WP5.1: User descriptions for MKM Search Tools

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1 Introduction

Workpackage 5 of the MKMNet network project is aimed at identifying the interactions between the different tools that MKM could generate. As opposed to describing existing tools and interactions, the objective is to identify inadequacies in existing MKM support. As a starting point for this, workpackage 5.1 of the MKMNet network project is aimed at identifying the users of MKM tools. In doing so, it will become clear what sort of supports users will need not as individuals but in the roles in which they interact with MKM tools.

The purpose of this document is to provide a structured description of the users as identified through the research activities of the network members. The paper briefly describes the methodology used to capture user descriptions. It then follows with a summary of the context and scenarios of the main user types. These scenarios are converted to tasks that indicate focal points for future MKM developments.

The appendix lists the scenarios generated by the network members.

2 Methodology

There are many ways to capture user-requirements from interactive tools representing the spectrum of human to computer oriented interactions. Some from straight software engineering, such as use cases [2], prescribe an interaction and very system focused. Others from more ethnographic approaches [1], are ideal for analysing existing systems and working practices.

With MKM, there are some tools but they are not currently integrated nor are the reaching their full potential with target users such as mathematicians and engineers. Thus a system perspective is likely to focus on the interaction of existing systems whereas there is no current environment of use, of the kind intended, that an ethnographic approach could adequately investigate. This suggests using scenarios as an appropriate methodology [3]. Scenarios allow for invention and the working through of an interaction without the need to specify the system. Also, they do not require an existing system or set of users as their starting point. In this way, scenarios can capture and structure the target users before appropriate systems or users are in place.

Whereas scenarios identify activities and a context of use, personas [4] also help to pin down the details of the user, the "context of mind", if you will. However, the methodologies built around personas are often small teams working closely on single systems. MKM is proposing a diversity of approaches and tools under an integrated approach and across a number of institutions. It was felt that personas would not have the necessary psychological impact in this setting to be effective. Thus, scenarios, as attached to concrete users, were preferred.

There are many forms that scenarios can take. The format used here was a light format to avoid focus on system issues and to highlight user goals and the support they would need. For this reason, the basic template for scenarios is:

1. *Type* — the type or role that the user has when they might interact with an MKM system
2. *Goal* — what the user is trying to achieve at the level of their motives not at the level of the interaction with any tool
3. *Needs* — specific needs or objectives that the user has when using an MKM system to achieve their goals
4. *Support* — the sorts of support that the system must provide in order for the user to achieve their goals/meet their needs
5. *Usage* — this is both the frequency with which the goal would occur and the role of the MKM system in achieving the goal

The users and goals were encouraged to be concrete, that is, rather than mathematician wanting to search journals, the type of user would be the type of mathematician and the goal would indicate something concrete that they might search journals for, for example, status of the Riemann hypothesis. This concreteness is central to scenarios and links more to the idea of personas. In doing so, it raises specific support that would be needed rather than speculative support in the whole area of searching. The aim is that concrete goals result in concrete support that MKM systems must provide.

It is important to stress that a single type of user may have multiple goals, in fact, too many to list. The goals then are expected to typify some of the actions of that type of user. Also, it may be easy to see how different goals would have natural commonality across users. The aim then is not to make scenarios exhaustive but broadly representative of the envisaged activities of typical MKM users.

Scenarios were collected from members of the MKMNet consortium either in the proposed format or were adapted to that format based on contributions made by MKMNet members. The complete scenarios are listed as the appendix to this document. The remaining sections of this paper draw out a more explicit picture of users and their goals.

3 Context

Scenarios are intended to provide some details of the context of the users because context can greatly influence the type of interaction that they can engage in. From the types of users and the types of activities proposed, there were no explicit references to unusual or unexpected contexts. Moreover, it seemed implicit that users would be engaged in some focused, professional activity, that is, attempting to achieve a specific work-related goal as part of their larger working activities.

Thus, the users can be considered in a context of an office or office-like environment working on a dedicated desktop system. It was not clear if the system would contain the

entire requisite knowledge base as a stand-alone system or whether it would act as a client to a local or even web-based server. However, it does seem clear that system should operate as if the user had sole use of uninterrupted, dedicated resources. The desktop style of system is also suggested by the integration required with other existing desktop packages. This is seen by references to: retrieving articles or documents; integrating retrieved information with authoring tools; compiling materials into a given format; entering queries in a WYSIWYG (what you see is what you get) style.

There is a tendency amongst the human-computer interaction to see desktop environments as essentially understood and of less relevance than more modern ubiquitous, pervasive and fun systems [5]. However, desktop systems are far from worked out. Word processors are commonly perceived as an immense source of frustration, calculators have bizarre interaction constraints [7] and all software developers are aware of the risks of introducing new systems into the workplace.

The professional, desktop environment, then, is one which is well suited to develop new tools for mathematical knowledge management. It does not introduce spurious complexity but it does require robust functioning systems that users want to use.

4 Types of Users and Their Activities

The scenarios specified lots of types of users though they were intended to be understood as realistic individuals engaged in concrete tasks. From these, several different types of user emerged. I have grouped these into two overarching categories: mathematicians and appliers of mathematics. This is for two reasons, partly because there is a lot of similar activity between the types within a category and between the two categories there is a considerable difference in background that users can be assumed to have. The division into two categories does not mean that a certain individual will only ever belong to one category or even one type within that category. Instead, the ideas is that, in a given activity, the user can be defined as one or other of these sorts of users.

In the following, the two categories are considered separately.

4.1 Mathematicians

Mathematicians are those I have classed as people whose main activity is in a mathematical subject, for example, school teachers, university students or researchers. These people can be singled out as a coherent group because of three features:

- Membership in the mathematical community
- Immersion in the language of the community
- A taught background and framework for their activities

Needless to say that the communities, languages and frameworks referred to can vary enormously between mathematical disciplines. However, the products of an individual's activities must end up relating back to the community and framework to which that individual belongs. This constrains to some extent how mathematician users want to see the results of MKM systems and the kinds of tasks that they will use MKM for.

Within the category of mathematicians, the three main types of user identified are:

- Teacher of mathematics
- Student of mathematics

- Researcher in mathematics

These appear, at first glance, to be still very general types. However, it seems from the scenarios that the main activities of each type were essentially the same regardless of their particular age, level or even specialism

4.2 Activities of Mathematicians

The scenarios for mathematicians can be used directly to understand the users. However, the intention here is to pick out some key themes in the activities of mathematician users to illustrate why they are a coherent category and how their background affects their activities.

Some typical goals of mathematicians are:

- Prepare a lesson on a particular topic
- Learn or master a topic
- Develop or understand a proof

To achieve these goals, mathematicians needed to be able to find things. What sort of thing needed varied but typically they were: results, that is to say, theorems or proofs; examples to illustrate a topic or a proof; exercises to stretch the learner and move beyond the taught material. This sort of support can be justified as vital to all three types of user.

How users found these things was also specified. In some cases, it was clear that users would enter a query of some form, say using WYSIWYG for formulas or using some text-based interface. Another quite distinct form was that mathematicians would like to find "things like this." This is to be understood as finding mathematical material, say exercises, by giving an examplar exercise, somewhat like a case-based reasoning system. Interestingly, the dimensions or attributes over which such a case-based query could be formulated was not made explicit.

Given the central rôle of proofs in mathematics, it is not surprising then that mathematicians are interested in proofs and using MKM tools to either check or explain proofs. This could be source of support students and researchers but also, if the tools could formulate variant proofs, could be very useful to mathematics teachers.

It is worth noting that MKM tools were not explicitly expected to support providing proofs. This may because those proposing the scenarios felt that such technology was too far away. My personal, complementary view is that mathematicians do not want support to do proofs because that is the "fun" part of doing mathematics. Checking and guidance is useful but proofs should ultimately come from the mathematicians themselves.

4.3 Appliers of Mathematics

Appliers of mathematics are those people for whom forwarding mathematical knowledge (either their own or others) is not a primary activity but for whom using mathematics well is an essential part of their activities. For example, appliers are scientists, engineers, programmers for animation or graphics. In contrast to the category of mathematicians they have the following features:

- Mathematically knowledgeable
- Focused on finding and applying results
- No given mathematical language

- Need learning support

It could be argued that the mathematicians also need learning support. However, their context is different — they are already working within a given pedagogical background and they do not look solely to the MKM system to provide the teaching needed to understand a particular piece of mathematics.

There are many types of user within this category so the reader is referred to the scenarios themselves rather than repeating the list of user types here. It is worth noting though that amateur mathematicians belong in the list of appliers rather than mathematicians because they do not necessarily belong to a mathematical community or have the language of a particular community.

4.4 Activities of Appliers of Mathematics

There are clearly many different possible activities for which an applier user could need MKM tools and the scenarios are by no means exhaustive. However, they do capture some common support that appliers need and which can feasibly be used to focus future interest. Some typical goals of appliers are:

- Produce realistic animation routines
- Evaluate the security of a system
- To improve/adapt an algorithm

To achieve these goals appliers need to be able to find algorithms, related algorithms or to learn concepts around algorithms. This means that they need to be able to search for algorithms both by querying and by asking for "algorithms like this." The problem with that though is the returned results may not be in a form required. For instance, a security evaluator may want a very formal form whereas an programmer may want something that helps them to learn quickly via informal concepts and examples. Thus, in any retrieval task for these users, it is going to be crucial that the user is able to quickly understand what is retrieved. This could take two forms: either a translation into the language of the user; or a digestable background document to a retrieved result. Both of these present technical challenges but the former needs to understand the user language whereas the latter requires the system to understand the mathematics. Solving only one of these problems may not help unless we know what would best suit the user's working practices.

In some cases, the problem for appliers is not so clear cut. In these cases, there are try to explore their problem domain, make the link with theoretical domains and then translate possible solutions back into the problem domain. It is not clear how best to support this but it suggests a fluid style of interaction where users can easily translate between different descriptions of a problem.

The issue of learning new parts of mathematics also suggests that results themselves are not sufficient. The appliers will want to see examples and have some more simple exercises in order to develop their understanding of the area. Thus, for appliers, educational support is a significant element of MKM tools.

A useful support for learning is also the ability to communicate with others. Mathematicians do not necessarily need the support for this to come from MKM tools — the assumption is that they already identify with a community. However, for appliers delving into a new specialist area of mathematics, links to similar workers could be very beneficial and made available through their tools.

5 Other Users

The scenarios have focused mainly on primary users [6], that is, users for whom MKM tools offer support of their activities. However, there are also secondary users who are those who are occasional users of the system or who do not use from the perspective of improving their own mathematical knowledge. These are people such as librarians who have an interest in providing a valuable and usable resource and people who provide the content for such systems.

In some ways, the needs of these people cannot be considered until the needs of the primary users have been met. However, in other ways, it is self-defeating to produce a system that cannot be supported adequately by librarians or content providers. Thus, these users have a crucial role in being involved in the development of MKM tools but currently it is in appropriate to directly address their needs until some more specific tools, or even just proposals for tools, are in place.

MKMNet is addressing secondary users in several ways. There are many corpuses of mathematics, informal and formal, wholly owned by members of the consortium. These can be adapted to provide a substantial initial content to MKM tools. Publishers are actively taking an interest in the future goals of MKM research. Also, members of the consortium are specifically engaged with librarians to develop requirements for MKM tools from their perspective.

In summary, at this stage, MKM research recognises the importance of secondary users however it is engaging with them as participants in the research rather than driving forces behind the research goals.

6 Support from MKM Tools

Arising from the goals and activities of the two main categories of user, there are a number of different fronts on which to develop MKM tools to meet the user needs. These are summarized here.

¿From the context of the users' work, MKM tools will need to address the following:

- Integrating MKM tools with existing tools used by mathematicians
- Providing access to MKM resources as if they were co-located with the user
- Existing workflows of mathematicians and appliers

In terms of the support that users will need, there seems to be a natural division between the core support needed across all types of user and secondary support needed by only a few user types. The core support requirements are:

- Search by topic (possibly across domains)
- Search by "things like this"
- Access to examples and exercises in the appropriate level and style
- Aids to understanding proofs
- Translation between different domains
- Translation between informal and formal

The secondary support requirements are:

- Links with other users
- Proof checking
- Repeatable retrieval over time (ie dynamic documents are not too dynamic!)

To conclude, from the user perspective, there are many ways in which MKM tools need to be developed. Some of these ways are independent whereas others have rich interaction and have the possibility to provide fascinating and valuable user experiences.

Acknowledgments

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A Scenarios of use for MKM tools

A.1 Teaching specific scenarios

Type	Mathematics lecturer
Goal	To prepare a question sheet on statistics
Needs	To find or modify existing exercises
Support	Retrieve statistics exercises based on difficulty and topic.
	Retrieve exercises similar to a given exercise.
	Retrieve datasets for examples.
	Organise exercises into a coherent set.
	Present exercises with consistent notation and format.
Usage	Weekly (maximum) and not extensive work

Type	Mathematics lecturer
Goal	To prepare a lecture on compactness
Needs	Understand student backgrounds and prepare materials
Support	Identify pre-requisites for compactness.
	Identify importance of parts of the lecture for a topic.
	Retrieve appropriate examples of right difficulty.
	Compile materials into uniform slide/script format.
	Find illustrations or demonstrations of ideas.
	Find useful references or related reading.
Usage	Weekly

Type	Mathematics lecturer
Goal	To prepare an examination on geometry
Needs	Access to examination resources
Support	Modify questions whilst maintaining difficulty.
	Retrieve appropriate questions on a theorem.
	Retrieve questions testing a particular technique.
	Compile questions into format of the teaching.
	Distil examination topics from the course.
Usage	Twice or three times a year

A.2 Learning specific scenarios

Type	Mathematics student
Goal	To begin learning fluid mechanics
Needs	To know where to start and what motivates it
Support	Find and revise pre-requisite calculus.
	Find materials that correspond to teaching style.
	Find out informal motivations for topic.
	Find examples with appropriate help or guidance.
Usage	Occasionally but intensively

Type	Mathematics student
Goal	To master differential equations
Needs	Deeper insight into structure of techniques
Support	Access to further reading or literature.
	Retrieve appropriate exercises with guidance/solutions.
	Gathering of theory to support exercises.
	Find similar exercises with or without solutions.
Usage	Daily

Type	Mathematics student
Goal	To understand a proof of completeness of the reals
Needs	To explore concepts in the proof
Support	Explanations of implicit/hidden proof steps.
	Access to definitions whilst reading.
	Ability to access resources at own level.
	Ability to read the same document regardless of location or settings.
Usage	Most days at some point

Type	Mathematics student
Goal	To prepare for an examination
Needs	Practice materials with appropriate guidance
Support	Find examination style questions.
	Find similar questions.
	To compile a practice paper in the course style.
	Assemble a memory card/personal crib notes.
Usage	Intensively once or twice a year

Type	Mathematics student
Goal	To produce a final year report on applications of Sylow groups
Needs	To find applications and theories even if not by that name
Support	Knowledge base that translates between theories and applications
	Pedagogical aids
	Links to the undergraduate community
	Exercises and examples on applications
Usage	Once or twice but very extensively and intensively

A.3 Research mathematician scenarios

Type	Research mathmatician
Goal	Research in topological group theory
Needs	Exhaustive set of theorems and definitions for a field
Support	Access to articles.
	Exhaustive, unified collection of knowledge.
	Identify the state of the research in the field e.g. open problems, latest theorems, under review.
	Links to other authors.
	Identify analogies to other fields to transfer results.
	Submit new research results and get a peer review.
Usage	Daily

Type	Research mathematician
Goal	To prove a technical lemma
Needs	Assistance to construct and check the lemma
Support	Up-to-date knowledge base
	Authoring tools
	Proof checking system
	Browsing linked to proof in hand and related proofs
Usage	Intensively and regularly

A.4 Applying mathematics scenarios

Type	Animator (compter games/film industry)
Goal	Produce realistic animation routines
Needs	numerical algorithms, geometrical properties of objects, geometrical theorems
Support	Find numerical packages + algorithms
	to solve conversion problems for combination of routines.
	Find geometrical theorems etc. for queries
	given in various forms (numerically, algebraically, ...).
	Transformation of geometrical properties into
	more abstract mathematics (algebra, algebraic geometry).
Usage	Intensively during work

Type	Physics researcher
Goal	Understand a quantum electrodynamics
Needs	Retrieve articles based on mathematical content
Support	Ability to enter formulaic queries in WYSIWYG fashion.
	Access to collections of articles.
	Retrieval based on meaning of formula rather than appearance.
	Reveal link between matrix and differential formulations.
Usage	Occasionally but regularly

Type	Theorem prover user
Goal	To produce formalised proofs on lattices
Needs	To relate formal proofs to traditional mathematics
Support	Search proof library without syntactic constraints.
	View prover files in the language of lattices.
	Retrieve prover files as documents on lattices.
	Links to mathematically related files such algebras.
	View formal proofs at different levels of detail.
Usage	

Type	Security Evaluator
Goal	To ensure the security of s/w system
Needs	Understand security descriptions for accuracy
Support	Links between threats and security functions.
	Translation between prose and formal specs and proofs.
	Retrieve elements based on a security mechanism.
	Links to informal ideas in the security model.
Usage	Extensive over evaluation period

Type	Security Developer
Goal	To produce secure software systems
Needs	To accurately implement a formal specification
Support	Translation between formal model and input code.
	Translation between formal models and
	interfaces and modules.
	Translation between formal models and UML models.
	Co-evolution of descriptions and systems.
Usage	Constantly during development

Type	Applied sciences engineer
Goal	To find better ways to achieve a difficult computation
Needs	To find algorithms with common goals and outcomes
Support	Knowledge base of algorithms
	Learning aids for algorithms eg high-level descriptions
	Descriptions of algorithms in language of engineer
	Search capabilities for related algorithms
Usage	Irregularly but intensively

Type	Applied sciences engineer
Goal	To explore theories/domains and their applications
Needs	To link from applications to a theoretical domain
	To link from a theoretical domain to applications
Support	Knowledge base of mathematical theory
	Pedagogical support for a theory
	Translations between theory language and application language
	i.e. a brokerage system
	Search using mathematical structures or objects
Usage	At the start of projects and sporadically afterwards

Type	Amateur mathematician
Goal	To discover an expression of the primitive of e^{x^2}
Needs	To explore many domains freely around a single concept
Support	Extensive knowledge base that translates between theories
	Pedagogical support for theories
	Links to community support
	Cheap (time/cost) search facilities
Usage	Weekly but not for prolonged periods