Practical tools for Group Model Building

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Several practical tools for Group Model Building (GMB) are introduced: Cling sheet whiteboards in combination with self-adhesive facilitation cards; the Modeling Tray and the use of digital pens for recordings.

Cling sheets are plastic-foil whiteboards that provide vast workspaces limited only by available wall-space. Self-adhesive facilitation cards allow for easy rearrangement of variables to clear up visual clutter and make feedback loops easier to pick up.

In the whiteboard-&-pen mode of GMB, the facilitator is usually the person editing the model, whereas it is normally the content coach editing the model in the computer-projector-mode. The Modeling Tray This allows for shifting role of the group-model-editor can back to the facilitator. Furthermore, the Modeling Tray allows for using the computer-projector-mode when conducting a workshop alone.

Digital pens combine the functionality of hand-written notes with the advantages of audio-recordings. They allow for more meaningful notes and decrease post-processing time after the workshop.

Keywords: Tools, Gadgets, Group Model Building, modeling team roles, participatory modeling, cling sheets, Modeling Tray, Digital Pens

Cling Sheets and self-adhesive facilitation cards

Introduction and problem definition

The actual model construction in Group Model Building (GMB) is usually carried out either using a computer with the model projected on a screen or using thick pens to write on a whiteboard or large sheets of paper (Vennix et al. 1996). Conventional

whiteboards are usually rather small and thus provide very limited workspace. Writing smaller to fit more structure onto the same space is not an option, because working with groups requires a certain minimum size of letters to keep variable names legible. This problem grows with group size because larger distances of viewers require larger letters.

Large sheets of paper provide workspaces as large as the available wall-space but have the disadvantage that unlike whiteboards, erasing is not possible thus preventing editing of the structures. Even on whiteboards reordering is more cumbersome than in the computer-projector mode, which allows for simply dragging variables to other places with the connecting causal arrows staying connected to them.

The use of magnetic hexagons on whiteboards (described in Vennix et al. 1996) makes reordering of variables possible skipping the step of erasing variables, but they still require redrawing of arrows and link polarities and in addition suffer from the workspace limitations caused by the whiteboards.

Tool description & Hypotheses

Whiteboards assembled from cling sheets (described in Andersen, Richardson 1997) are an interesting alternative to conventional whiteboards for group model building. This whiteboard-foil sticks to surfaces via static electricity. Cling-sheet whiteboards combine the advantages of large sheets of paper with the advantages of whiteboards: vast workspaces and erasability.

Self-adhesive facilitation cards (*Stick-it* cards) are similar to normal facilitation cards. They can take the role of the magnetic hexagons, in making whiteboard use more flexible by allowing for rearranging of variables without rewriting them. They also make the diversity of colors and shapes of facilitation cards available for use on whiteboards. This adds to the color-coding possibilities of the pens used.

Cling sheet whiteboards in combination with self-adhesive facilitation cards also have lower costs than buying many/large whiteboards. Furthermore, they can quickly be assembled in rooms that do not offer conventional whiteboards.

Mode of use, experiences & discussion

When buying cling sheets the checkered versions should be avoided because the structures are much easier to read on the white versions. Turning around the checkered versions so the checkers are facing the wall is of little help as they shine through the foil.

Cling sheet whiteboards only work well on reasonably smooth walls (woodchip wallpaper or roughcast will not work). Therefore the walls of the room should be inspected prior to the workshop. If experienced modeling team members cannot do this themselves in due time ahead of the workshop, it can also work to have the clients send pictures of the walls (both over-view photos and close-ups of the surface, ideally with a ruler indicating cm/in in the picture.

The use of transparent glass walls poses special challenges: the overlap of the rows needs to be minimized because it leads to dark stripes and even the slightest billows become visible distractions. Thick, dark pens are required. If possible transparent walls are to be avoided.

Before setting up a cling-sheet whiteboard, it is a good idea to put scotch tape over all the perforations. This prevents the pens from writing on the wall behind the cling-sheets. The tape should be applied on the backside of the cling-sheets because if it is applied on the front, the ink of the pen will not stick to it.

The cling forces are often not sufficient to hold large whiteboards on all surfaces. Therefore scotch/crepe tape should be applied in the corners and on the edges. Avoid other types of tape (e.g. duck tape) as it may not come off without damaging the surfaces it was taped to. The right tension on the tape is important as both too much and too little tension can cause the foil to billow.

As most people tend to draw more from top to bottom than the other way around when drawing causal arrows, it is wise to let each row of cling sheets overlap the row below. A few scotch tape connectors are also advisable (ideally on the back or rather small).

When the walls that the cling sheets are taped to are also white, drawing a frame at the whiteboard edge with a thick red permanent marker can mitigate the danger of drawing over the edge of the whiteboard onto the wall. This marker should be stored separately from the other erasable markers so they are not accidentally applied for regular whiteboard use.

Not all whiteboard markers (and especially not all flipchart-markers) will function properly on cling sheets. Some markers seem to work fine at first, but then experience an undesirable ‘fading’ effect. The cause is that the ink of these pens contracts due to the surface tension of the liquid ink before it dries. It is therefore a good idea to test all markers before the workshop on cling-sheets and wait for at least half an hour to see if the appearance changes. This should not be done in the morning before the workshop but back home. This means: the modeling team is well-advised to bring their own markers even if the customer is providing a facilitation box.

After a few hours have passed, the ink becomes harder to erase (this often differs with marker color and brand). It has proven useful to bring a kitchen rag and some alcohol-based glass cleaner spray to cleanly erase dried ink.

The opportunity for rearranging variables implies that the model development process is not captured in the final result alone. It may therefore be wise to take some photos before each rearrangement phase to capture intermediate versions.

It should be noted that cling-sheet whiteboards cannot bring all of the flexibility of the computer-projector method to the whiteboard: reordering still requires redrawing the causal arrows and link polarities. As a result, reordering on whiteboards may still tend to be done less than in the computer-projector mode because it may feel too cumbersome and time-consuming to do this on the fly while modeling.

While cling-sheet whiteboards can be used several times, they do deteriorate: after some use, they don't look completely white anymore. Modeling teams may therefore tend to set up fresh cling-sheets every so many times or even with each new group. Together with the self-adhesive facilitation cards this does lead to a pile of waste after a workshop that can be avoided in the computer-projector mode.

Further research

In some setups participants not only provide verbal input but also wield the pen. This is especially the case if the aim of the workshops is more about learning (systems thinking capacity building) than about the analysis of specific problems. If participants set up their own causal loop diagram, they usually feel satisfied with something that is visually still much too cluttered to be understood by anyone who has not developed it. It would be good to develop a GMB-script that specifically addresses this issue activating participants to clean up their results in an extra round.

Conclusions

An unrivaled advantage of cling-sheet whiteboards is the size of the workspace thereby allowing for seeing the model in totality. This is contrasted with the computer-projector-mode that requires scrolling around. Even zooming out is limited by the resolution of the projector that limits legibility of small letters. Cling-sheet whiteboards are also the mode of choice for workshops in which participants are supposed to edit their models themselves.

The Modeling Tray

Introduction and problem definition

While the combination with self-adhesive facilitation cards increases flexibility in reordering and thereby does lead to a reduction of visual clutter somewhat, visual clarity may still not reach that of computer models. Furthermore, it is still less flexible than the computer-projector mode approach, where arrows and link polarities are attached to variables and move with them, whereas on a whiteboard, the arrows need to be redrawn. As a consequence, computer use allows for on-the-fly clean-up to enhance visibility whereas whiteboard models are often cleaned only up the end or even after the GMB workshop. This not only has the disadvantage that the refined version will not have the same recognition value. In fact it may feel *so* much less familiar to the participants than the original whiteboard version, that an additional activity is needed to transfer model ownership from the whiteboard model to the refined computer representation (script: *Transferring Group Ownerships from One Image to Another*) (). As a consequence, the modeler may feel a tradeoff between refining the model optimally and keeping some of the original visual structure to ease recognition by workshop participants.

One subliminal reason for many GMB facilitators still using whiteboards and pens in spite of these limitations, may be that the computer-projection method actually invokes

a subtle but important shift in roles within the modeling team (see Vennix et al. 1996 for details on roles within the modeling team). This role-shift becomes most clear by introducing an additional role of the *group model editor*. In whiteboard-mode this role falls together with the *facilitator* role (who holds the pen), whereas in computer-projection-mode this role is usually combined with the *content coach* role (who operates the computer). The facilitator indicates to the *group-model-editor* what structures she wants to see and he would then implement these structures on the group-model projected onto the screen. It is not until he is invited to do so by the facilitator that the *group model editor* plays out the role of *modeler/content coach* to introduce some ideas of his own. In whiteboard-mode, the person in the *modeler/content coach* role is free of the role of *group model editor* and can therefore exclusively concentrate on thinking about the model, modeling ahead of the group, trying different approaches in parallel and helping the facilitator to think of ways to conceptualize participants ideas in SD modeling terms.

This shift of the *group model editor* role from the person holding the *facilitator* role to the person holding the *content coach* role has been necessary when using computer- instead of whiteboard-mode for the following reason: The *facilitator* needs to interact with the group, and this interaction is not only via spoken words, but also importantly via body language, which is greatly inhibited when sitting behind a computer. Such body language includes constant eye contact, talking with hands and arms and on occasion walking towards a workshop participant that the facilitator is talking to (which is eased by a seating arrangement of a U-shape or group tables). The latter may happen for the simple reason that the participant has a low voice or it may (sub-)consciously indicate an enhanced listening intensity by the facilitator. The facilitator may have a hard time understanding the aspects that the participant is trying to explain to her and wants to signal 'I'm not giving up on understanding you, I'm trying hard' to invite the person to try explaining more. At other times the facilitator may want to encourage a silent person to participate. Such a move may sometimes also be used to shield a participant against unfavorable group dynamics e.g. whey the rest of the group perceives a question as 'dumb'. The facilitator taking sides with that person holds the opportunity that participants will feel more open towards asking questions without the fear of loosing their face. Hardly any of this is possible when sitting behind a computer. Furthermore, sitting behind a computer would send a body language message to the workshop participants that the computer operating facilitator was interacting with that machine, was communicating with it and thus was diverting some of her attention from the group to the machine. Worse yet, a computer operating facilitator would appear to be 'hiding behind wall' which the screen of the laptop is building up between her and the workshop participants. So far, the only alternative to sitting *behind* the computer – sitting *in front* of it – would mean pointing ones back to the group and therefore isn't an option.

Shifting the role of the *group model editor* not only diverts attention of the *content coach* from modeling ahead but it also requires facilitator and *content coach / group model editor* to being a very effective team. The *group model editor* will gather from the discussion of the *facilitator* with the group much of the facilitator wants represented on the screen. If the team of the two has not reached this effectiveness yet, the facilitator will frequently need to shift communication from the group to the *group model editor* to

give orders of what to model, which slows down the process and may even sometimes hold the danger of loosing participants attention.

In addition to the undesirable consequences of the above-mentioned role shift, sometimes the (suboptimal) need can arise to conduct Group Model Building sessions alone. There can be many reasons including financial constraints of the project or lack of further members of the modeling team. Since in this case all oft the modeling team roles are concentrated in one person, the *facilitation* role, including the above-mentioned body language requirements, thus far has precluded the use of the computer-projection method leaving the whiteboard-method as the only way to go.

To alleviate some of these shortcomings I have devised a tool that allows for keeping the *group model editor* role with the person holding the facilitator role even when using the computer-projector method: The Modeling Tray.

Hypotheses

The Group Modeling Tray:

- allows for using the computer-projector method when conducting GMB workshops alone
- compared to pen and whiteboard, the facilitator does not have to block participants view of the model
- gives the *group model editor* role back to person holding the *facilitator* role and thereby lets modeler/content coach focus on content, thinking & modeling ahead (just as in whiteboard mode)

Tool description & construction

The basic technical idea is relatively simple: the facilitator needs a remote/wireless way for operating the pointer (drag around, right button, left button) as well entering and editing variable names.

Figure 1: Modeling tray in action

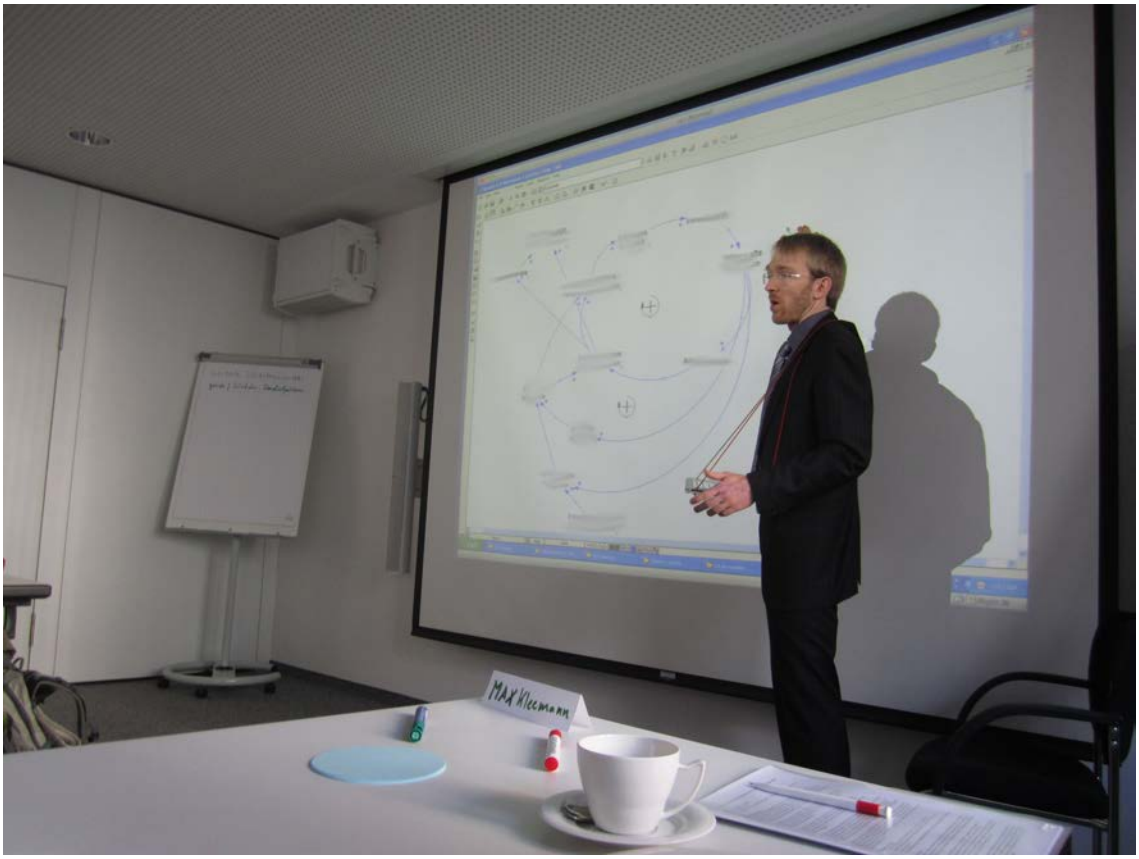

Figure 2: Close-up of modeling tray in action (earlier version without the wide neck strap introduced in later versions)

In this case this has been implemented by using a wireless keyboard and wireless trackpad that have been mounted on a plywood board that is supported by a length-adjustable neck strap similar to a vendors tray (see Figure 1 & Figure 2). The attachment of the keyboard and trackpad to the tray has been implemented using velcro-tape (see Figure 4). Note that the velcro-tape is attached to the upper edge of the trackpad only, because the clicking switch of this specific trackpad (Apple) is built into the two rubber knobs at the lower edge. So additional velcro at the lower edge would inhibit clicking. Attachment needs may vary when using trackpads of other manufacturers. To make the tray more comfortable to wear, a wide strap taken from a bag has been mounted to the tray (see Figure 3 & Figure 4; not yet included in the versions seen in the previous pictures). The yellow strings in the picture are made from accessory cord available in outdoor/climbing shops. The connection between the accessory cord and the neck strap is implemented as a clove hitch, which facilitates quick adjustment of the inclination of the tray. The accessory cord runs through holes drilled into the plywood board and have a simple knot below it. The cord ends have been welded with a lighter to keep them from frazzling.

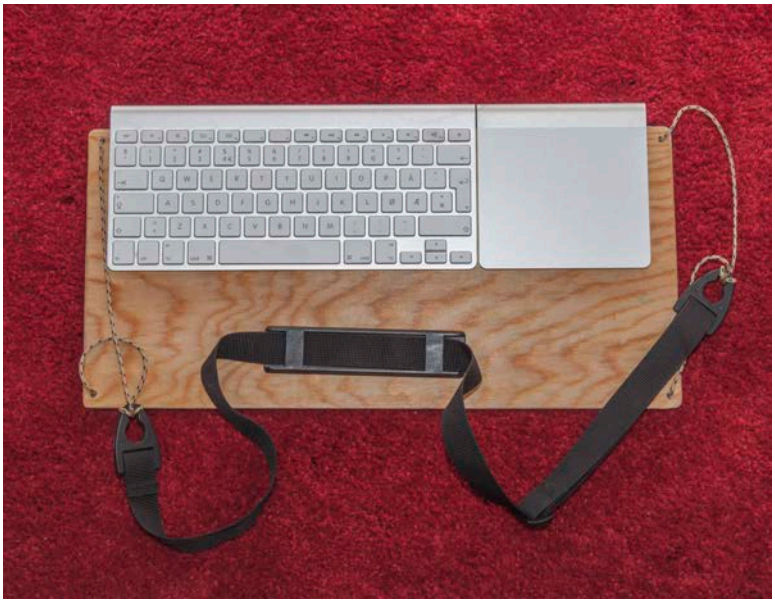

Figure 3: Assembled Modeling Tray

Figure 4: Disassembled modeling tray with velcro visible

Mode of use, experiences & discussion

The modeling tray allows for conducting GMB workshops alone using the computer-projector method. It should be noted that this is clearly a suboptimal as compared to a modeling team even with the modeling tray: Having to operate the modeling software adds to the danger of cognitive overload that the facilitator is exposed to anyway, as he is trying to carry out all of the team roles in parallel. He should better be extremely familiar with the operation of the software to reduce this problem. Modeling alone works well for relatively short modeling sessions but has proven straining for regular

modeling sessions. The conventional 2+person-setup is much better, especially if persons can switch roles after breaks.

The tray tends to get heavy on the neck. In order to minimize this problem the wide neck strap was introduced in the current version. For the same reason it is important for the facilitator to get into the habit of NOT resting the hands and arms on the tray when s/he is not operating it (e.g. wile listening to a participant). It is also a good idea to put the tray aside during phases where it is not needed (e.g. GMB-scripts not involving model editing such as *Nominal Group Technique*).

Just as with pen and whiteboard, the facilitator will be switching between listening/talking to participants and editing the group-model. While doing the latter, the facilitator should not point his back to the group for too long. He can stand at the side or within the U-shape (but then move around not to block sight for too long).

The facilitator should furthermore avoid standing too close to the screen so as to keep an overview of the whole screen. Standing too close will also make the picture appear 'pixelish' for her, which is straining for the eye, especially for large screen areas where projectors are far away from the screen. It has often proven useful to maximize the resolution of the projector to minimize this problem and zoom in to make variables most legible. This requires testing before the workshop because some resolutions simply look awful for technical reasons. While modeling alone may be faster than an inexperienced modeling team it may still be slower than an experienced team. The facilitator can still only either talk to participants *or* edit the model, while two persons can do some work in parallel.

Just as working on the whiteboard requires bringing reserve pens, reserve batteries are needed for modeling tray use. Ideally these should be rechargeable for environmental reasons. It requires remembering to charge them prior to the workshop but regular batteries also require remembering to buy them. There are also keyboards/trackpads with built-in rechargeable batteries, but one should make sure that they either last through the whole day and/or to recharge them during the break, especially during lunch time. In case of Apple keyboards and trackpads it may be advisable to rather buy older versions that have exchangeable batteries rather than the new models with built-in batteries to be more flexible.

While the modeling tray does alleviate some of the shortcomings of the normal computer approach compared to the whiteboard, it doesn't get rid of them all:

While it's relatively easy to hand a pen to a participant, it is impossible to transfer knowledge of SD-software operation into someone's head, so it is useless to hand over the modeling tray to someone. I have had participants coming up to the screen to show where they want things moved to, though. I am also planning on having at least one laser pointer for the group in the future, so they can point at things from where they sit.

Another shortcoming of the computer-projector approach is that it allows seeing only part of the model once it grows beyond the size of the screen. The ability to zoom out is limited by projector resolution and legibility of the variable names and link polarities, so the facilitator may decide to divide the model into sectors.

The Modeling Tray approach even has advantages compared to interactive smart-boards: The latter are usually either relatively small (with implications for workspace or even group size). Also smart-boards have the problem that standing too close precludes retaining an overview and may cause eye-strain due to pixelish appearance as mentioned above. With the modeling tray you can stand at a distance, even with/behind the group, which may have the advantage of the group focusing on the model rather than on the facilitator.

Before developing the modeling tray I had been experimenting with wiimote-&-infrared-pen-based approaches to turn conventional whiteboards into low-cost smart-boards. The seeming elegance of this approach is hampered by the limited distance that the wiimote can have from the screen (otherwise the invisible pixels of the infrared-camera become too large so objects can no longer be dragged on the screen). Of course the above-mentioned limitations of normal smart-boards also apply to the wiimote-ones.

Further research

I am planning on experimenting further in the 2-Person-set-up in order to test the hypotheses with respect to shifting the group-model-editor role back from the content coach to the modeler and see what advantages and disadvantages this brings along. It will be interesting to see how the GMB-experience is changed by the Modeling Tray in the 2-person setup both for the facilitator and content coach and the workshop participants. Will the advantage of freeing the content coach from model editing outweigh the additional cognitive load on the facilitator or the other way around leading to suboptimal results?

It would also be very interesting to have an experienced process coach observe how moving the facilitator totally out of sight during modeling (behind the group) influences group dynamics. Will it lead to an increased focus on the model leading to better and/or faster modeling results or will an eye-to-eye connection of facilitator and participants turn out to be an important part of the group dynamics? Weather forecasts for example still have people in the view rather then the voice coming from the off.

One additional question is whether *facilitator/group-model-editor* and the content coach could work on the same computer. That way, the *content coach* could sit behind the computer dive into modeling and if invited by the facilitator could work on the same screen suggesting model structures. He could even simply move model structures he is suggesting from the laptop screen onto the projector screen and even copy-paste structures that participants choose to adopt. This should be done with care though, not to endanger model ownership causing boundary object failure. This is currently limited by the fact that every computer usually has only one mouse pointer and only one window can be active (i.e. edited at the same time). Possibly, SD-modelers with more programming experience could estimate whether simultaneous input on one computer is easy or difficult to implement?

A technical development detail includes softer, even wider cushioning of the neck strap in future versions (photography equipment may be a good source as the same problem applies in more extreme form to cameras).

A different approach to improve wearability would be to experiment with hip-support of the tray. A large belt buckle already helps somewhat to rest it, but hip-belts, e.g. from trekking backpacks may be an interesting field of experimentation.

Unfortunately some SD-softwares do not make use of the possibilities of modern input devices, such as pinch-zoom or two-finger scrolling on a trackpad. Even some of the most well-known SD-softwares only allow up-and-down scrolling and not side-ways scrolling. There are workarounds but they don't bring along the same user-friendliness. Bringing SD-software to the state of the art in terms of the possibilities of input devices could make the modeling tray even more attractive to use.

As mentioned above, it is also good to not only have a laser pointer yourself, but also at least one additional laser pointer for the group, maybe even with different colors.

Conclusions

The modeling tray is a promising approach that opens up the use of the computer-projector approach to a wider set of conditions including the all-roles-in-one-person set-up. Additional advantages may arise out of shifting the role of the *group model editor* from the person who is the *content coach* back to the *facilitator*, although this requires further experimentation.

Digital Pens for Recording

Introduction and problem definition

During GMB sessions one modeling team member, the *recorder*, takes notes and if allowed to do so by the participants may use a dictaphone for making an audio recording (see Vennix et al. 1996 for details on roles within the modeling team).

Taking notes by hand can make it difficult to keep up with the speed of the discussion, especially if several things happen in parallel. Typing notes into a computer may be faster if the recorder is well-trained in typing, but has the disadvantage that it is not easily possible to add drawings.

If furthermore the GMB-session progresses rapidly, the recorder may not be able to both fully understand what is being said and take detailed notes due to limited cognitive processing capacity.

While conventional dictaphones in principal allow for improving notes after the workshop this requires high investments of time especially as it is difficult to find a specific point in a recording.

Tool description

Some digital pens allow for simultaneously recording both hand-writing and audio. These two media are connected in such a way, that if the pen tips on a word in the notes,

the audio recording starts playing at exactly the point in time when this note was written.

In the following the example of Livescribe / Anoto is used to describe the technology. Other pens such as the Neo smart pen function in a somewhat similar manner. The digital pens facilitate note recording of writing/drawings via a built-in infrared camera that is recognizing a special micro-dot pattern on a special paper (see Figure 5).

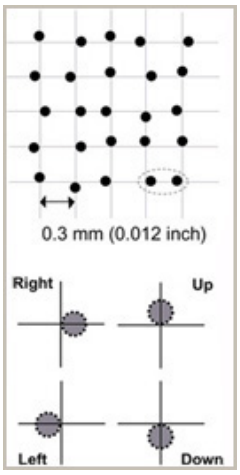

Figure 5: Principle of Micro-dot pattern: small dots on the paper code the location on the paper as recognizable by the digital pens camera (Anoto Corporation)

The pen does not need any button besides the power button because the micro-dot paper allows for *virtual buttons* on the micro-dot paper. For example to start a recording, one simply tips the *record-button* on the paper with the tip of the pen and the recording starts. There are more buttons to pause, stop a recording and setting bookmarks as well as for playback in postprocessing including increasing the playback speed, volume etc.

Experiences & Discussion

The connection between written notes and audio allows for taking only skeletal notes during the workshop in order to maximize understanding and then flesh out the gaps after the workshop. The post processing time is substantially reduced by decreased search time for the respective sections in the audio recording. This is even enhanced as recorders quickly develop a set of symbols that they use in their notes during the workshop that aids their post-processing after the workshop (such as symbols for: “listen to this again”, or “not understood”, “important”, “see slide #x” etc.)

Some digital pens that have a built-in microphone also allow for attaching a headset with stereo-microphones instead. The latter produces a much higher quality audio recording because of higher microphone quality. In addition, a headset eliminates the writing sounds of the pen or the ‘clunk’ of the pen being put down on the desk during a writing pause and the sound problems that may result from the microphone facing towards the desktop instead of towards the speakers. In order for the stereo microphones to record the audio at the same distance as the ears on a humans head, the headset is

usually carried around the neck with the ear-buds hanging down on each side the breast. Adhering to this ear-distance bears the additional advantage that listening to the recording with the headset or other headphones, brings about a very realistic 3D-audio experience that makes picking out single voices out of a conversation much easier for the human brain.

While some digital pens record the audio directly on the pen, others record on wirelessly paired mobile devices such as smart phones or tablets. While the latter case holds the advantage of larger recording space and lower purchase cost for the digital pen, it also implies that the microphone of the mobile device is used because these sort of digital pens usually do not have a microphone themselves. This implies that the quality of the audio recording is determined by the microphone of the mobile device. Unfortunately these are often optimized for the speaker being close to the phone and may not perform well if the speaker is some distance away from the microphone. That is why for GMB-purposes smart pens with headset microphones have proven to yield better results. The issue with the limited recording space can be dealt with by purchasing a pen with large space and/or by purging the memory before the workshop after archiving the recordings on the computer.

Since the battery time may be more limiting than the memory available for recordings, it is important to recharge the digital pen during longer breaks, especially over lunch. However, short breaks should not be used because attaching the pens to the computer usually also starts the data transfer and if that is not complete before the end of the break, the necessity of ending a transfer prematurely may cause problems later on.

Some of the pens that are paired with mobile devices record into a cloud space on the web, whereas others record onto the mobile device directly. Even those that record onto the device directly may require to upload the recordings to a cloud-space in order to then transfer the recordings to the computer. This may pose data security issues because even if workshop participants have agreed to their voices being recorded, this does not mean, that they automatically also agree to these recordings being uploaded to the internet, where it may potentially be subject to undesirable access by third parties. It may be easier to get permission for voice recordings if participants know that the recording is stored on the pen and then transferred directly to the computer, which is why this type of smart pens is preferable for GMB-use.

It should be noted that in most countries any type of voice recording (be it conventional dictaphone or smart pen) legally requires the content of the speaker. It is therefore wise to get written permission by all participants. The paper that the participants sign should also contain the terms that the modeling team binds itself to concerning the purposes for which the recordings are to be used, the group of people who will have access and possibly also the time after which the recordings will be deleted. There is a trade-off concerning the strictness of these terms: the more restrictive the less useful, but the higher the chance that all participants sign it. The latter is necessary as each participant has a veto-right, i.e. voice recordings require a unanimous approval of all participants. It may make sense to combine this with the permission to take photos and how these are to be used but using check marks so that participants can separately opt in or out for photos and voice recording. The vote should be secret to avoid peer-pressure influencing participant's decisions.

The Micro-Dot-Paper can either be bought or printed, given the availability of reasonably good laser printers (ink-jets are not precise enough). The author has mostly used purchased paper as it is still of slightly better quality than printouts (legibility of notes).

It is also important to note that the ink-cartridges of some digital pens (Livescribe) are not of the standard type but they are shorter. It is therefore wise to have spare cartridges handy during the workshop should the old ones go empty.

Speaking of ink-cartridges, it can be handy to use different colors during and after the workshop for post processing if one wants to keep a view of what was added afterwards. This color-differentiation is unfortunately lost upon transfer to the computer though, because the current pen models have no way of recognizing the color of the ink-cartridges.

GMB-suitability of different models:

The author has used Livescribe pens (http://www.livescribe.com). First the model 'Pulse' (no longer sold) and currently the model 'Echo'. With the former, the headset was included, with the latter it had to be bought separately. The experience of the author has yielded two major disadvantages of this manufacturer: The first is the insufficient customer support which concerns computer software bugs, limited support of older pen models by newer desktop software versions. Email support seems to use automatic answers instead of real persons (without indicating this), which can lead to awkward and unhelpful answers. In addition it is important to keep insisting by replying in a timely manner, so that the issues are not simply closed. The second disadvantage is the limited lifetime of the displays of the pens. At some point they start loosing contrast until they can only be read in total darkness. This does not limit the functionality of the pens very much though, especially since the menu items can also be spoken by the pen. For reasons described above, the 'wifi' and 'livescribe 3' models seem less advisable for GMB-purposes (but contain other features that maybe interesting outside of GMB and that are not available on the 'Echo'). The latter pen does have the advantage of not needing a display though thus avoiding the display issues.

An alternative may be the Neosmartpen (http://www.neosmartpen.com). While the author has no experience with pens of this brand, this product seems less bulky and thick than the livescribe 'Echo' but may be more comparable to the 'livescribe 3' or normal pens. This may enhance writing comfort. Limitations are the connection to the mobile device including the lack of stereo headset support and the need for using a cloud space service (google drive or Evernote) for sync between the app and the computer.

Other uses

It should be noted that digital pens have also proven very useful for the education of System Dynamics students, especially for note-taking during lectures. It frees up cognitive capacity for listening to complex lectures and aids post-processing. Lecture

notes including audio can also be shared amongst students, which has proven especially helpful, if a student had to miss a lecture for being ill.

Further research

The recordings of digital pens still contain the information of *what* has been written *when* even after transfer to the computer. It is possible to see the text being written on the screen while listening to the voice recording. This opens up additional possibilities for research into group processes because unlike with regular paper, the written results still contain process information. If a group for example develops a model together on a micro-dot paper using a digital pen, researchers could then afterwards analyze how the model was developed looking and not just what model came out of it. Thus digital pens could be used to inquire into the dynamics of group work of students or community processes.

It should be noted that there are also micro-dot whiteboards with specialized digital pens available or microdot-equipped flat-screen displays that may be suitable for group processes. (See http://www.anoto.com for details)

Conclusions

Digital pens are a helpful tool for recorders of GMB-sessions because they allow for higher quality notes by reducing the cognitive load on the recorder, who can take skeletal notes since they can be fleshed out during post-processing. Post processing is more efficient due to reduced search time on the audio-recording. Pen models vary in their suitability for GMB purposes both for technical and legal reasons.

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