tool kit, build upon 5 Whys and offer a diagrammatic means of capturing the information. They're sometimes known as cause-and-effect diagrams or herringbone diagrams. Figure 2 (below) shows a basic example. Again, they appear simplistic; and once again, I say beware of dismissing the simple and obvious! As with 5 Whys, the interaction between the people using the technique is perhaps the heart of the process, but the process guides and facilitates the discussion and discovery of information. Like 5 Whys, Ishikawa diagrams will help you to get to the root cause of your issue.

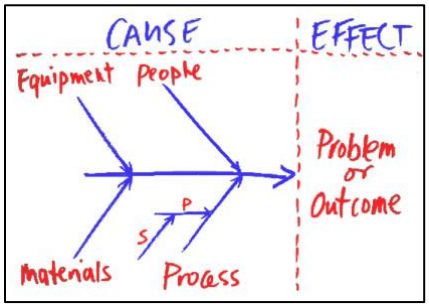

Figure 2. Basic Ishikawa Diagram

To use an Ishikawa diagram:

A) Determine a clear, brief description of the issue. Write it at the head of the fish bone skeleton, on the end of the spine

B) Decide the major categories for causes and create the ribs of the skeleton, writing one category at the end of each rib bone. These vary depending upon the industry and the situation in which the Ishikawa diagram will be used. I generally use a variation of the 6 Ms (used in manufacturing industries). These are shown in Table 1, below.

M	Description	Recommendation for SAS
Machine	Equipment / Technology	Hardware or software

M	Description	Recommendation for SAS
Method	Process	Process
Material	Includes Raw Material, Consumables and Information	Data
Man Power	Physical work / Mind Power (brain work)	People
Measurement	Inspection	Inspection
Mother Nature	Environment	Environment (physical or logical)

Table 1. Major Categories for Ishikawa Diagram

C) Now challenge the assembled group to contribute possible causes under each of the major categories. There are many ways to do this, such as by brainstorming or by asking each person to contribute one suggestion for each major category. Place each suggestion alongside the associated rib. As with mind-mapping, you might want to divide and sub-divide your suggestions. Remember, at this stage we're looking for potential causes, not solutions

D) Now review the diagram. Remove any suggestions which clearly don't apply to the specific issue at-hand, and try to garner further suggestions for categories where there are fewer suggestions. To drive down to the root cause, it may be appropriate to adopt a 5 Why approach for each suggestion

E) Discuss the diagram and agree the causes that you all think are the most likely to be at the root of the issue. It's okay to rely on experience and instincts at this point

F) Finally, develop plans to confirm that the potential causes are the actual cause. It is important to concentrate on proving the root cause before taking action to resolve the issue

Ishikawa diagrams are a great way to engage all participants and get a balanced list of ideas. They provide structure for any review session, and they encourage participants to push beyond symptoms to uncover potential root causes. However, you'll get the best results if you have a precise problem definition at the start of the review session.

If you look carefully, you can find tools for drawing nice, neat Ishikawa diagrams but, in my opinion, you can't beat getting a group of people armed with marker pens and sat around a whiteboard or drawing board. The human interaction is an important part of the process.

First documented by Kaoru Ishikawa in the late 1960s, Ishikawa diagrams are a firm part of many sets of practices including Six Sigma and the Information Technology Infrastructure Library (ITIL).

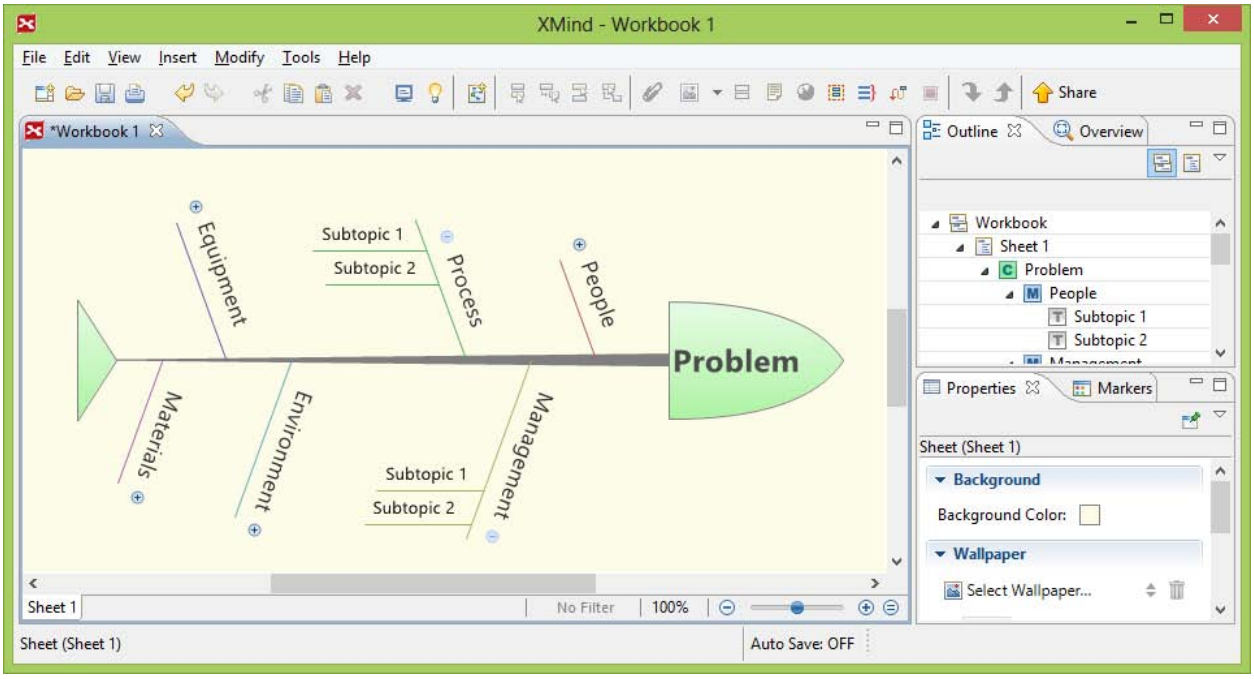

Figure 3. XMind - Cause & Effect Diagram

My preferred tool for recording Ishikawa diagrams is XMind. The tool offers multiple means of entering the information onto the diagram, and offers good printing and exporting options too. And finally, it offers a good range of different pricing options (starting with the free edition for personal use). Take a look at http://www.xmind.net.

However, there's a PROC ISHIKAWA in SAS (see Figure 4, below)! It's part of SAS/QC (for Quality Control of processes). I've never used any PROCs from QC so I can't vouch for it. If you're licensed for SAS/QC and using SAS Display manager, PROC ISHIKAWA provides an interactive environment in which you can:

- Add and delete arrows with a mouse. You can also swap, copy, and so forth
- Highlight special problems or critical paths with line styles and colour
- Display additional data for each of the arrows in a popup notepad
- Display portions of the diagram in separate windows for increasing or isolating detail. You can also divide sections of the diagram into separate Ishikawa diagrams
- Merge multiple Ishikawa diagrams into a single, master diagram
- Display any number of arrows and up to ten levels of detail
- Foliate and defoliate diagrams dynamically
- Save diagrams for future editing
- Save diagrams in graphics catalogs or export them to host clipboards or graphics files
- Customise graphical features such as fonts, arrow types, and box styles

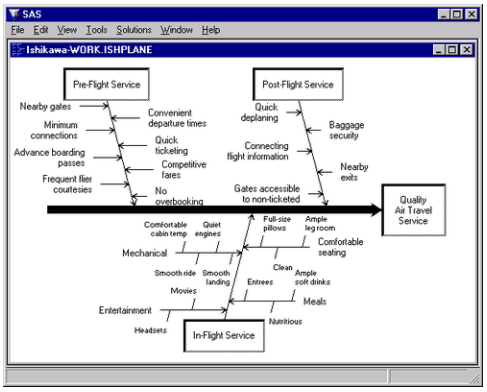

Figure 4. Ishikawa Diagram in SAS/QC

I stand by my assertion that flipcharts and marker pens are the best tools, but if you want to record your efforts (and perhaps make small changes subsequently), XMind and SAS/QC are both good options.

THE UBIQUITOUS MIND MAP

Who hasn't seen or drawn a mind map? Loved and despised in equal measure!

A mind map takes a central, core subject and then visually expands on it by adding visual links to associated subjects and then linking those subjects to related sub-subjects, and on and on. Mind maps are a great means of getting away from a linear approach and allowing a wider range of thoughts on a subject. Mind maps are a great means of reviewing a problem, its symptoms and its likely causes. In fact, mind maps can be useful in many aspects of our working life:

- Note taking
- Brainstorming (individually or in groups); problem solving
- Studying and memorisation; jogging your creativity
- Planning
- Researching and consolidating information from multiple sources
- Presenting information

- Gaining insight on complex subjects

The key to generating a good mind map is to make good use of colour and iconography. Adding elements such as these makes your visual readable on more than one level and can reveal otherwise hidden patterns. However, don't forget the business purpose of the exercise. I've seen plenty of mind maps that are more art than science (just try searching for mind map images in Google)!

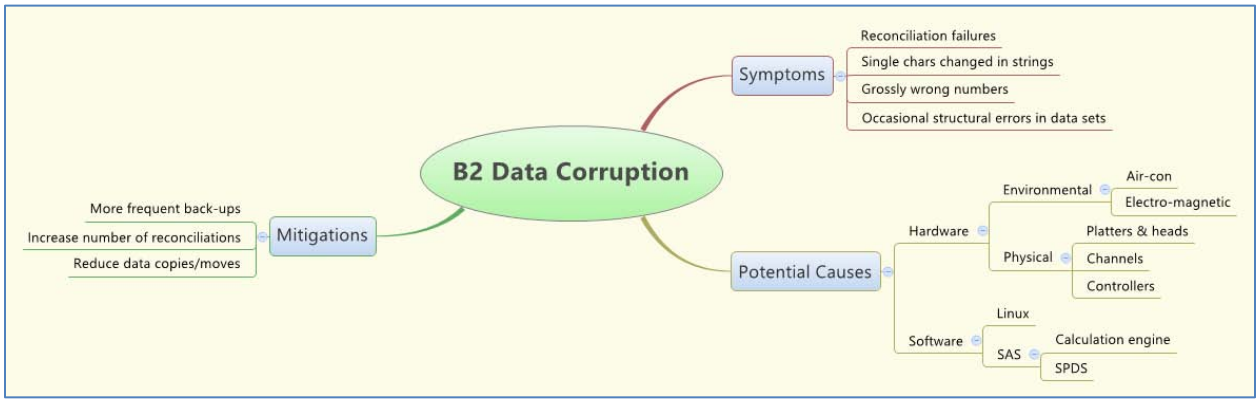

Figure 5. Mind Map for Data Corruption Issue

We're spoilt for choice when it comes to mind mapping software. I've already mentioned XMind for Ishikawa diagrams and it does a great job of producing mind maps too (see Figure 5, above). Other tools worth considering are the excellent open source FreeMind (http://freemind.sourceforge.net) and the cloud-based bubbl.us.

AFFINITY DIAGRAM

If the Ishikawa diagram and Mind Map are a means of drawing a tree-like structure then the Affinity Diagram is an alternative means of achieving the same purpose. The distinctive element of the Affinity diagram is that it is usually drawn bottom-up. Whilst the Ishikawa and Mind Map are drawn by starting with general topics (or questions) and then drilling down into detail, the process of drawing an Affinity diagram begins with a brainstormed set of detailed observations and facts.

The bottom-up idea can sound unstructured, but is it ever a bad thing to have too many ideas? Probably not, but if you've ever experienced information overload or struggled to know where to begin with a wealth of data you've been given, you may have wondered how you can use all of these ideas effectively.

When there's lots of "stuff" coming at you, it is hard to sort through everything and organise the information in a way that makes sense and helps you make decisions. Whether you're brainstorming ideas, trying to solve a problem or analysing a situation, when you are dealing with lots of information from a variety of sources, you can end up spending a huge amount of time trying to assimilate all the little bits and pieces. Rather than letting the disjointed information get the better of you, you can use an Affinity diagram to help you organise it.

Also called the KJ method, after its developer Kawakita Jiro (a Japanese anthropologist) an Affinity diagram helps to organise large amounts of data by finding relationships between ideas. The information is then gradually structured from the bottom up into meaningful groups. From there you can clearly "see" what you have, and then begin your analysis or come to a decision.

Here's how it works (the sequence is summarised in Figure 6, below):

1. Make sure you have a good definition of your problem (ref: DMAIC)
2. Use a brainstorm exercise (or similar) to generate ideas, writing each on a sticky note. Remember that it's a brainstorm session, so don't restrict the number of ideas/notes, don't be judgemental, don't be afraid to re-use and enhance ideas on existing sticky notes, and don't try to start solving the problem (yet)
3. Now that you have a wall full of sticky notes, sort the ideas into themes. Look for similar or connected ideas. This is similar to the Ishikawa's ribs, but we're working bottom-up, and we're not constrained a by a set of ribs as our start points. When you're doing this, it may help to split everybody into smaller teams
4. Aim for complete agreement amongst all attendees. Discuss each other's opinions and move the sticky notes around until agreement is reached. You may find some ideas that are completely unrelated to all other ideas; in which case, you can put them into an "Unrelated" group

5. Now create a sticky note for each theme and then super-themes, etc until you've reached the highest meaningful level of categorisation. Arrange the sticky notes to reflect the hierarchical structure of the (super)themes

You're now in a similar position to where you would be with an Ishikawa diagram and can proceed accordingly. The benefit of the Affinity diagram over Ishikawa is that the bottom-up approach can produce different results and thereby offer different perspectives on your problem.

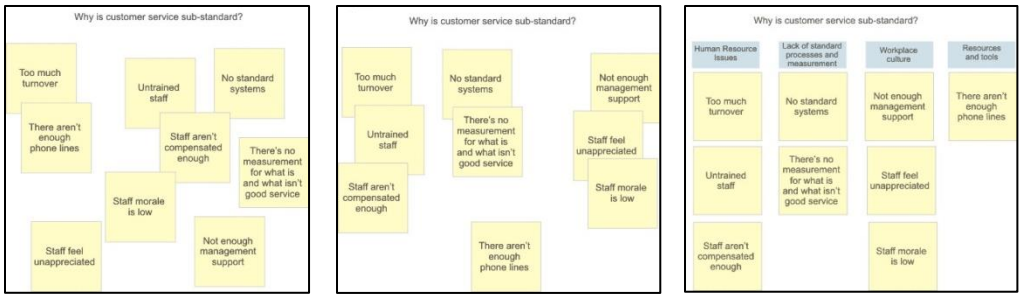

Figure 6. Sequence of Activity Producing an Affinity Diagram

Affinity diagrams are great tools for assimilating and understanding large amounts of information. When you work through the process of creating relationships and working backward from detailed information to broad themes, you get an insight you would not otherwise find. The next time you are confronting a large amount of information or number of ideas and you feel overwhelmed at first glance, use the Affinity diagram approach to discover all the hidden linkages. When you cannot see the forest for the trees, an Affinity diagram may be exactly what you need to get back in focus.

THE HUMBLE TABLE / MATRIX

An integral part of our standard office tools for decades, the humble table is often over-looked as an excellent tool for capturing lists and relationships between elements of a problem.

When comparing two lists, there is sometimes a simple one-to-one relationship which can be easily documented in a side-by-side table. However, when a single item from one list may be related to several items in the other list, then the side-by-side format does not work, as in Figure 7 (below).

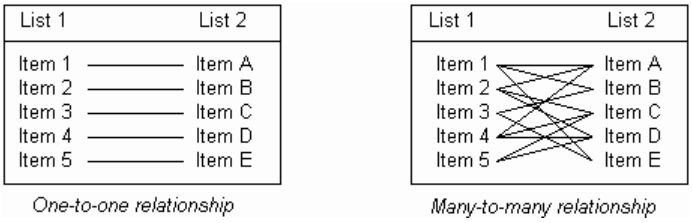

Figure 7. Relationships Between Lists

The Matrix diagram allows two lists to be compared by turning the second list on its side to form a matrix. Figure 8 (below) shows how the relationship between two items can now be indicated in the square or cell where the row and column of the two items cross.

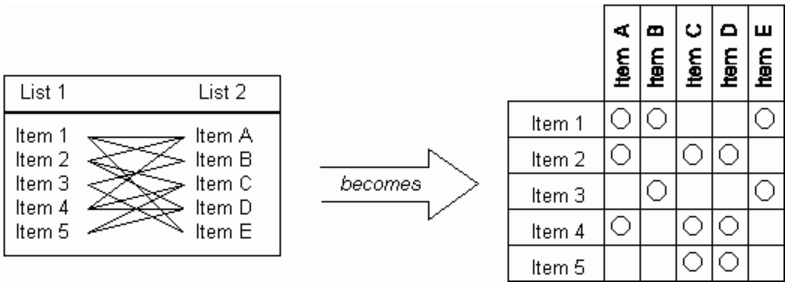

Figure 8. Many-to-Many Relationships in a Matrix

The matrix can be thought of as a special form of table where the cells contain a simple symbol or number, which is derived from a defined set of rules.

A common extension to matrices is to use different symbols in the matrix cells in order to show the strength of the relationship between pairs of items. The overall strength of the relationship between an individual item and the whole of the other list can also be determined either by visually checking the diagram or by allocating a numerical value to each symbol and summing rows and columns.

The basic matrix shown above is the most common matrix in use, and is called an L-Matrix, due to its shape. Where more than a simple comparison of two lists is required, other matrices are available, and are shown inFigure 9. These also have descriptive letter names which indicate their shape.

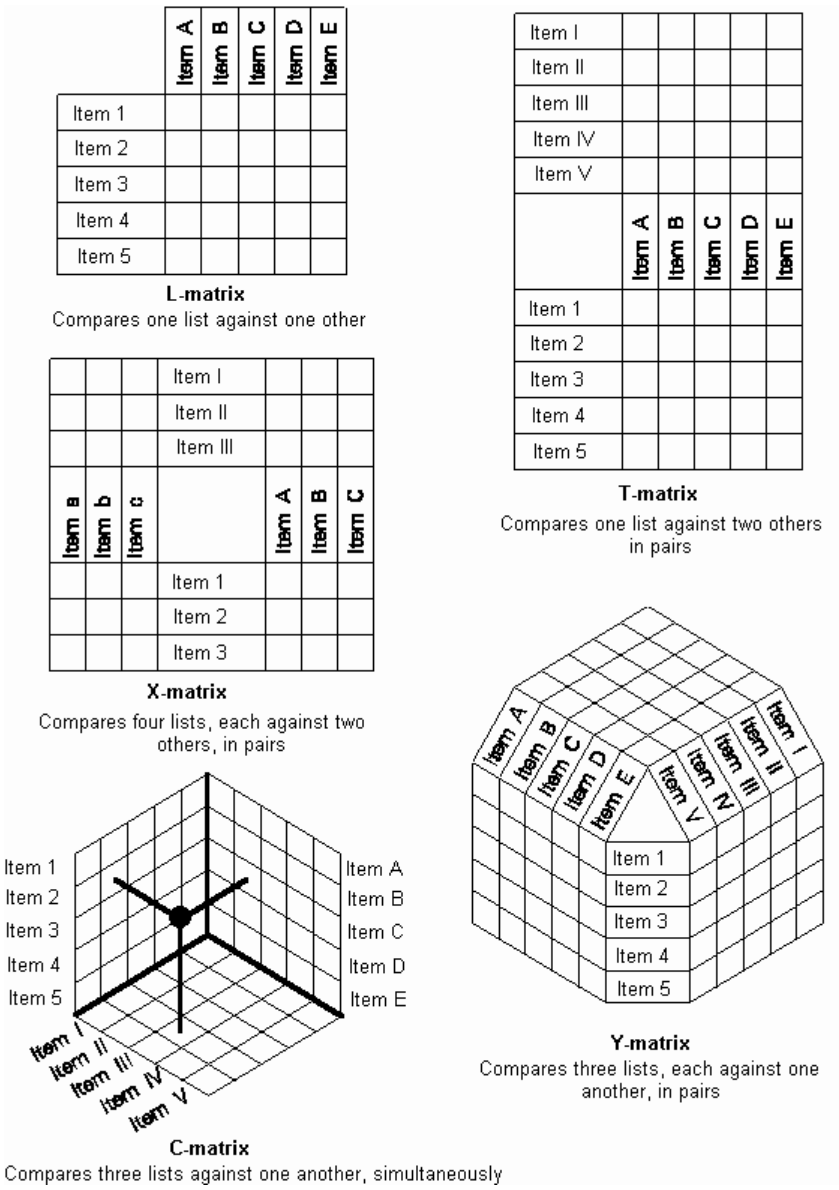

Figure 9. Different Types of Matrix Diagram

MEETING PREPARATION WITH SIPOC

Creation of the diagrams in this paper is assumed to occur within a facilitated meeting of subject matter experts. As with all meetings, preparation and planning is almost guaranteed to increase the value of the meeting's outcomes. A SIPOC diagram is a good tool for helping the meeting organiser to make sure all of the necessary subject matter experts and all of the useful material will be available during the meeting.

A SIPOC diagram also communicates the meeting's purpose to the attendees and helps ensure the right outputs are produced.

SIPOC is an acronym for Supplier, Input, Process, Output, and Customer. There is more than one way to approach a SIPOC diagram but my favoured approach is to think of the process that you wish to follow in the meeting; think of the agenda. For example, as meeting organiser, you might want an agenda that looks like this:

- Situation reports from those with information on the symptoms and impact of the issue
- Brainstorming session to identify potential causes
- Create Affinity Diagram from causes
- Prioritise causes (in order to decide the sub-set that is most worthy of immediate action)
- Create a resourced action plan
- Etcetera – for example, consider temporary mitigations & bypasses, and a communication plan

For each step in the agenda, there's an implicit output (and a set of "customers" who will use them); some outputs may have been explicitly requested by senior stakeholders or technical partners. However, just like writing a computer program, we need to identify the inputs are required to "feed" the process and allow the generation of the

desired outputs; and we need to know who will supply the inputs, i.e. who will attend the meeting and/or send the materials to the meeting organiser. We capture all of this in our SIPOC diagram (see the example in Table 2, below).

Supplier	Input	Process	Output	Customer
Brian	Listed description of symptoms	1a. Reporting Team sit rep	Shared understanding of problem	Attendees
Peter	Outcome from initial review of code. Potential points of failure	1b. Development Team sit rep	Shared understanding of potential and likelihood of a code fault (versus other causes)	Attendees
Stewie	Logs from disks & controllers. Potential points of failure	1c. Storage Team sit rep	Shared understanding of potential and likelihood of a h/w fault (versus other causes)	Attendees
	(1) above	2. Brainstorming session to identify potential causes	Sticky notes with description of all potential root causes	Attendees
	(2) above	3. Create Affinity Diagram from causes	Affinity diagram	Attendees plus Service Mgr (Lois)
	(1) & (3) above	4. Prioritise causes	List of potential causes to be given immediate investigation	Attendees plus Service Mgr (Lois)
	(4) above	5. Create a resourced action plan	Resourced action plan	Attendees plus Service Mgr (Lois) and application owners (Meg & Chris)
		Etcetera		

Table 2. Example SIPOC Diagram

In some respects, a SIPOC diagram is just a souped-up agenda, but the addition of the extra columns helps ensure everybody enters the meeting fully prepared and they all know what is the expected outcome(s) of the meeting. In this way, the meeting is more effective.

Identification of suppliers ensures it is clear who will provide each piece of information; identification of customers ensures all stakeholders will receive what they want/need from the meeting.

WINDOWS PROBLEM STEPS RECORDER

I said earlier that I would focus on people and processes rather than tools. However, if you're using Microsoft Windows, you may find this tool useful. Windows 7 Problem Steps Recorder (PSR), known more simply as Steps Recorder in Windows 8, is a well-hidden nugget of gold in Windows! Have you ever had the task of recording the steps you took in Windows? Perhaps to describe a problem, or maybe to create some user guide documentation, or perhaps to record your activities for audit purposes. Regulated industries such as pharmaceuticals demand that evidence of test execution be collected.

The PSR is a great tool for quickly documenting a series of steps that you take on your PC. Screenshots are automatically captured by the recorder (showing keystrokes and screen clicks) and comments can optionally be added to provide a more detailed description of what is happening. Once the recording is finished, the screenshots and comments are saved to a zip file.

Figure 10. Windows Problem Steps Recorder

To start the Problem Step Recorder, click the Start menu, then type Problem in the search field; you will see Problem Step Recorder in the results list (in Windows 8, type Steps). The resulting application window is shown in Figure 10, above. Click the Start Record button. It's pretty simple to use, but if you need an overview you can refer to the PSR

video on Microsoft Technet (http://technet.microsoft.com/en-us/windows/dd320286); for further help, check the How Do I Use PSR article on the Microsoft web site (http://windows.microsoft.com/en-US/windows7/How-do-I-use-Problem-Steps-Recorder).

CONCLUSION

Humans are visual-oriented creatures. Yet, many people do not use any form of visualisation capabilities, whether for goal-setting or simply solving problems. My personal experience shows that problem-solving is easier when you approach it from a "visual thinking" process. This can be as simple as creating a few sketches or as complex as a structured diagram using predefined symbols.

Diagrams stimulate both the creative (right) half of the brain as well as the logical (left) half. Using colours helps, too, especially if there is some structure in how you use colour. For example, you could use different coloured text to represent different types of solutions, or coloured lines, backgrounds, borders, etc.

The benefits of approaching problem-solving from a visual perspective include:

- It is easier to absorb visual diagrams rather than a mass of text
- It is easier to update a diagram than to rewrite text
- They're a great memory trigger for a more complex concept. So if you only have time to sketch out an idea but in your mind you have some complex thoughts about your idea, a diagram can help you retrieve your thoughts at a later point

There are a few downsides that must be considered too. I've listed some below. In my experience, a good facilitator can overcome these issues:

- As with writing the first word of a report, it can be difficult to commit to the first symbol or element in a diagram. Some of the approaches above help with this by offering starting points, e.g. Ishikawa's six Ms
- Some people feel compelled to be an artist and are held back by their inwardly perceived lack of drawing skills. I have found that the knowledge that the diagram will ultimately be recorded in an electronic form, e.g. XMind, puts peoples' minds at ease
- Might feel like you have to get it right immediately. A plentiful supply of paper and/or use of a wipeable whiteboard can help. However, it must be emphasised that it's the quality of the content that's important, not the presentation

In my experience, the upsides far outweigh the downsides. Diagrams are an excellent means of applying a form of structure to your problem solving, guiding your colleagues through a process without them feeling constrained or burdened by their knowledge of the process.

I hope all of your problems are little ones!

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Andrew is Managing Director of RTSL.eu, a leading European SAS specialist consultancy. Having first used SAS in 1983, Andrew's experience and knowledge covers breadth as well as depth. Andrew shares his experience through his www.NoteColon.info blog and has presented conference papers in the UK, Europe and USA on a variety of SAS topics.

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