From Bitmaps Back to Brains: DML-CZ and EuDML Projects

Document Engineering for Digital Libraries

Petr Sojka et al.

Masaryk University, Faculty of Informatics, Brno, Czech Republic
<sojka@fi.muni.cz>

University of Birmingham, School of Computer Science
Artificial Intelligence and Natural Computation Seminar
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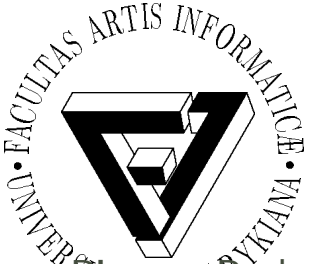
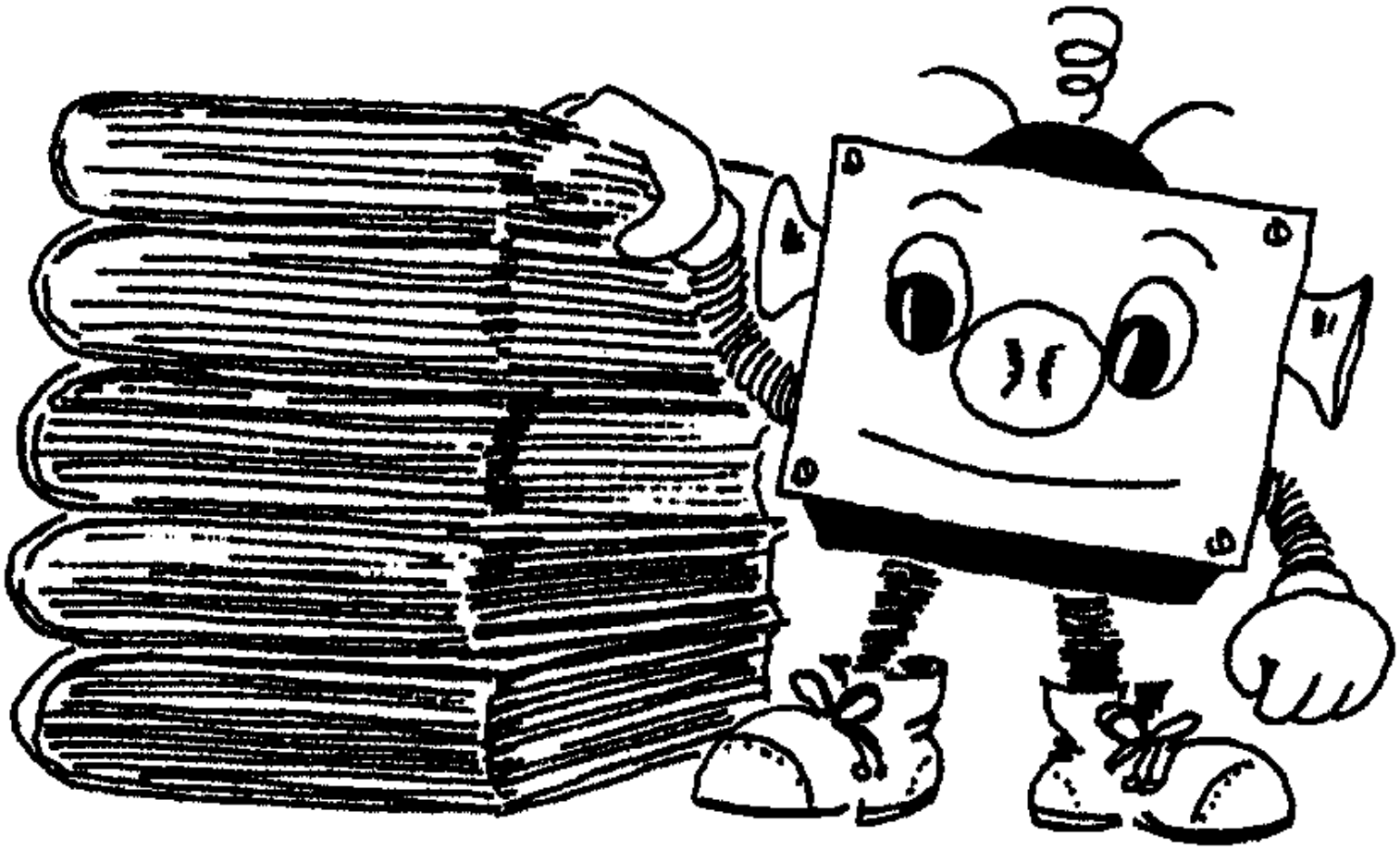


Outline and two take-home messages

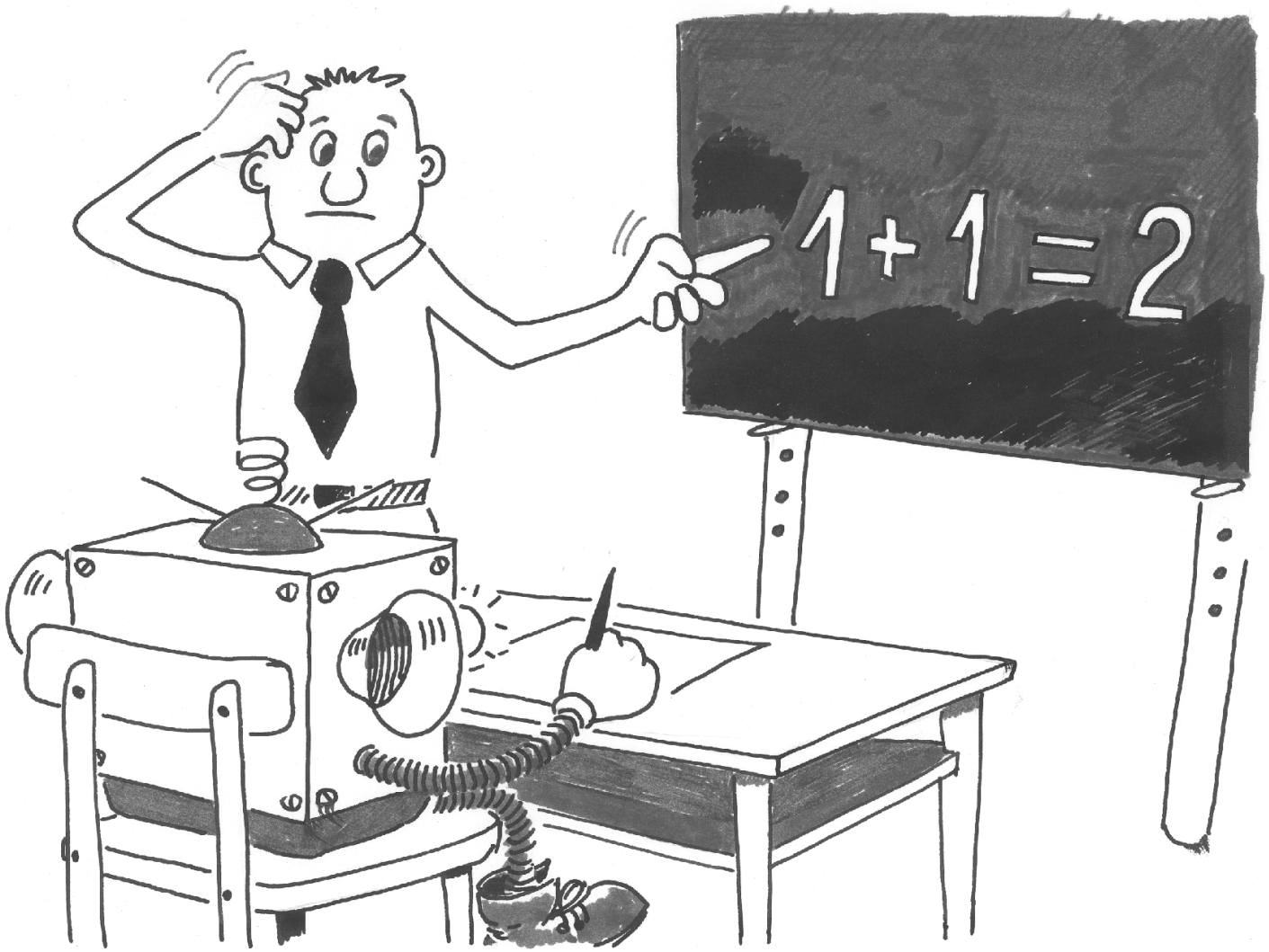
1. Pictorial overview
2. Motivation, vision of PubMed Central for Mathematics
3. Complexity of digitization workflow of The Czech Digital Mathematics Library DML-CZ
4. Document engineering technologies and tools for DML-CZ and EuDML
5. Tools developed (PDF recompressor et al.)
6. Results: already compressed 2-layer bitonal PDFs squeezed to 38%
7. Summary, conclusions and future work

From paper to *digital* library and processing

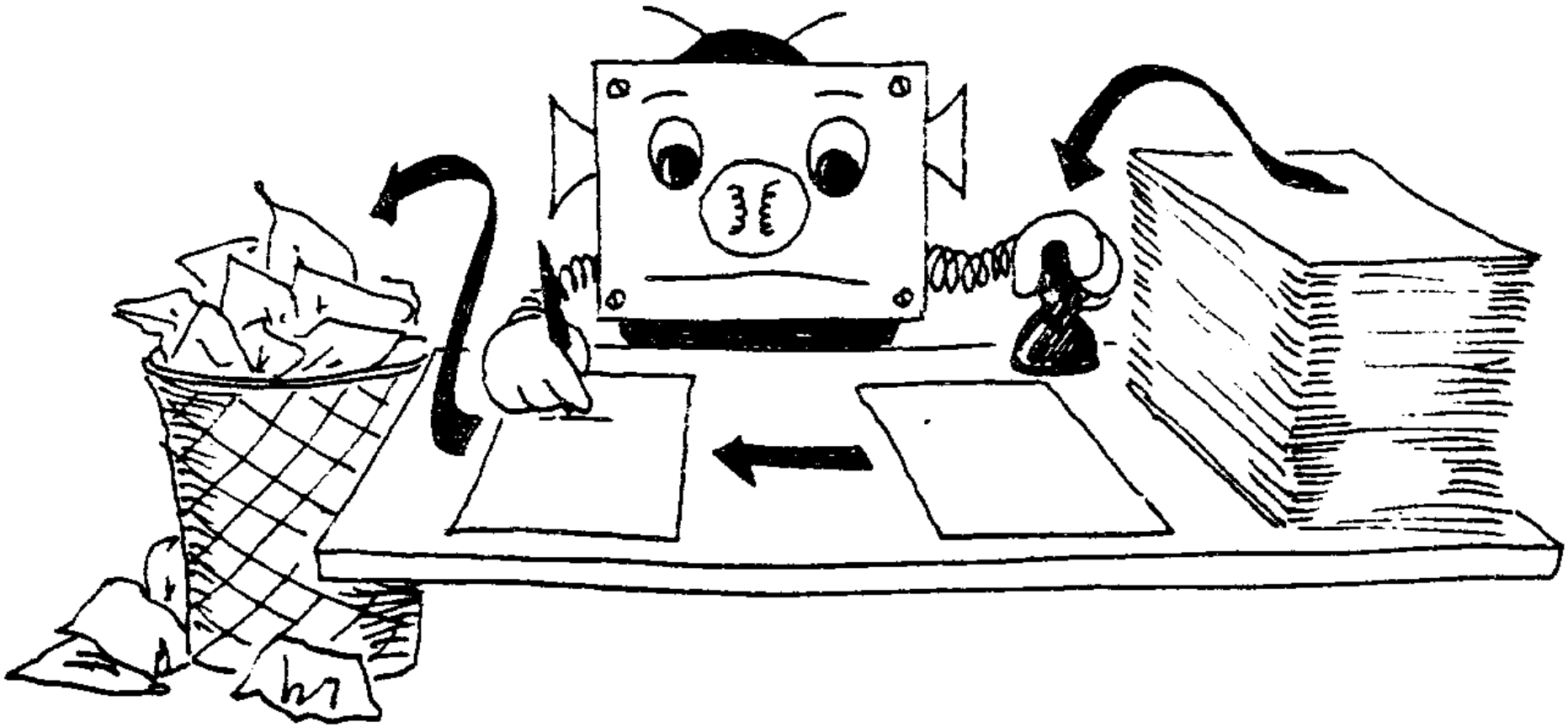


Information overload in globalized scientific world

Information overload also in specific domains (mathematics)

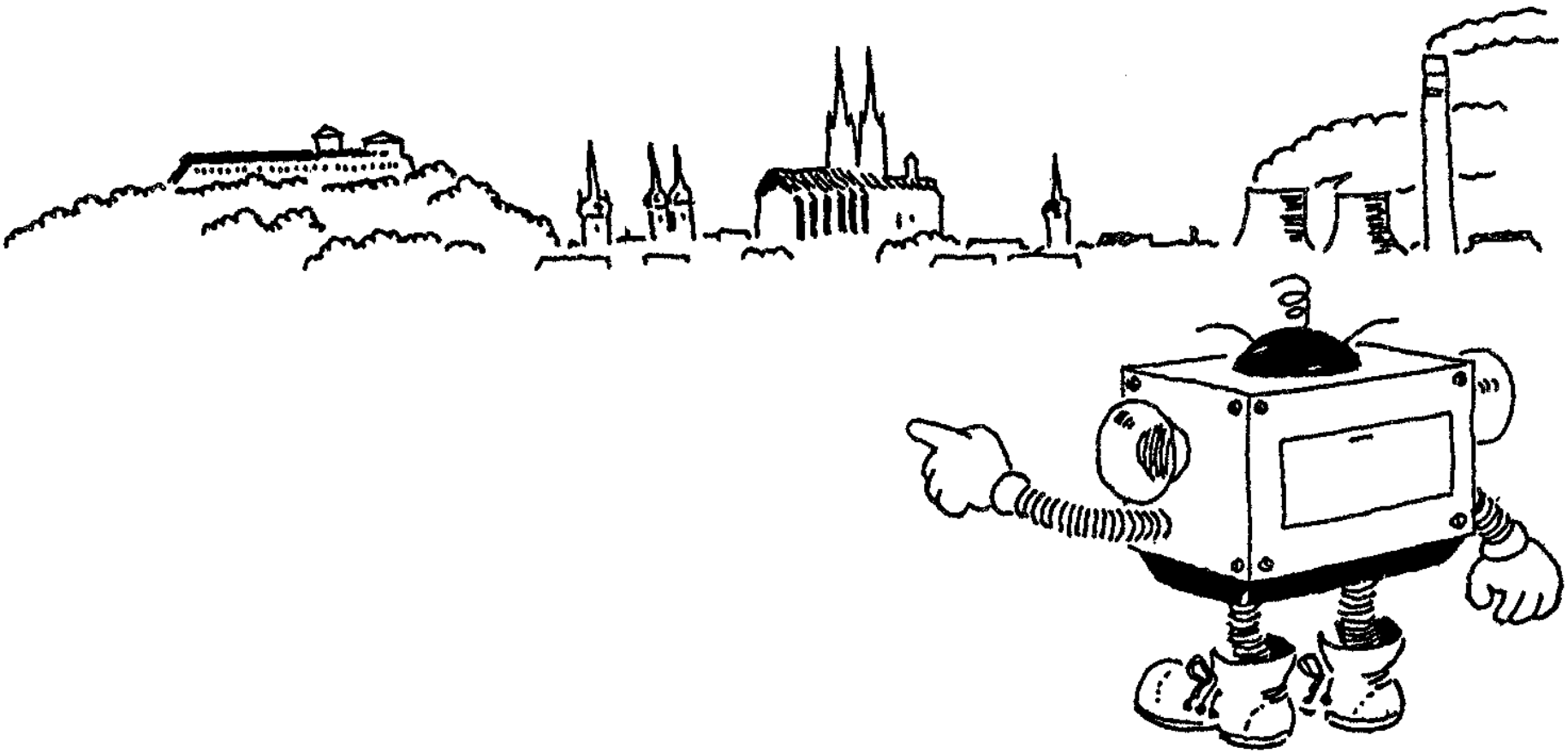


Document Engineering (DocEng): from paper to digital workflow

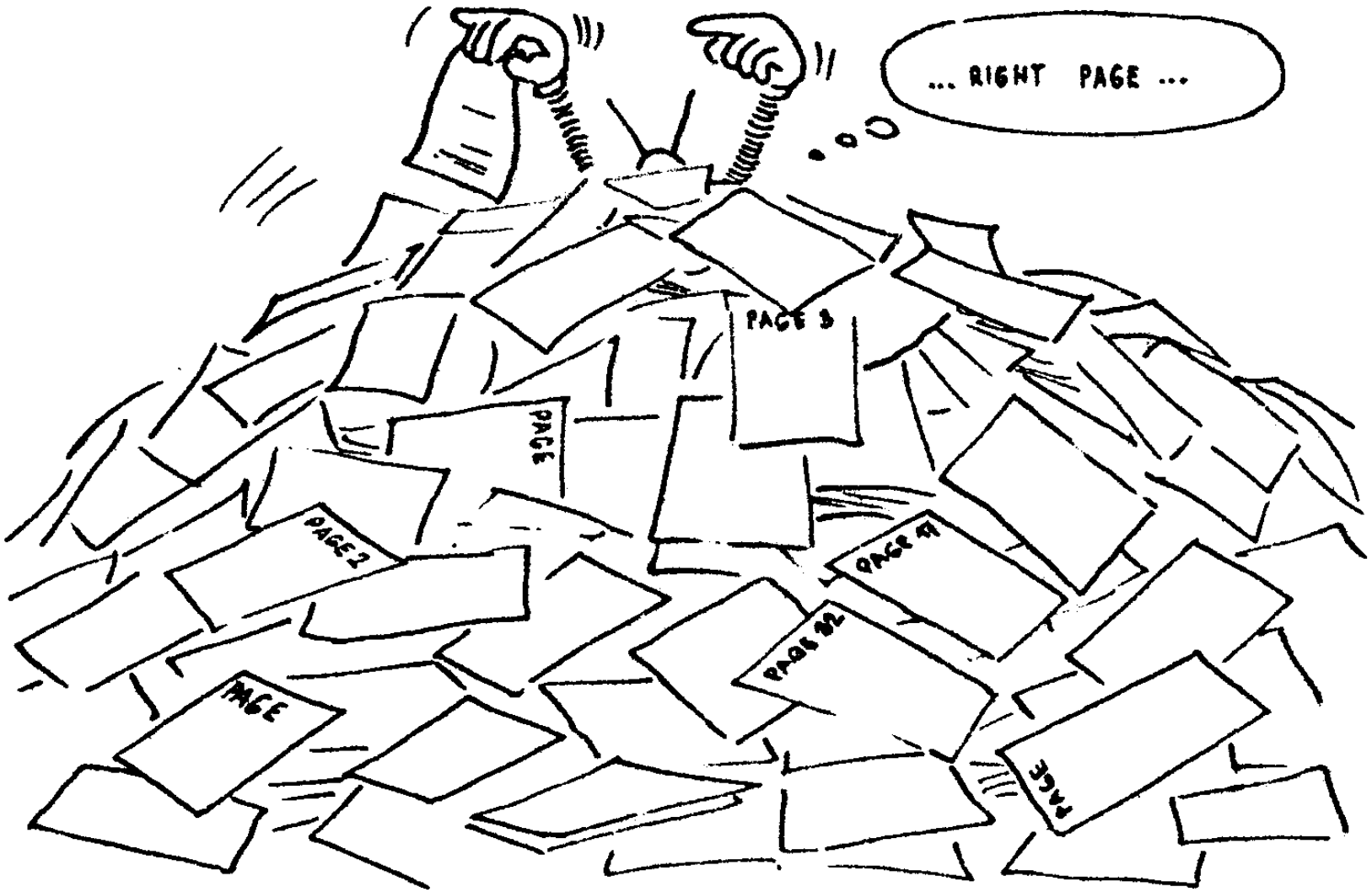


DocEng: retro-digitization, digital library development

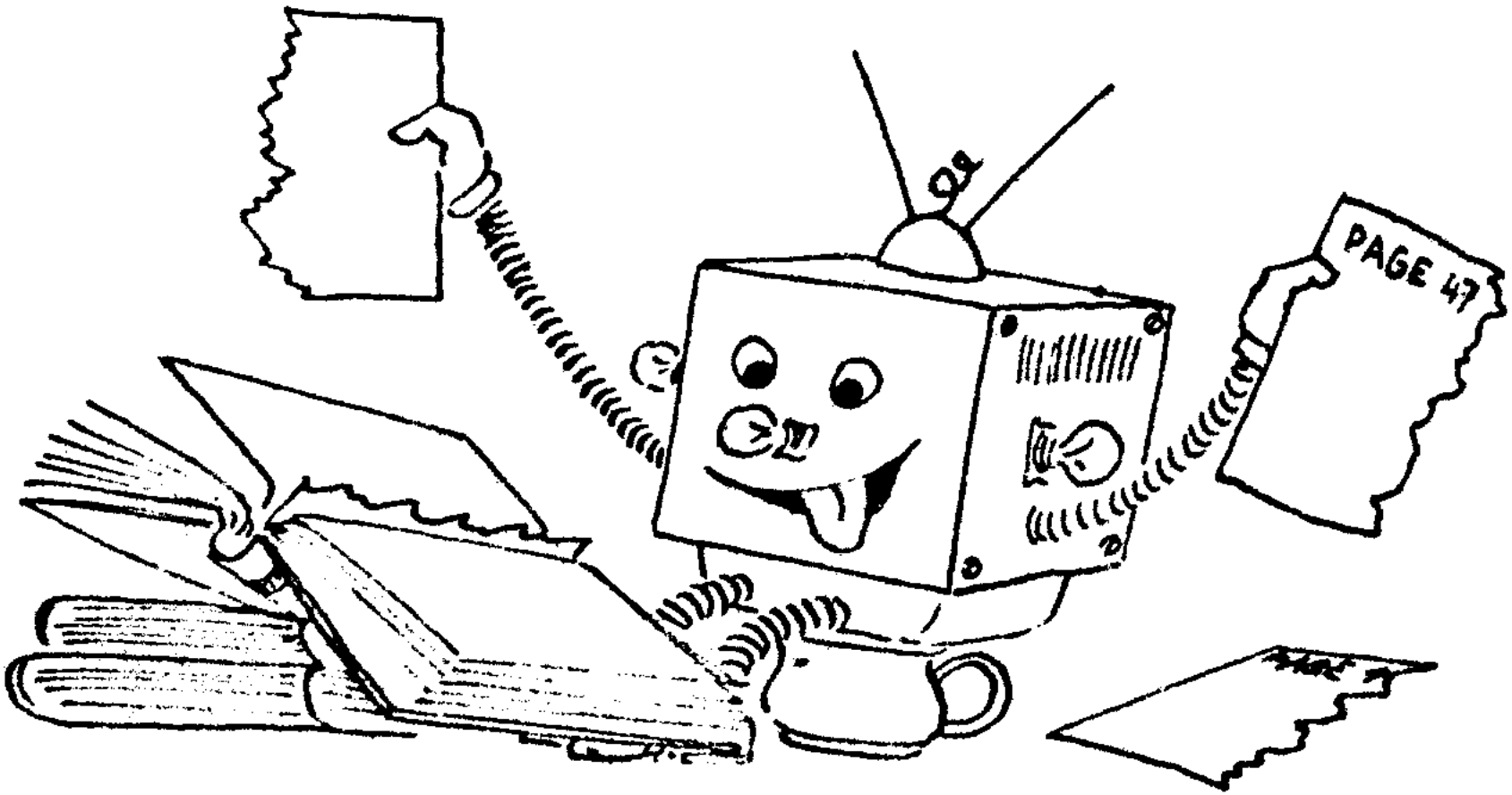
DocEng for specific/local (Brno, CZ) purposes



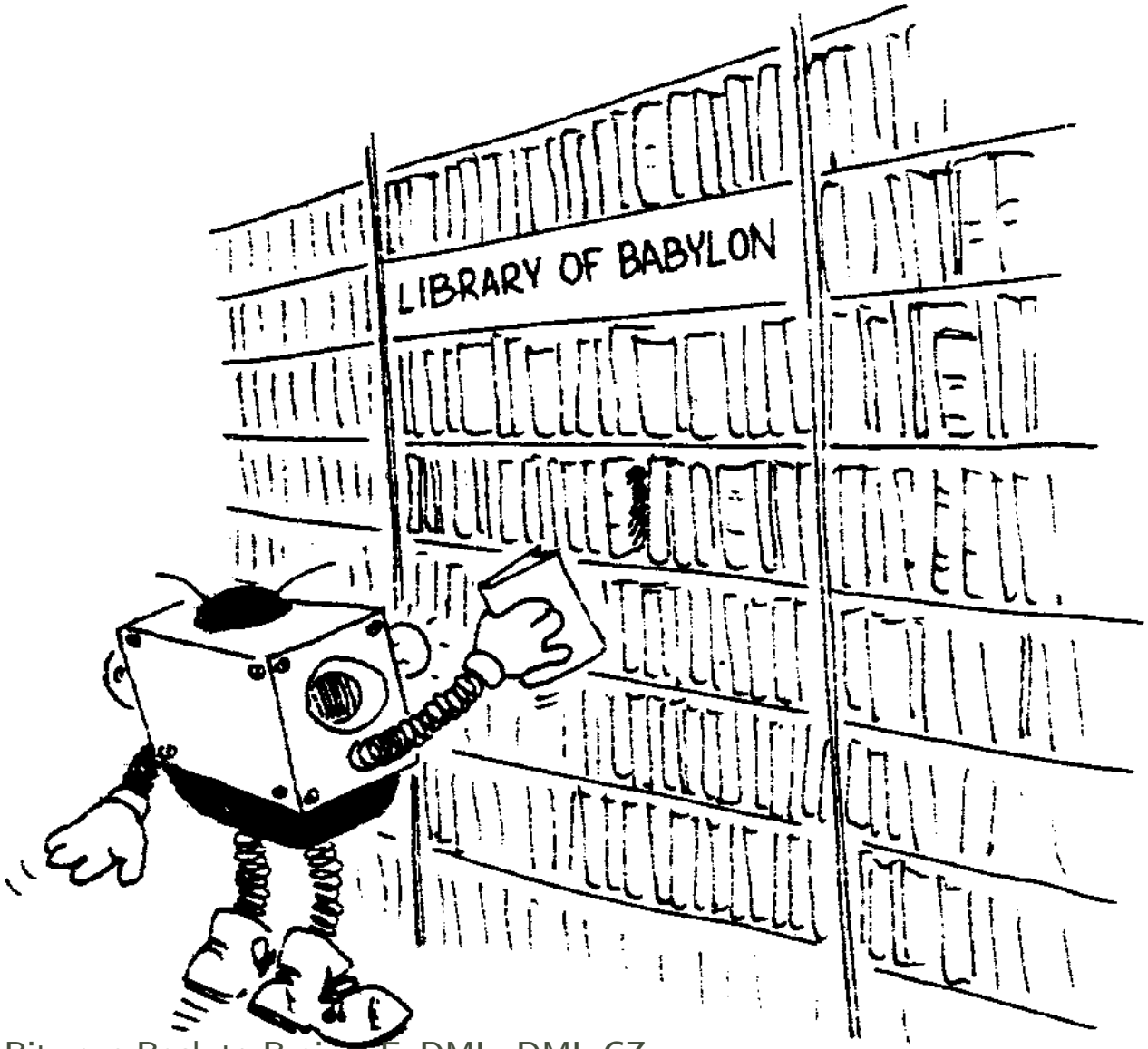
DocEng in DML-CZ: new workflows and data processing



DocEng in DML-CZ: new tools

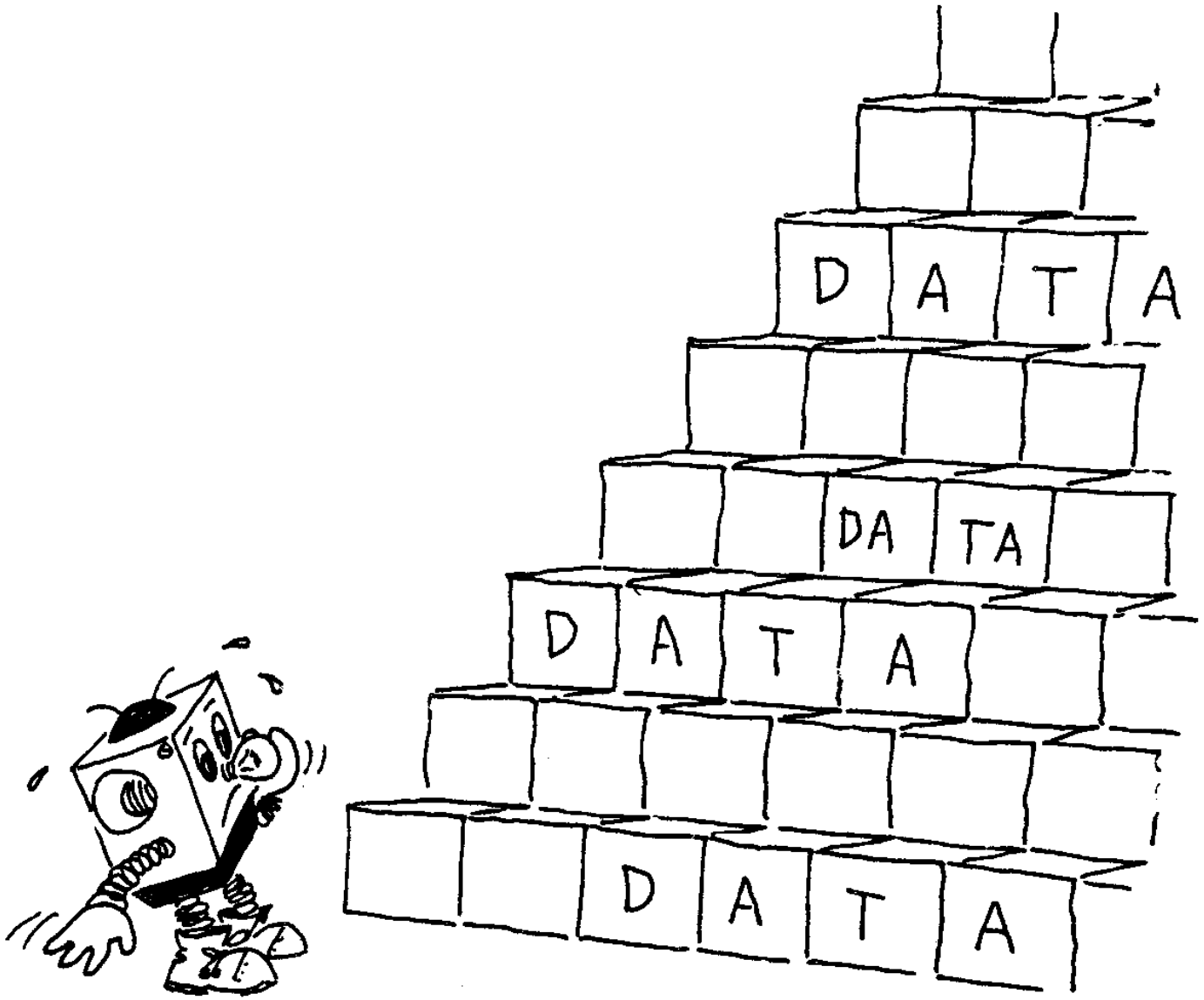


‘Bottom up’ deployment towards EU or worldwide scale

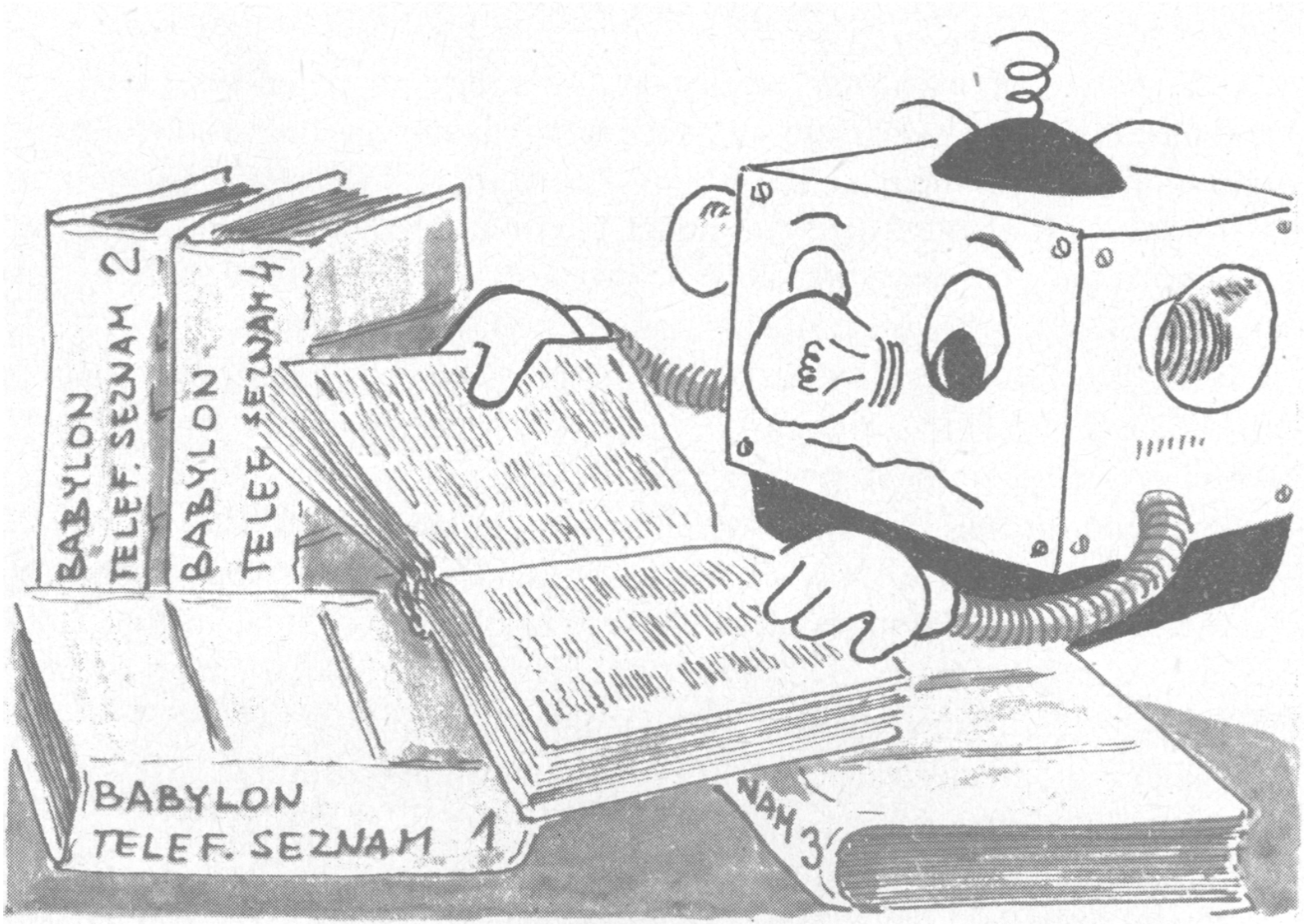


The European Digital Mathematics Library: EuDML

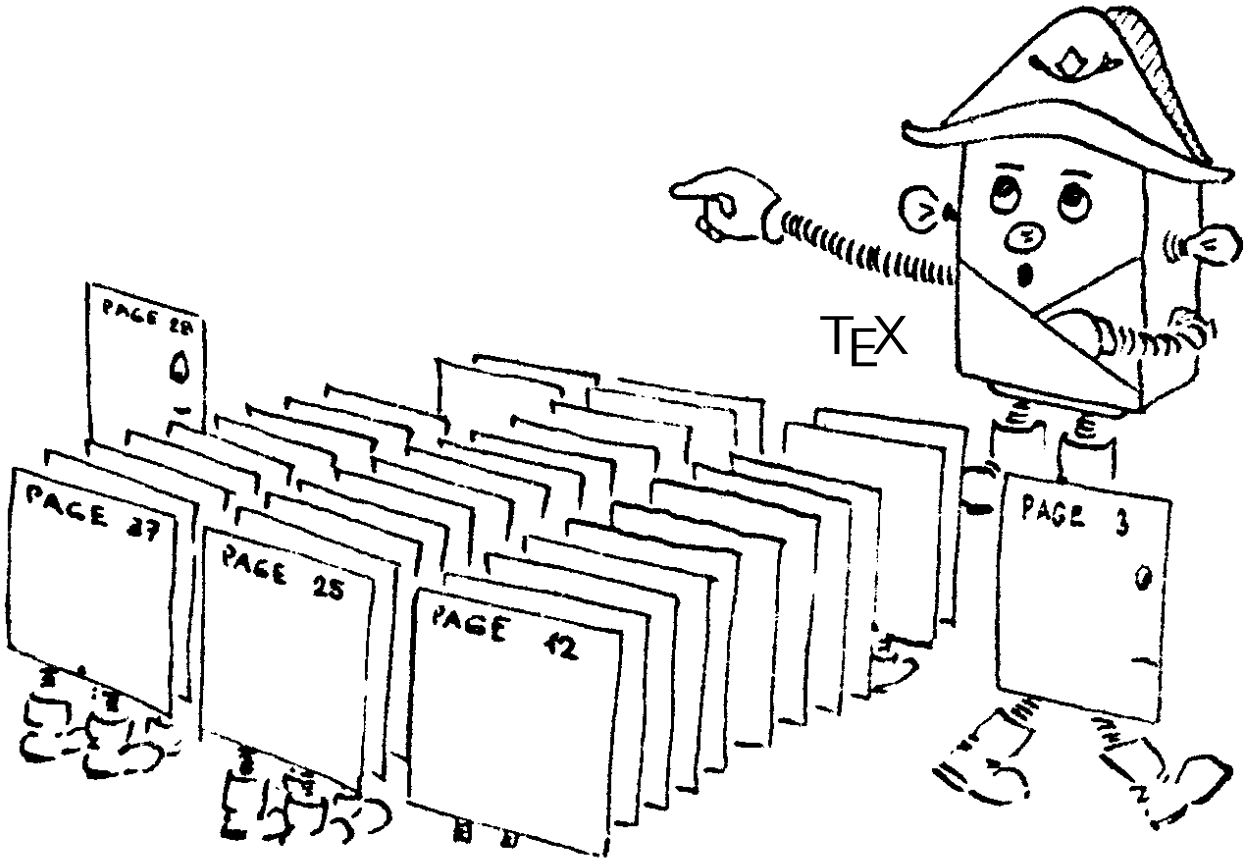
EuDML: from local data collections to the virtual DL



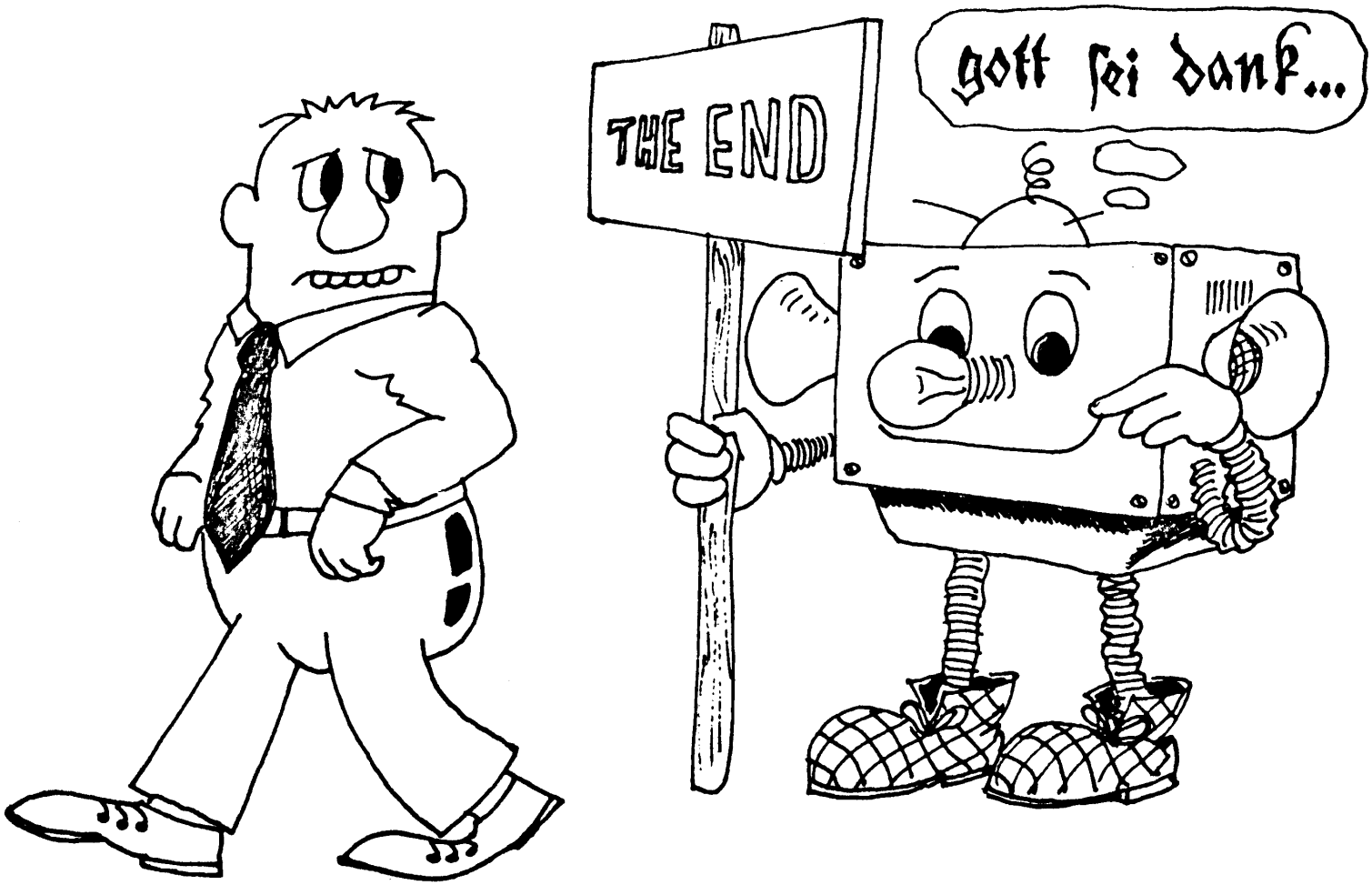
DocEng for EuDML: scalable [PDF] tools development



Yes, you can! You can have visibility, scalability, similarity fulltext metrics, 38% of original size PDFs,...



End of talk overview



Decade of the vision of WDML as PubMed 4 Math

In the beginning was vision of all mathematical knowledge, *peer reviewed, verified* (100,000,000 pages) and engineered into one-stop e-shop/DL.

Progress of IT, connectivity, cheap storage, new information retrieval technologies (Google).

AMS supported NSF preparation grant (in 2003) for WDML—Worldwide digital mathematics library, planned to be funded by de Moore foundation ($100,000,000 requested). Application was *not* successful.

Vision of European Digital Mathematics Library

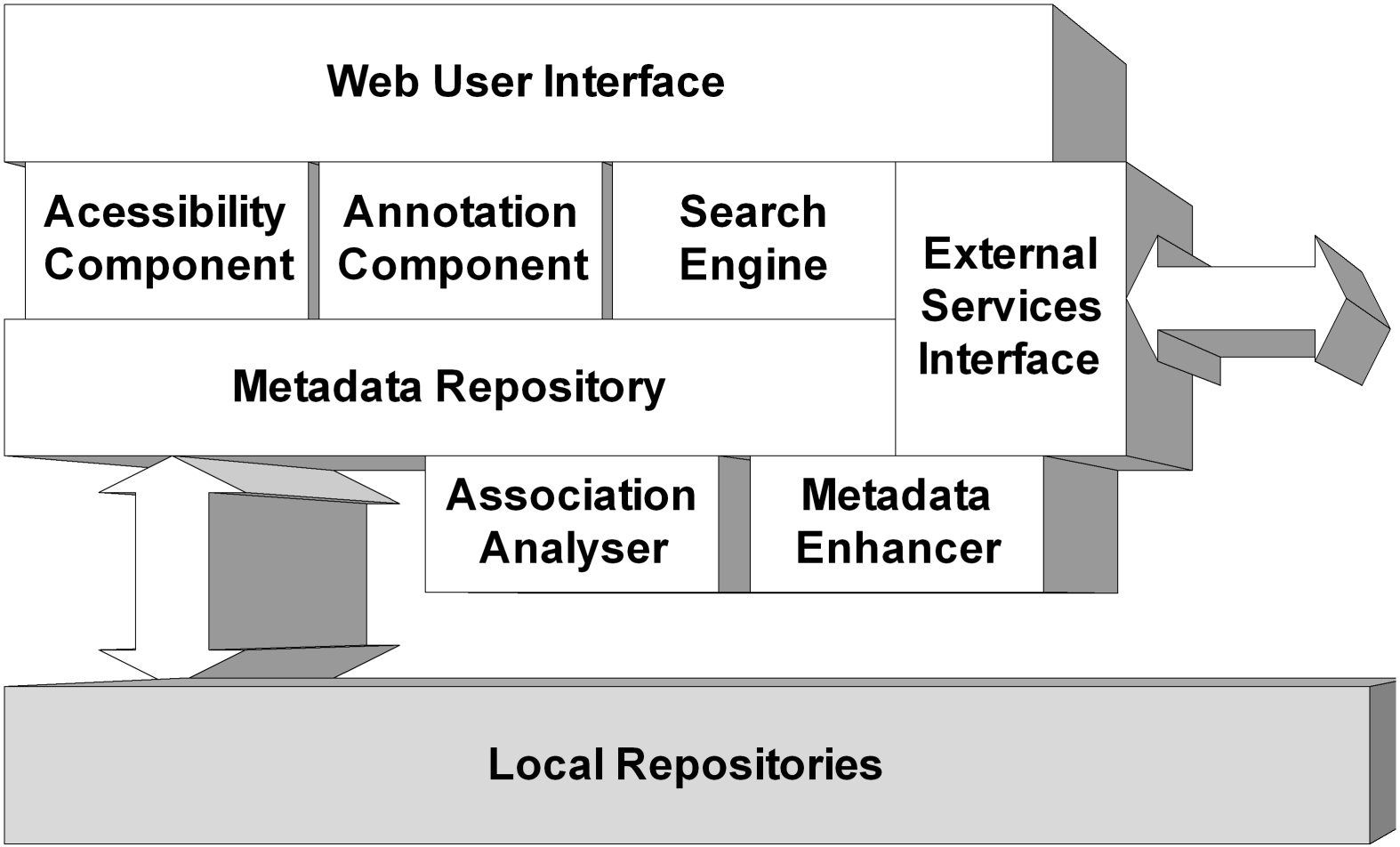
Even other attempts on the European level (FP5, FP6) were not successful. Finally three year project or *European Digital Mathematics Library, EuDML* (programme EU CIP-ICT-PSP, type Pilot B, EU contribution *(1.6 MEur, 50% of total budget only)*

started from February 2010. The strategy of EuDML The EUROPEAN DIGITAL MATHEMATICS LIBRARY is:

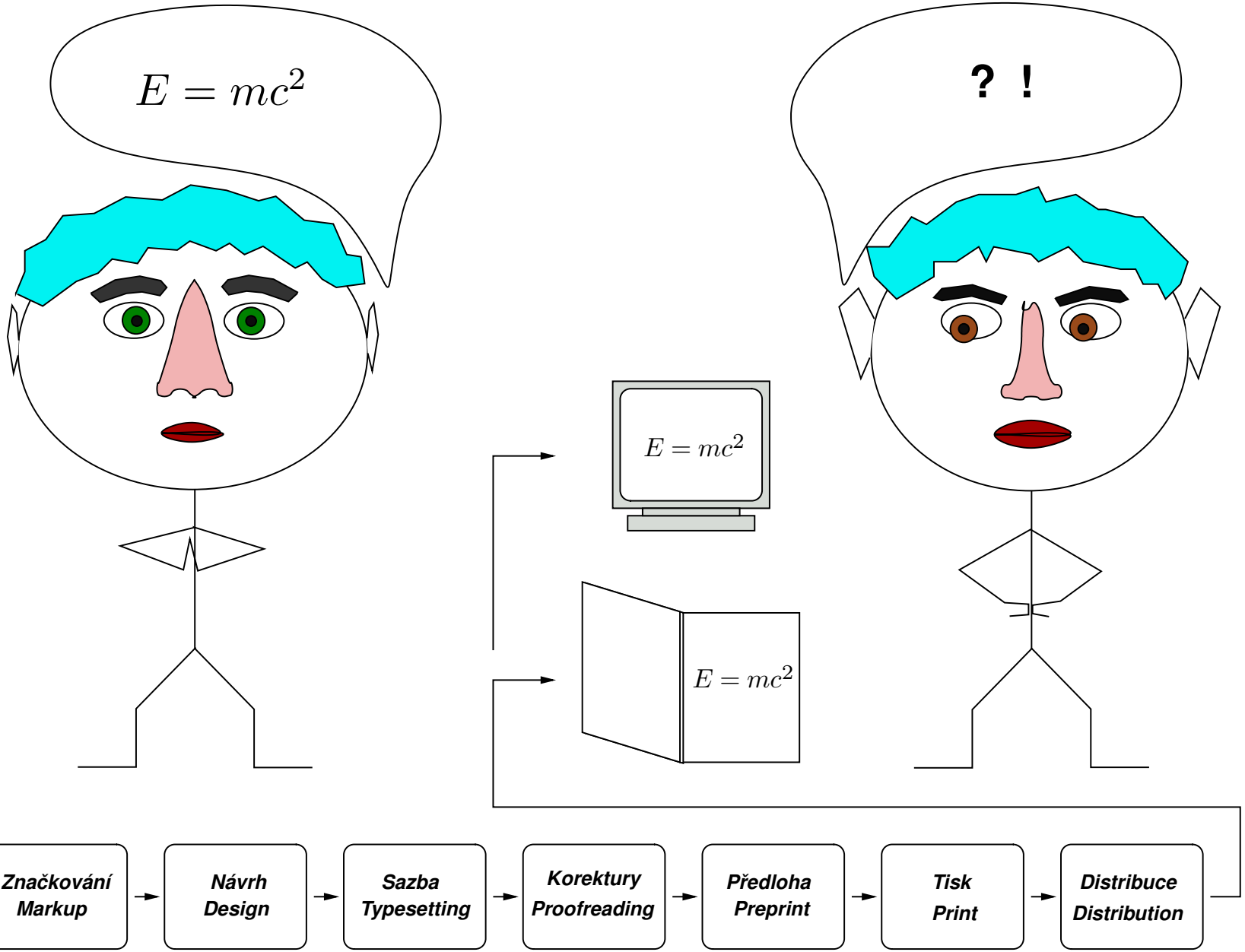
- to master the technology, develop tools and offer them;
- concept of *moving wall* to motivate and engage commercial publishers without Open Access bussiness model;
- to collect data (from existing local or publisher's) *digital libraries* into 'one-stop shop' and achieve critical mass in the domain $\rightarrow$ 'a must/me too' effect then as with PubMed.

EuDML as a virtual library portal

EuDML will be a *virtual* library based on data from smaller data providers, DLs and publishers:



European Digital Mathematics Library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Značkování
Markup
Návrh
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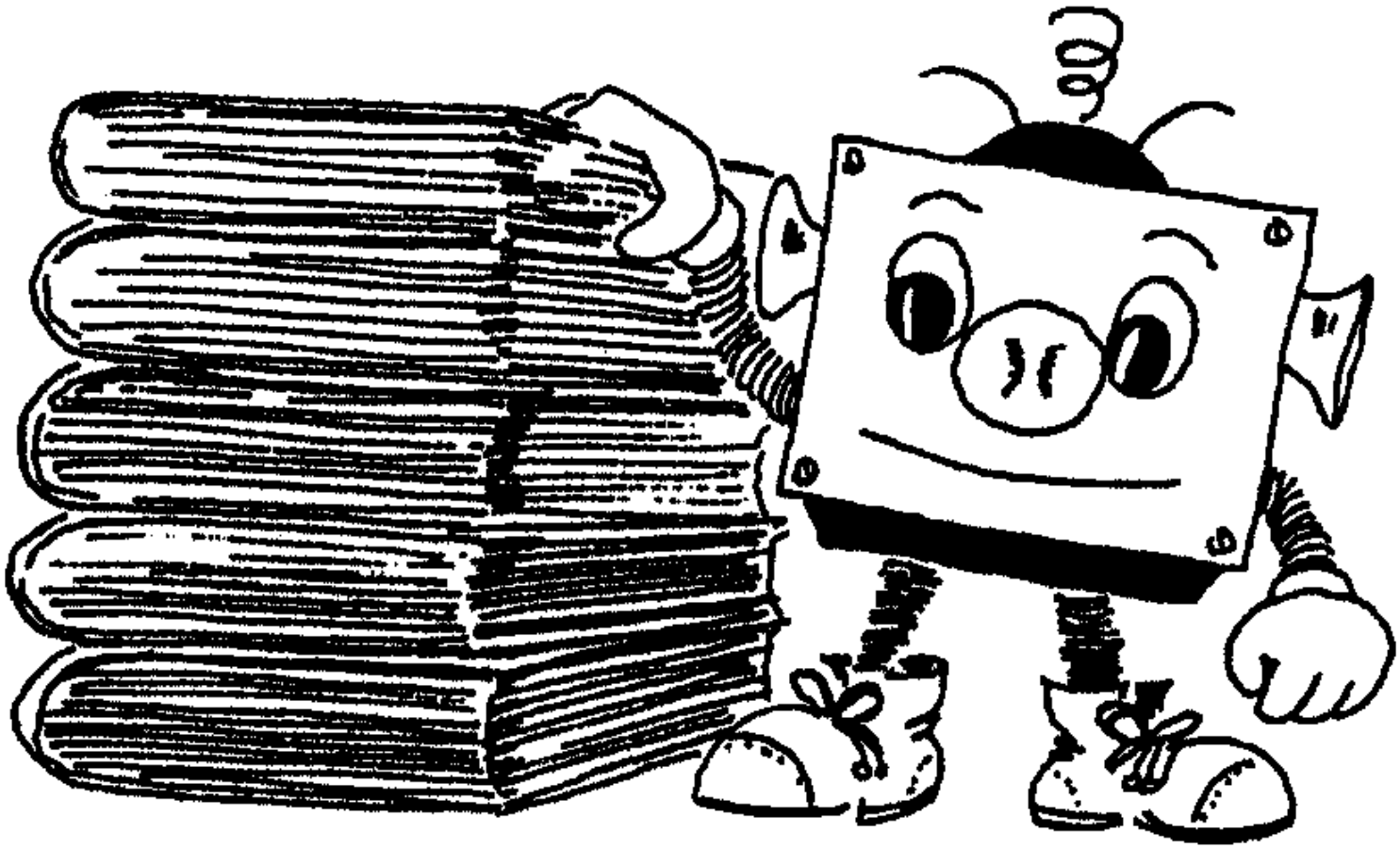
Sazba
Typesetting
Korektury
Proofreading
Předloha
Preprint
Tisk
Print
Distribuce
Distribution

Bottom up—from building bricks of regional repositories

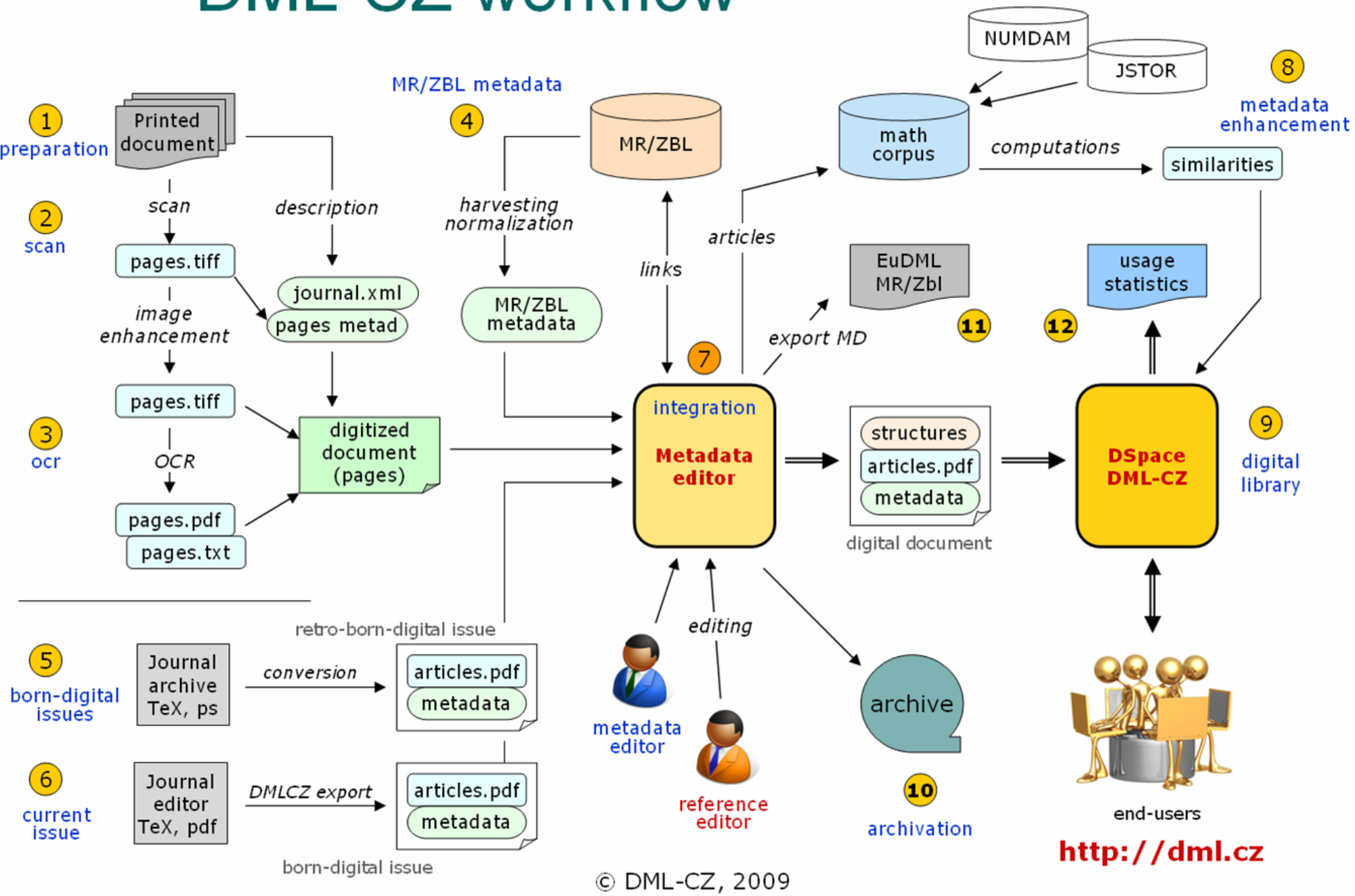
As DML content providers serve mostly publisher's or regional DML repositories as The Czech Digital Mathematics Library DML-CZ or NUMDAM, DML-PL, DML-PT, RusDML,. . . : aggregating content from local repositories to build the bigger (global?) DML.

Example of DML-CZ: up and running digital mathematics library <http://dml.cz> with nearly 30,000 papers (300,000 pages). For more, see (who, what, browse, browse similar, how to search).

From paper to digital processing, from local to the whole

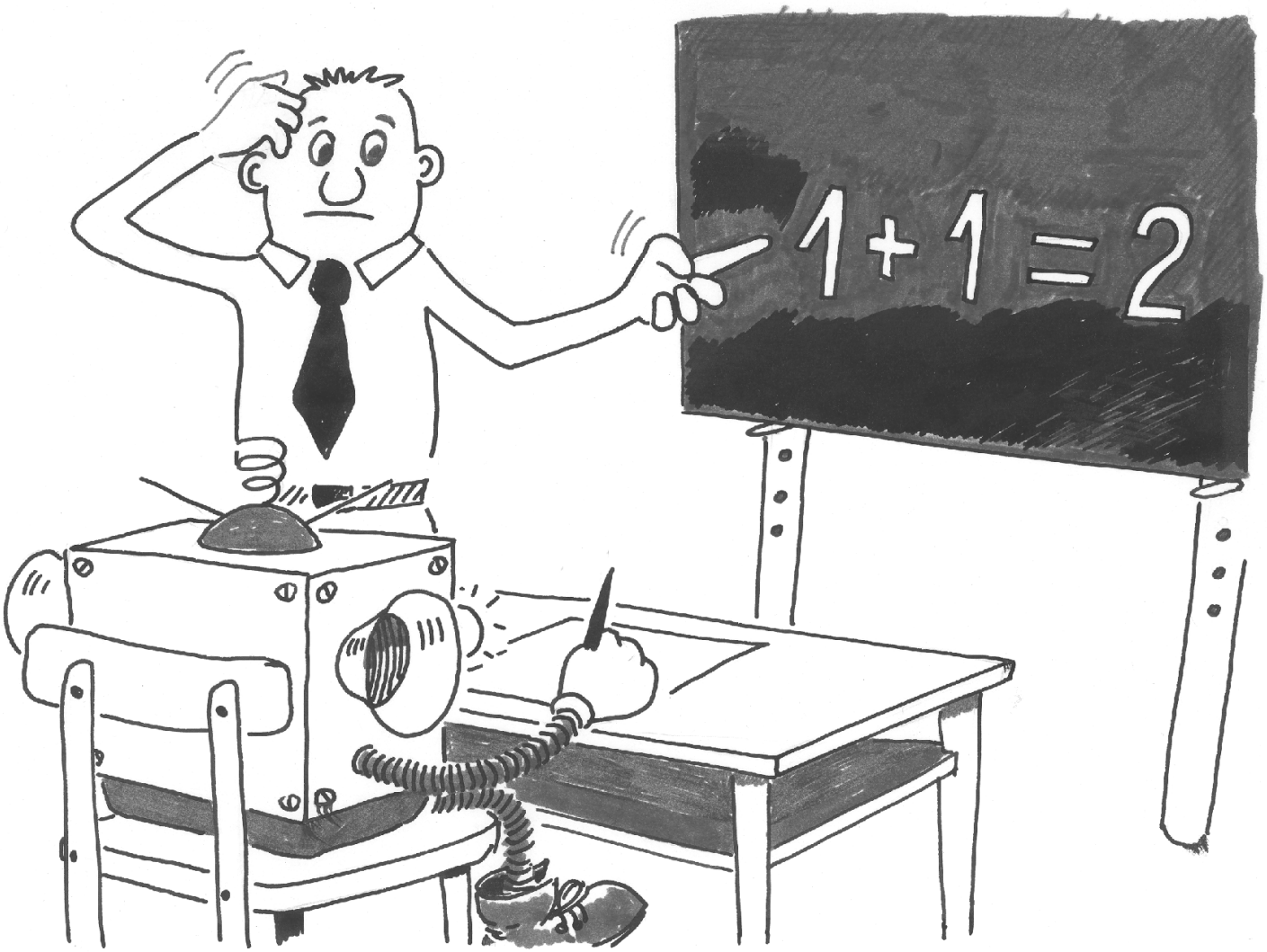


DML-CZ workflow



Take care! "God is in the details." (Mies van der Rohe)

Challenges of Math handling: OCR, indexing, search...



DML-CZ—data: scientific math published in CZ/SK

Proof. Let $\hat{K}$ be a cube, $\hat{K} \subset \hat{G}$; put $K = \varphi^{-1}(\hat{K})$. According to theorem 50 we have $K \in \mathfrak{A}$ and it follows from theorem 24 that

$$P(K, v) = \int_K f(x)\,\mathrm{d}x\,. \tag{89}$$

The functional determinant T of the mapping $\psi = \varphi^{-1}$ fulfils the relation $T(\varphi(x)) \,.\, \det M(x) = 1$, so that

$$\int_K f(x)\,\mathrm{d}x = \int_{\hat{K}} f(\psi(y)) \,.\, |T(y)|\,\mathrm{d}y = \int_{\hat{K}} \hat{f}(y)\,\mathrm{d}y\,. \tag{90}$$

From theorem 50 (and relation (86)) we see that $P(K, v) = P(\hat{K}, \hat{v})$; relations (89), (90) show therefore that $P(\hat{K}, \hat{v}) = \int_{\hat{K}} \hat{f}(y)\,\mathrm{d}y$, which completes the proof.

Remark. The reader may compare this paper with [6].

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[1] *V. Jarník:* Diferenciální počet, Praha 1953.
[2] *V. Jarník:* Integrální počet II, Praha 1955.
[3] *J. Mařík:* Vrcholy jednotkové koule v prostoru funkcionál na daném polouspořádaném prostoru, Časopis pro pěst. mat., *79* (1954), 3—40.
[4] *Ян Маржик* (Jan Mařík): Представление функционала в виде интеграла, Чехословацкий мат. журнал, *5* (80), 1955, 467—487.
[5] *J. Mařík:* Plošný integrál, Časopis pro pěst. mat., *81* (1956), 79—82.
[6] *Ян Маржик* (Jan Mařík): Заметка к теории поверхностного интеграла, Чехословацкий мат. журнал, *6* (81), 1956, 387—400.
[7] *S. Saks:* Theory of the integral, New York.

Резюме

ПОВЕРХНОСТНЫЙ ИНТЕГРАЛ

ЯН МАРЖИК (Jan Mařík), Прага.

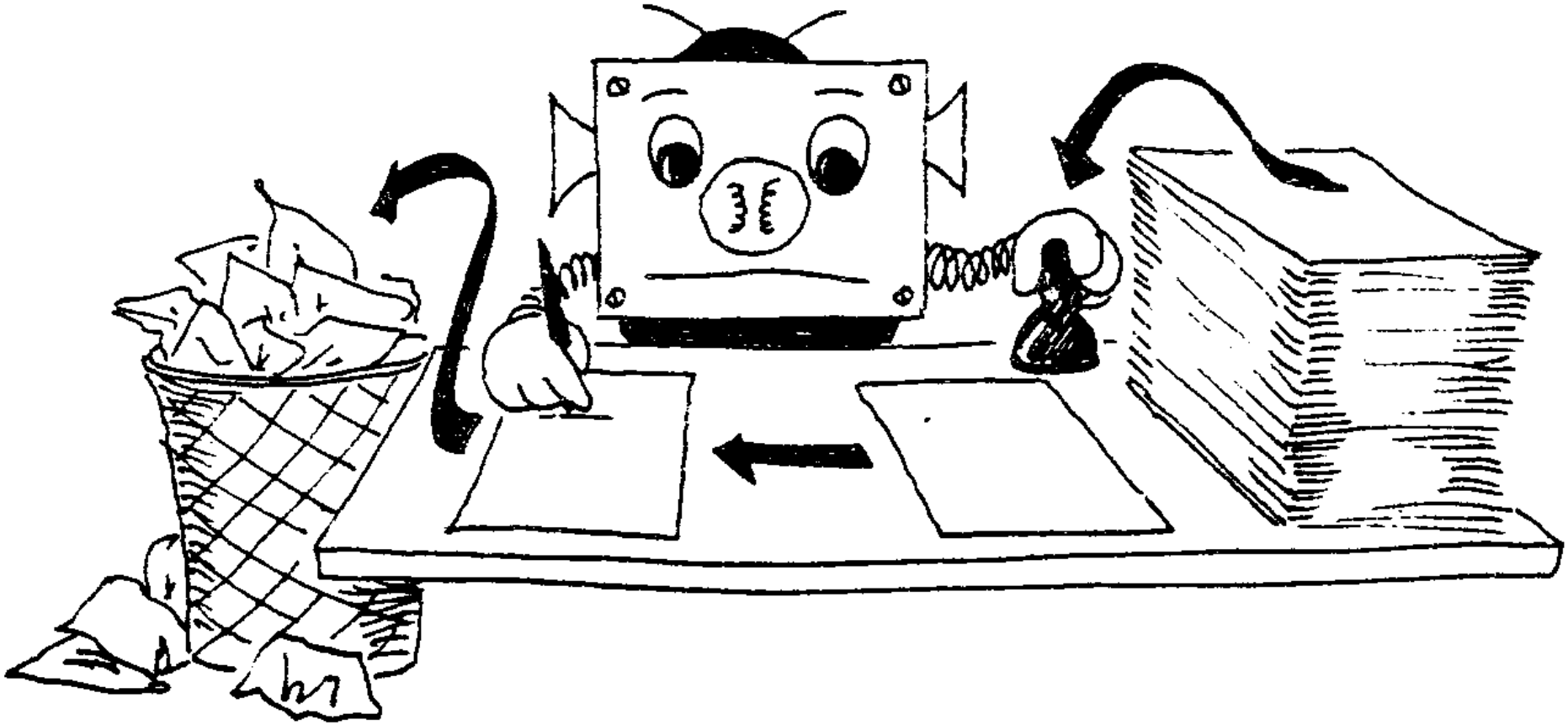
(Поступило в редакцию 10/X 1955 г.)

Пусть m — натуральное число; пусть E_m — m-мерное евклидово пространство. Для всякого ограниченного измеримого множества $A \subset E_m$ положим $\|A\| = \sup \int_A \sum_{i=1}^{m} \frac{\partial v_i(x)}{\partial x_i}\,\mathrm{d}x$, где $v_1, \ldots, v_m$ — многочлены такие, что $\sum_{i=1}^{m} v_i^2(x) \leqq 1$ для всех $x \in A$. Пусть $\mathfrak{A}$ — система всех ограниченных измеримых множеств A, для которых $\|A\| < \infty$. Теорема 18 тогда утверждает: *Пусть $A \in \mathfrak{A}$; пусть D — граница множества A. Тогда на системе $\mathfrak{B}$ всех борелевских подмножеств множества D существует мера p и на*

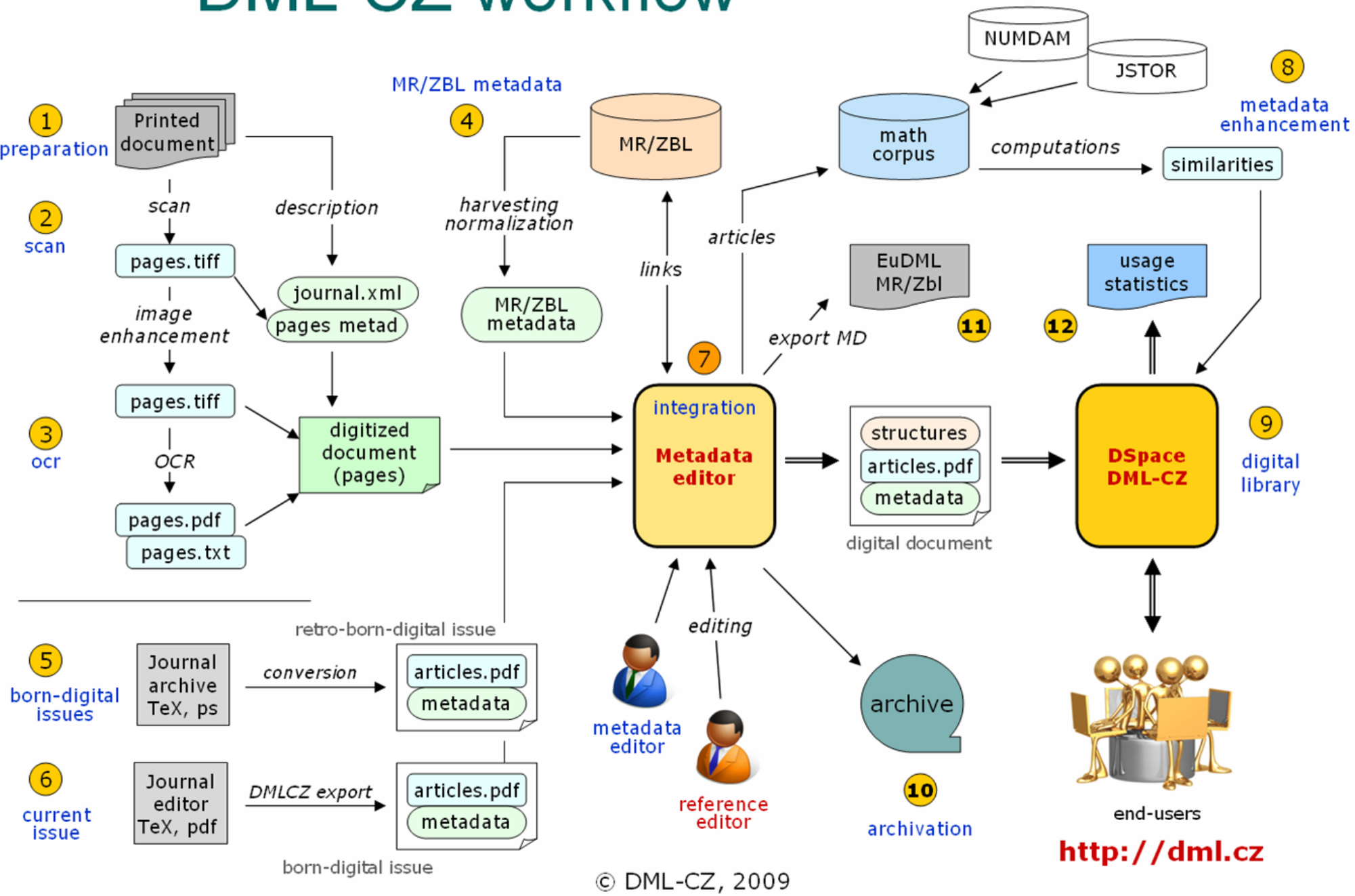
ИОСИФ ВИССАРИОНОВИЧ СТАЛИН

1879—1953

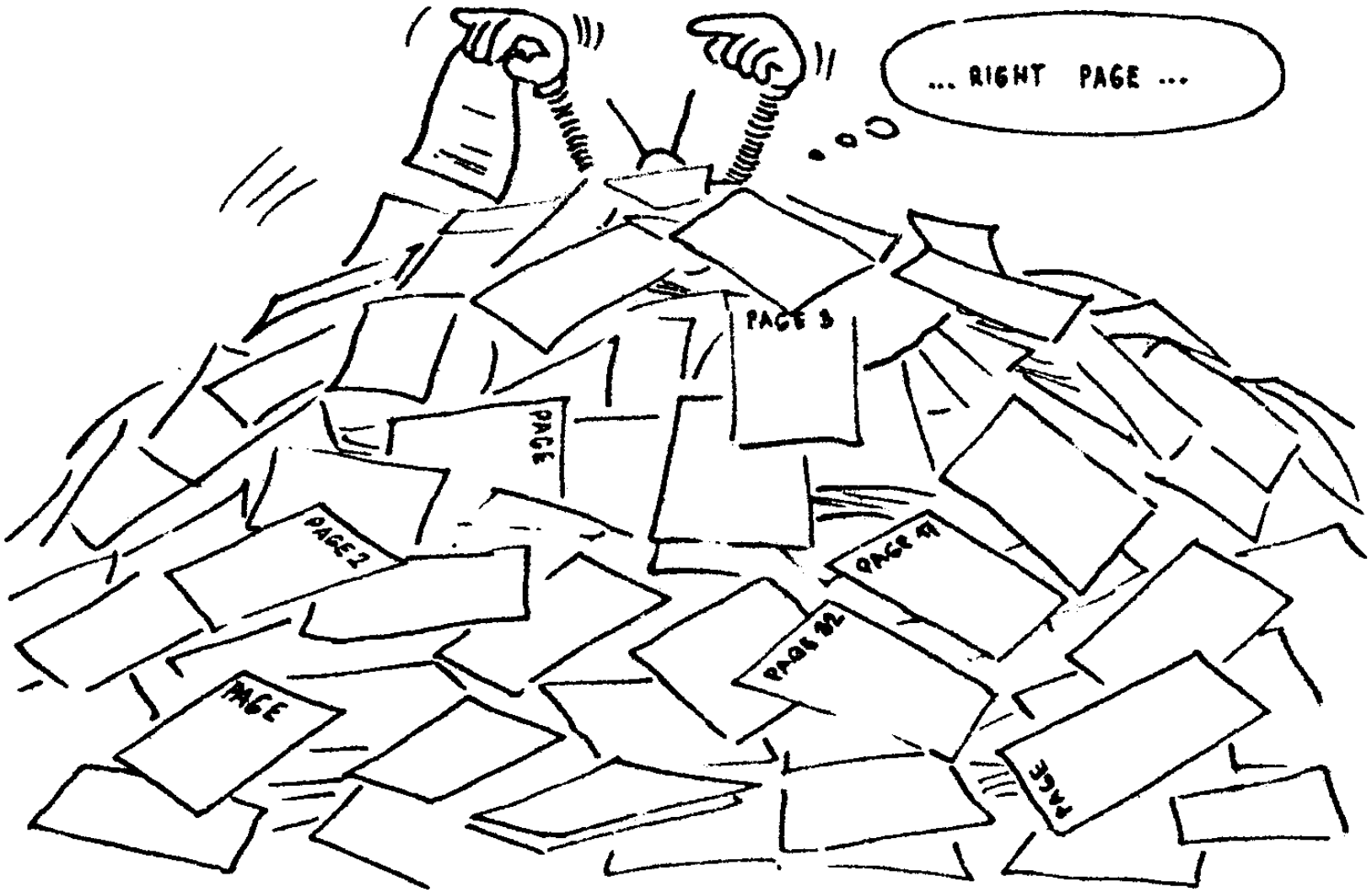
Document engineering—from paper to digital *workflow*



DML-CZ workflow



DML-CZ document engineering—data processing



DML-CZ challenges and lessons learned

DML-CZ, the Czech Digital Mathematics Library, now serves almost *300,000 pages of 30,000 math papers*. Challenges were

- *migration of existing workflows (retro-digital, retro-digital and born-digital) into the repository*
- negotiations with Google Scholar towards better visibility
- math indexing and search
- copyright and sustainability issues
- visualization
- space and processing demands
- ....

Document engineering 4 DML processing challenges

Data heterogenity, plethora of formats, validation and conversions:

retro-digital period: scanning, geometrical transformations (BookRestorer), OCR (FineReader, InftyReader), two-layer PDF

retro-born-digital period: not complete .tex or .dvi data, bad formats, bitmap fonts of low resolution

born-digital period: typesetting by TEX with export of [meta]data into digital library

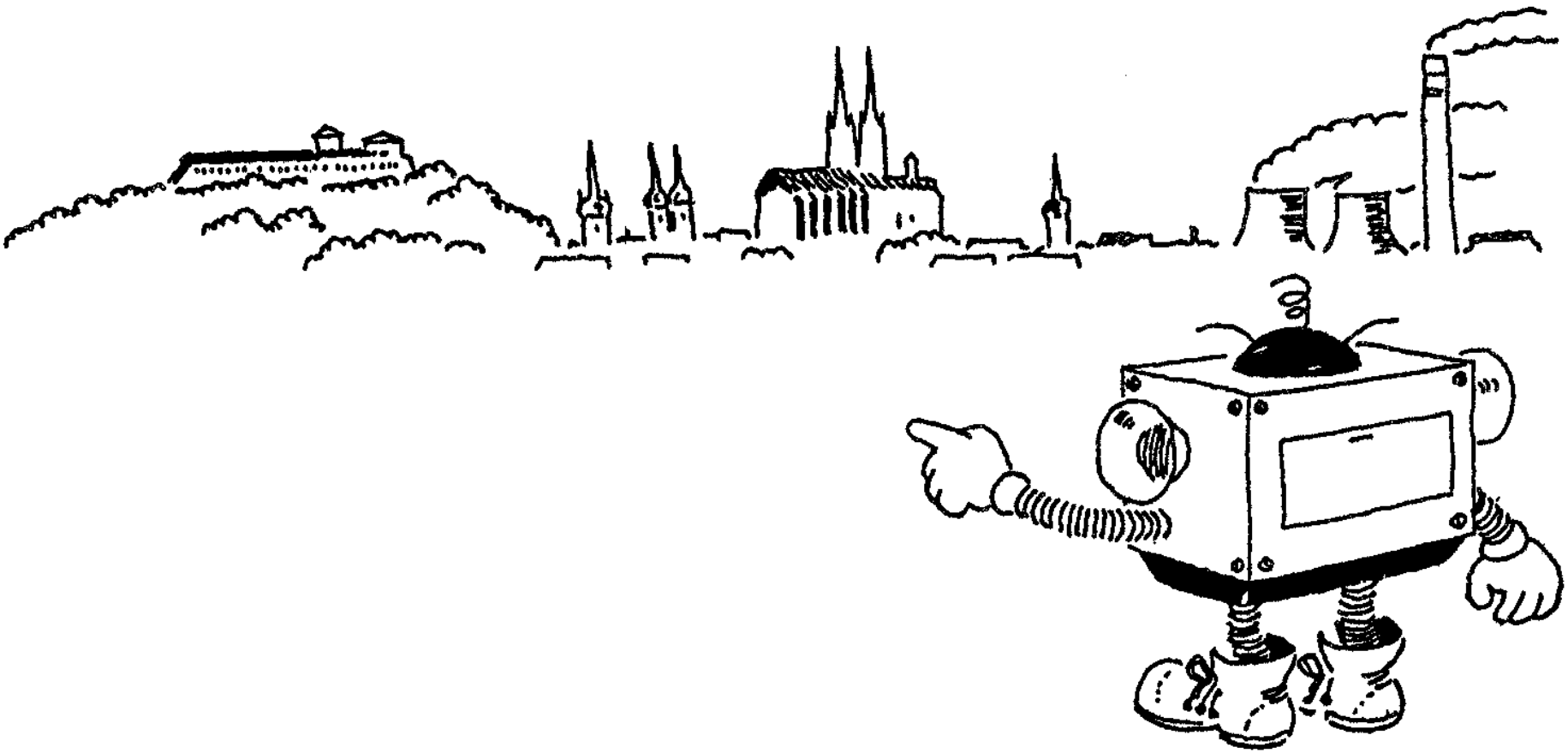
world of authors: LATEX, TEX notation of mathematics

world of applications/data exchange: XML, MathML

big volumes: $\rightarrow$ high automation to save costs

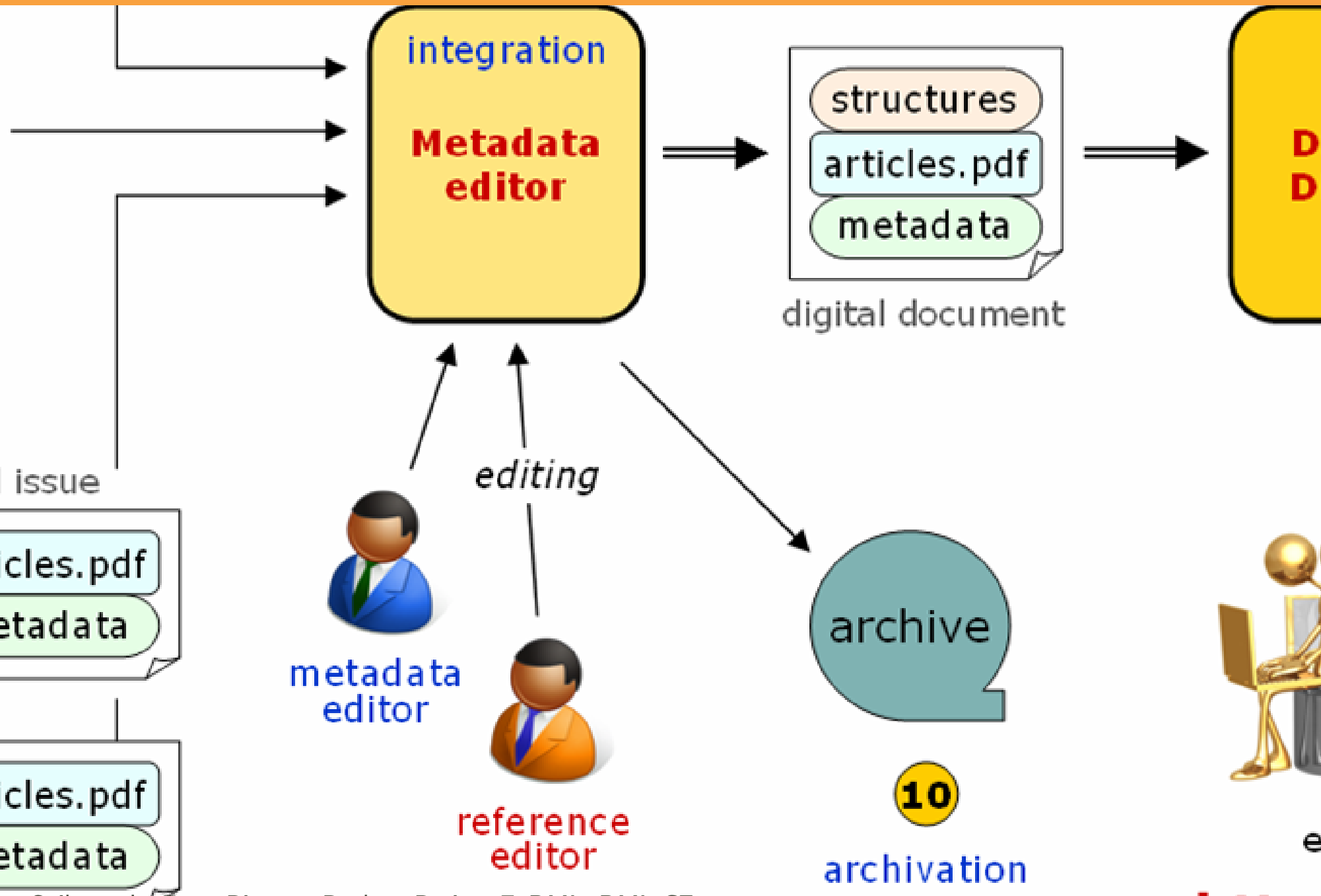
Document engineering technologies and tools

6+ years of local (Brno, CZ) document engineering



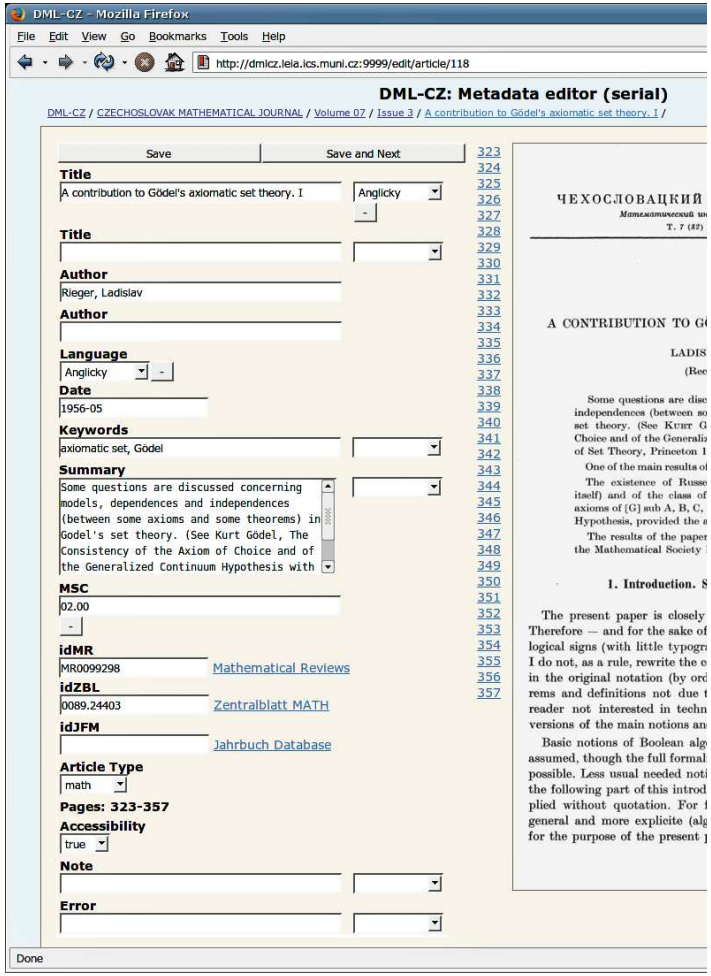
Verified and proven technologies (in DML-CZ)

- Scanned image processing and transformations (with BookRestorer) (BT Pulkrábek)
- Mathematical optical character recognition: OCR by combining FineReader (SDK 8.1) and Infty by prof. Suzuki (MT Panák, Mudrák, BT Vystrčil)
- Pre-MSC era papers' automated classification by MSC (with Radim Řehůřek)
- gensim framework: similarity article computations aka document clustering (PhD research by Radim Řehůřek)
- web-based long distance metadata editing: web application metadata editor


integration
Metadata editor
structures
articles.pdf
metadata
digital document
issue
editing
metadata editor
reference editor
archive
10
archivation

Metadata Editor http://editor.dml.cz

Web-based client-server tool allowing long-distance editing in any browser
open source development (ICS MU) from scratch (Ruby) for [meta]data import, editing, validation, batch checking and correction.
To test, try <http://editor.dml.cz:9129>, admin/admin

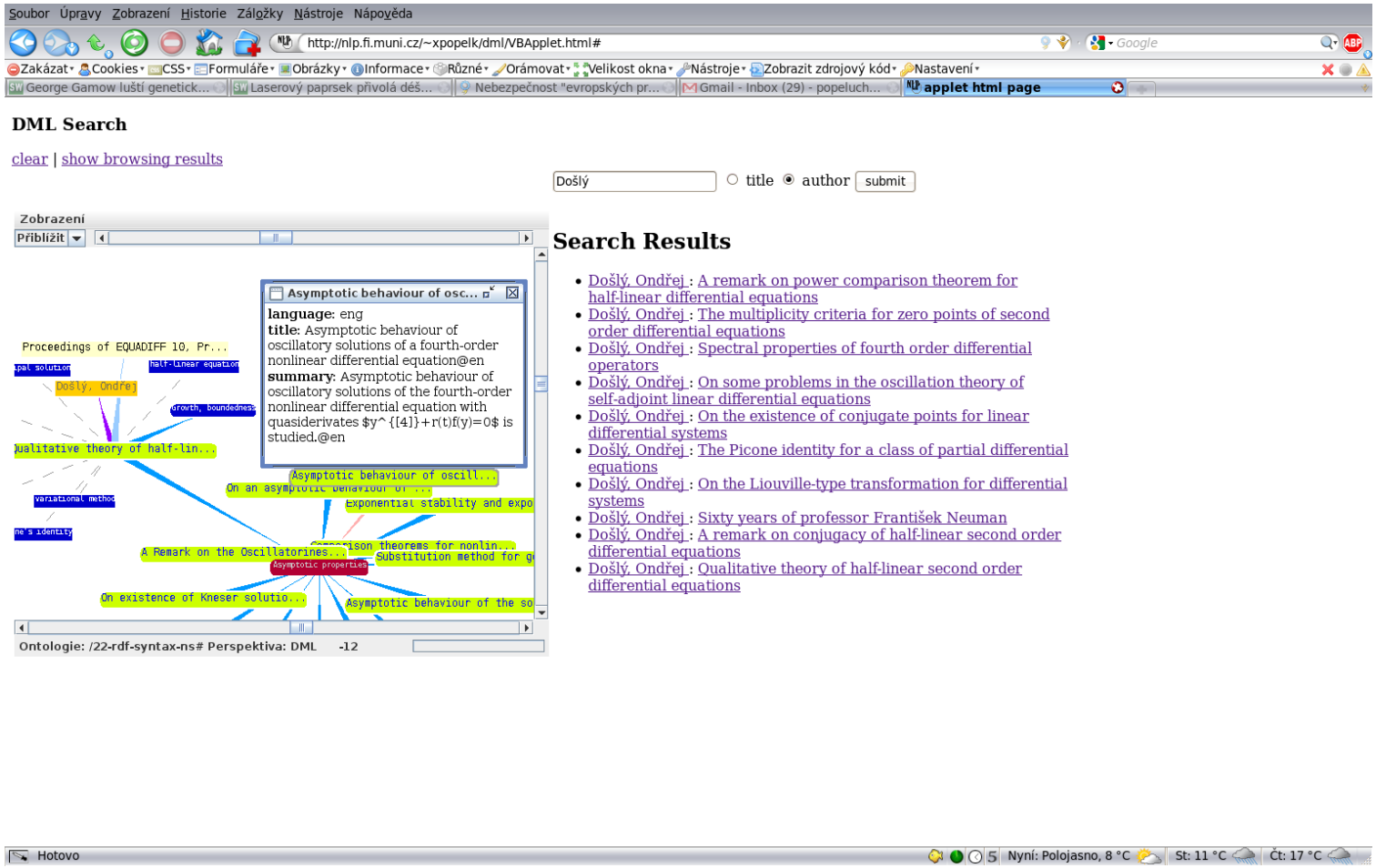


Verified and proven technologies (in DML-CZ) (cont.)

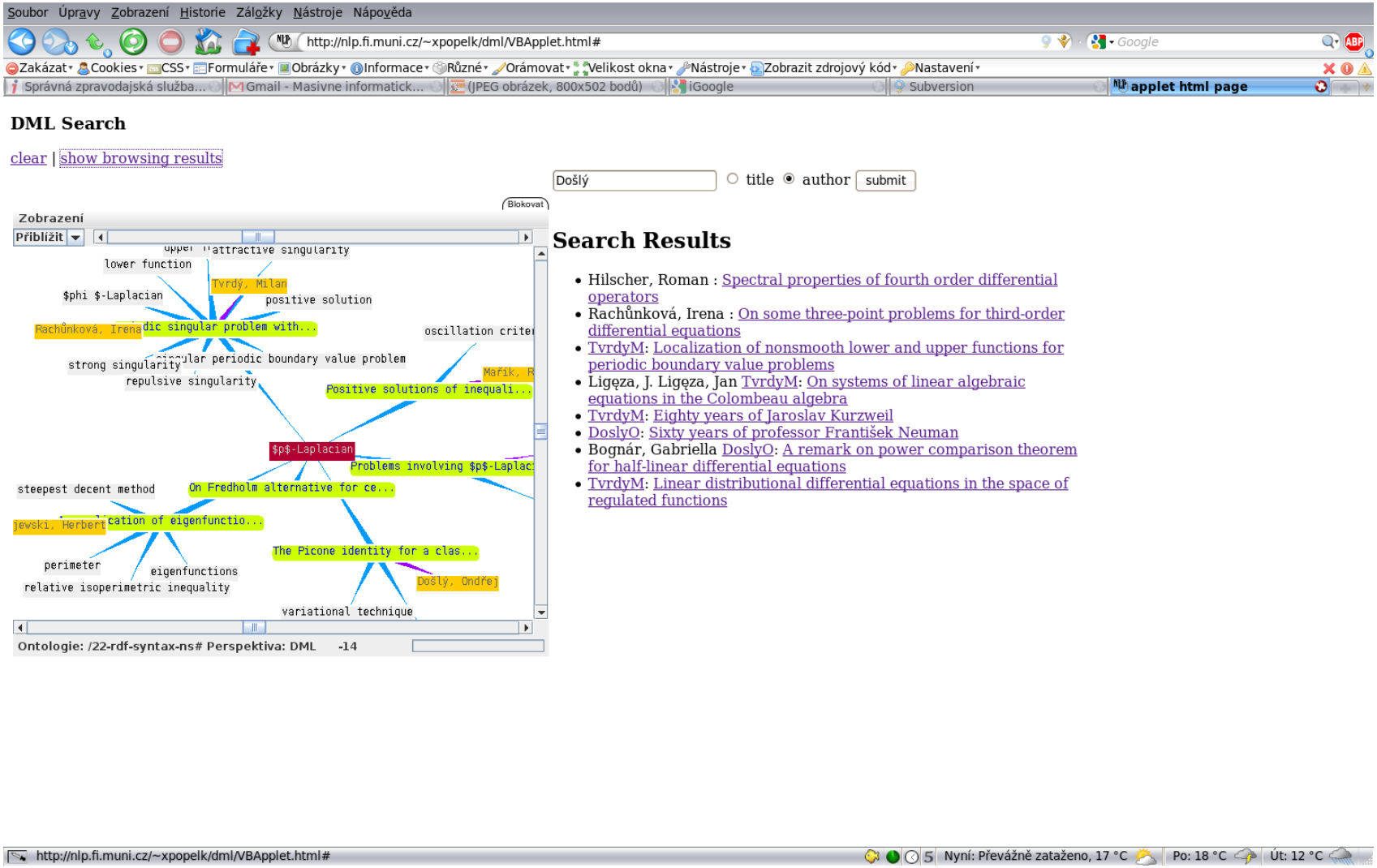
- Google Scholar partnership: interface to use our metadata instead of those parsed from landing pages' HTML
- Math retrieval: math formula indexing and search (MT Vítězslav Dostál, BT Martin Liška, BT Peter Mravec)
- Citation linking: CiteCrawl (BT Lukáš Lalinský)
- Born-digital publishing system [for Archivum Mathematicum and for other 10 journals] and retro-born-digital paper conversions and enhancements (BT&MT Michal Růžička)
- Visualization and browsing interface (MT Zuzana Nevěřilová)

Verified and proven technologies (in DML-CZ) (cont.)

Metadata (in RDF) visualisation, browsing: Visual Browser tool (MT Zuzana Nevěřilová) for [Eu]DML GUI.



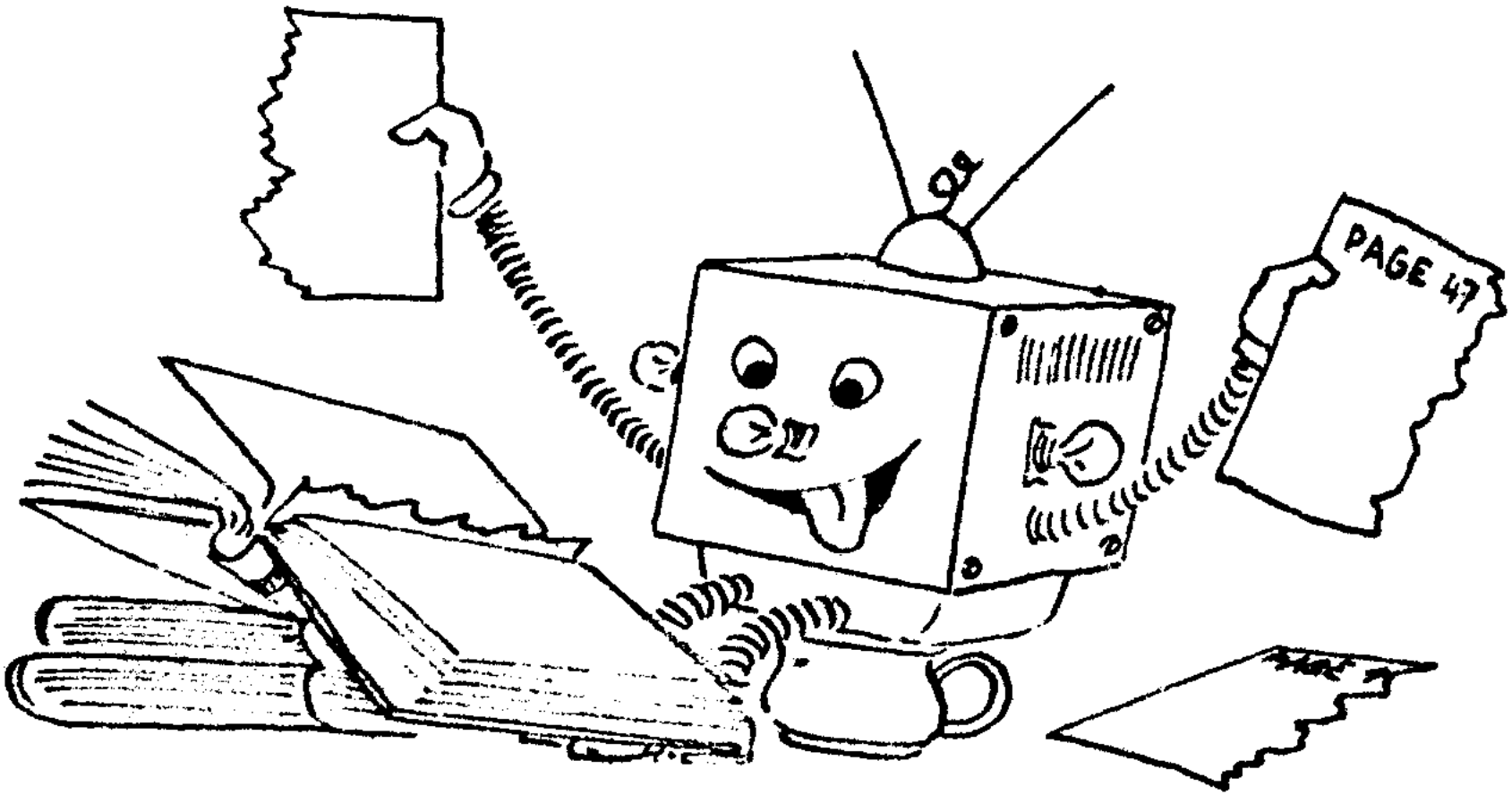
Visual Browser visualisation



Verified and proven technologies (in DML-CZ) (cont.)

- batch digital signature of PDF: `pdfsign` (BT Peter Bočák)
- optimization of PDF: `pdfopt` (from `ghostscript` suite), `pdfsizeopt.py` (by Google sponsored Peter Szabó)
- PDF recompression using JBIG2: an application based on `jbig2enc`/`Leptonica` (started as BT by Radim Hatlapatka)

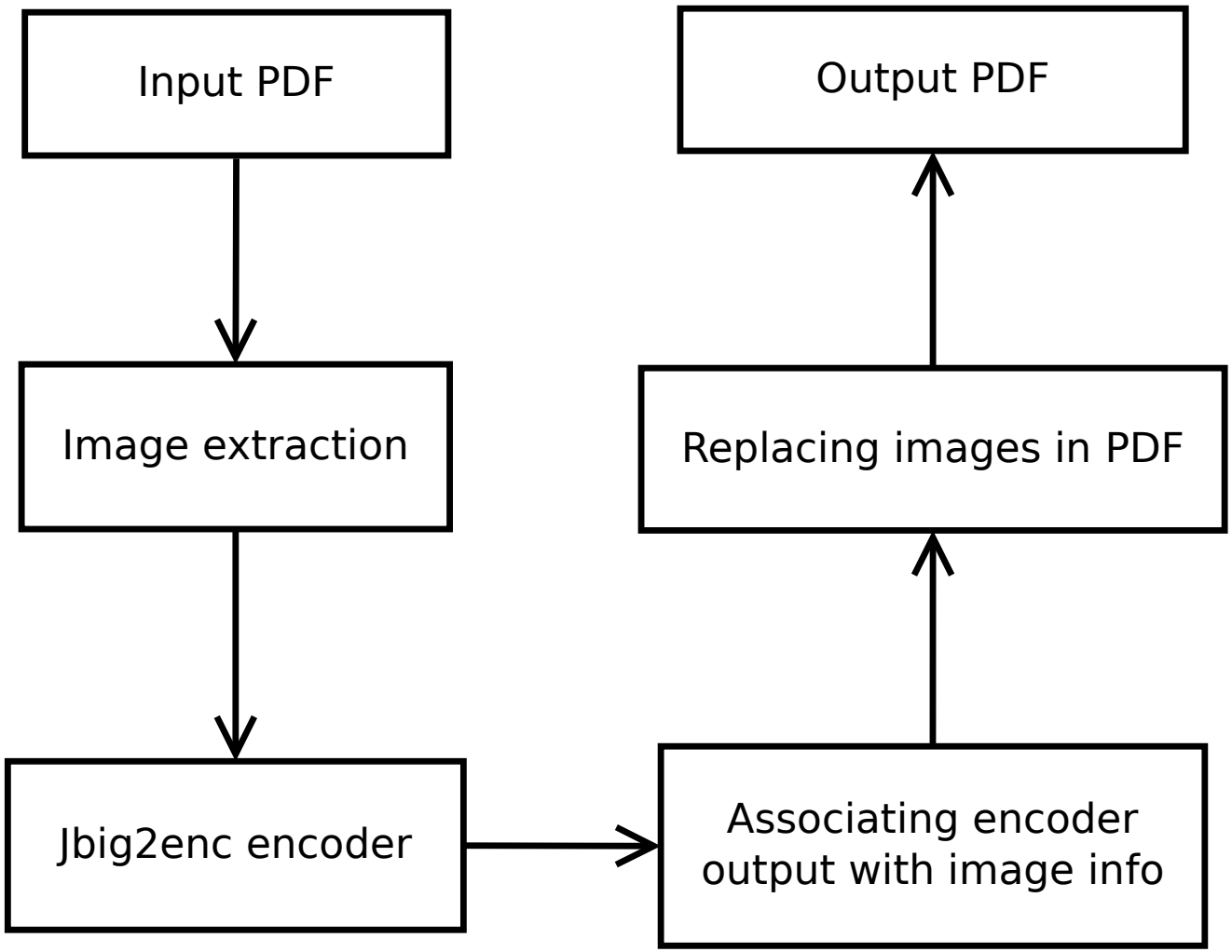
PDF tools



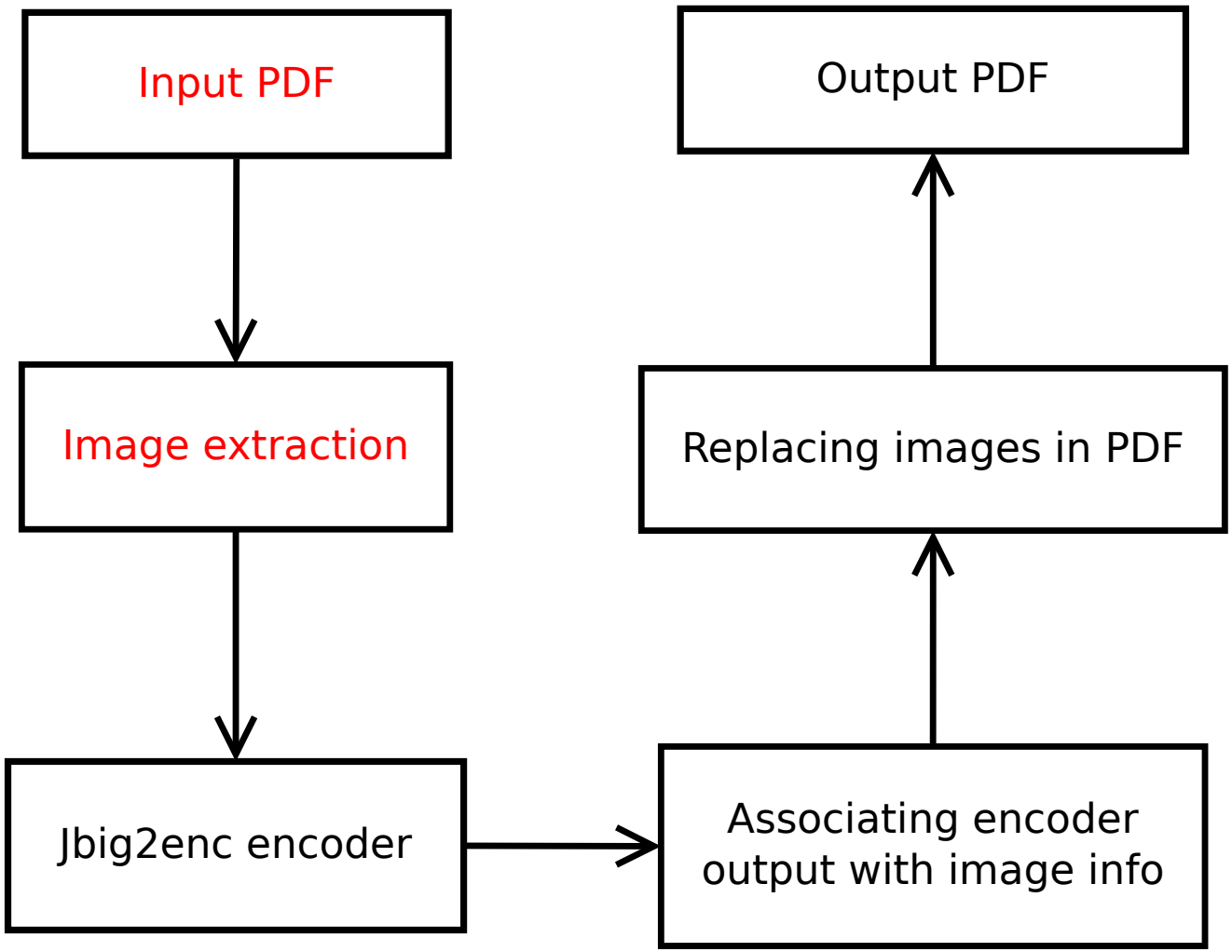
PDF recompressor

- Open-source tool written in Java for recompression of bitonal images
- Uses benefits of standard JBIG2 which is supported in PDF since version 1.4 (Acrobat 5)
- Uses improved `jbig2enc` with symbol coding used for text area
- Supports multi-page compression

PDF tools: PDF recompressor



PDF recompressor: input PDF



PDF recompressor: input PDF

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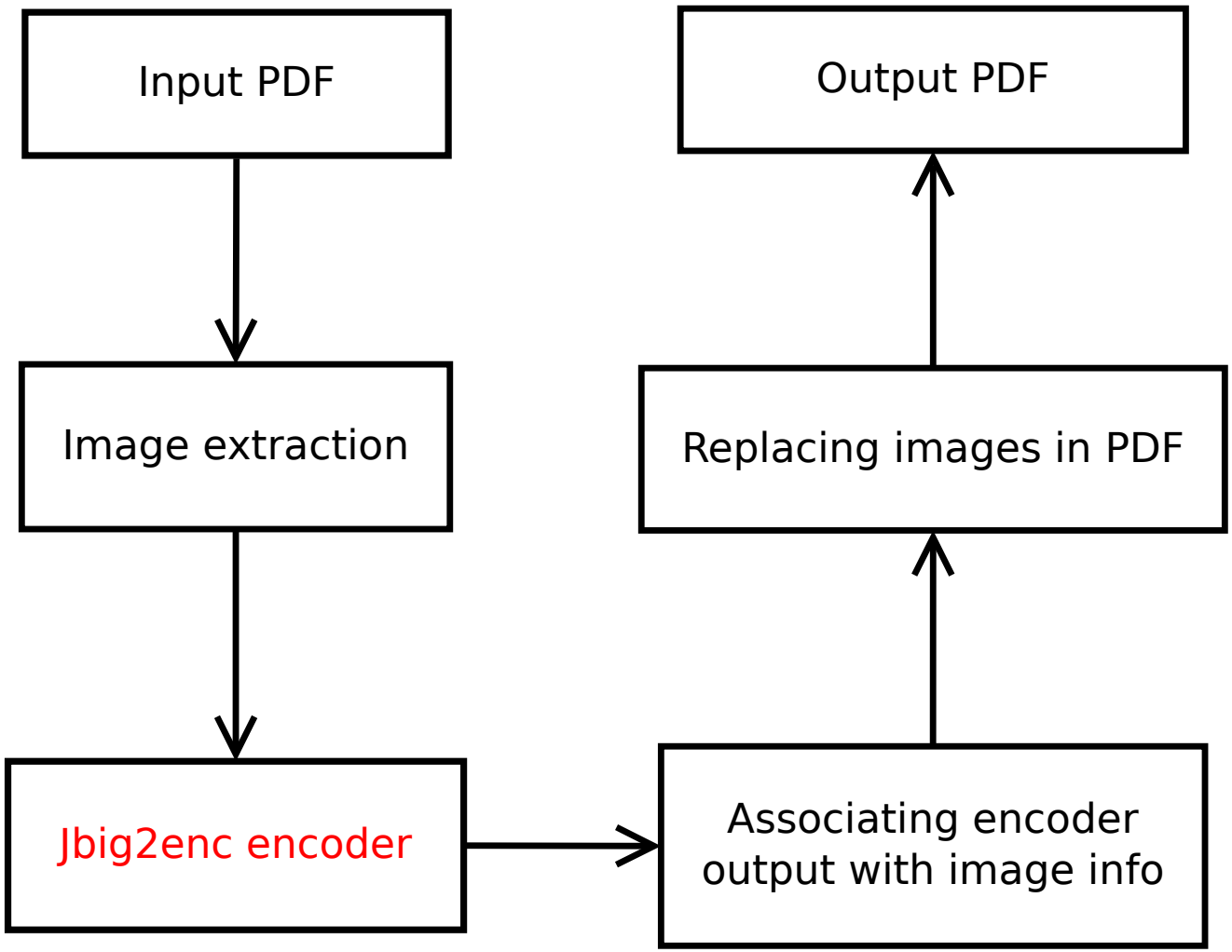
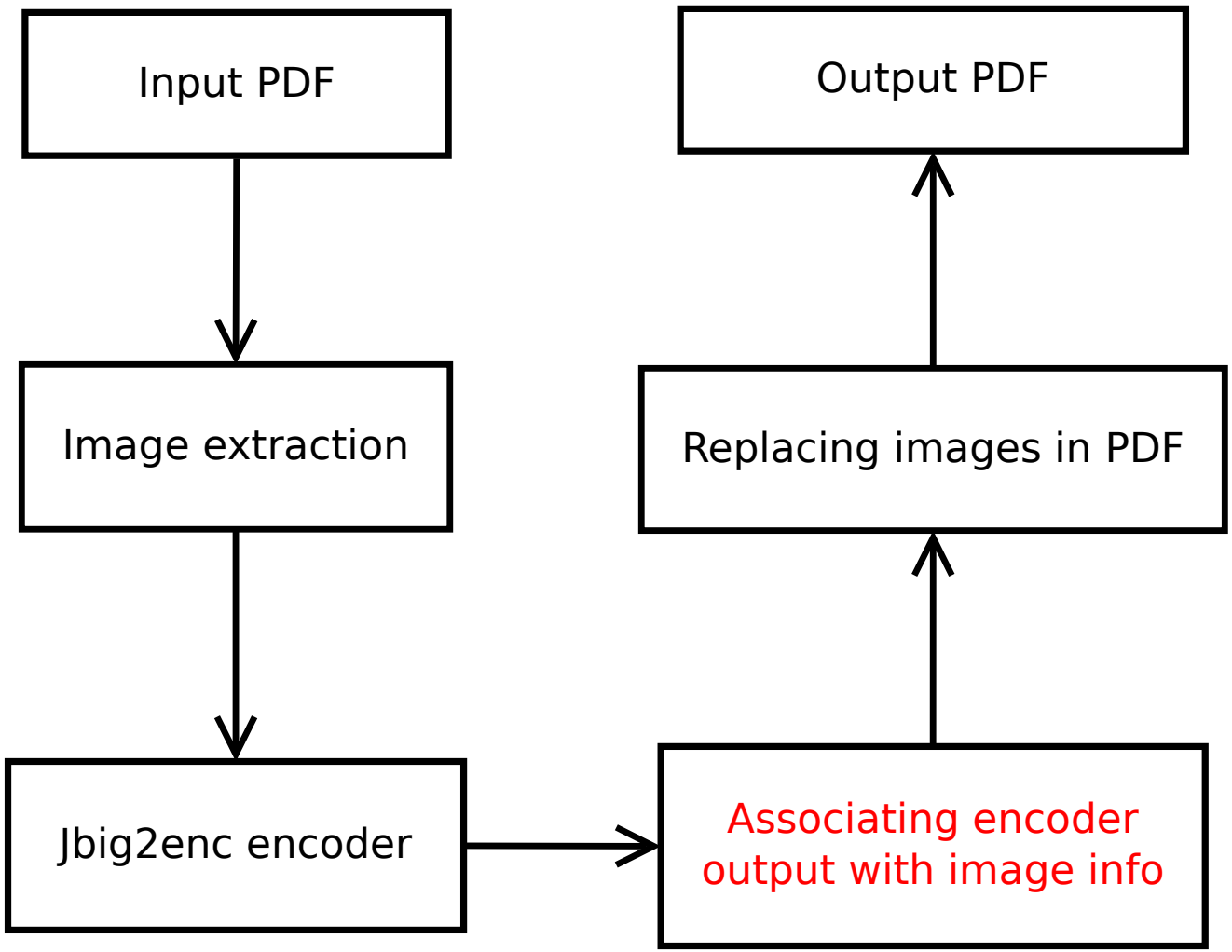
27 0 obj << /Type/XObject
        /Subtype/Image
        /Name/im1
        /Length 47053
        /Width 2294
        /Height 3502
        /BitsPerComponent 1
        /ColorSpace/DeviceGray
        /Filter/CCITTFaxDecode
        /DecodeParms << /K -1
                /EndOfLine false
                /EncodedByteAlign false
                /Columns 2294
                /EndOfBlock true >>
        >>
        stream
        ...
        endstream
```

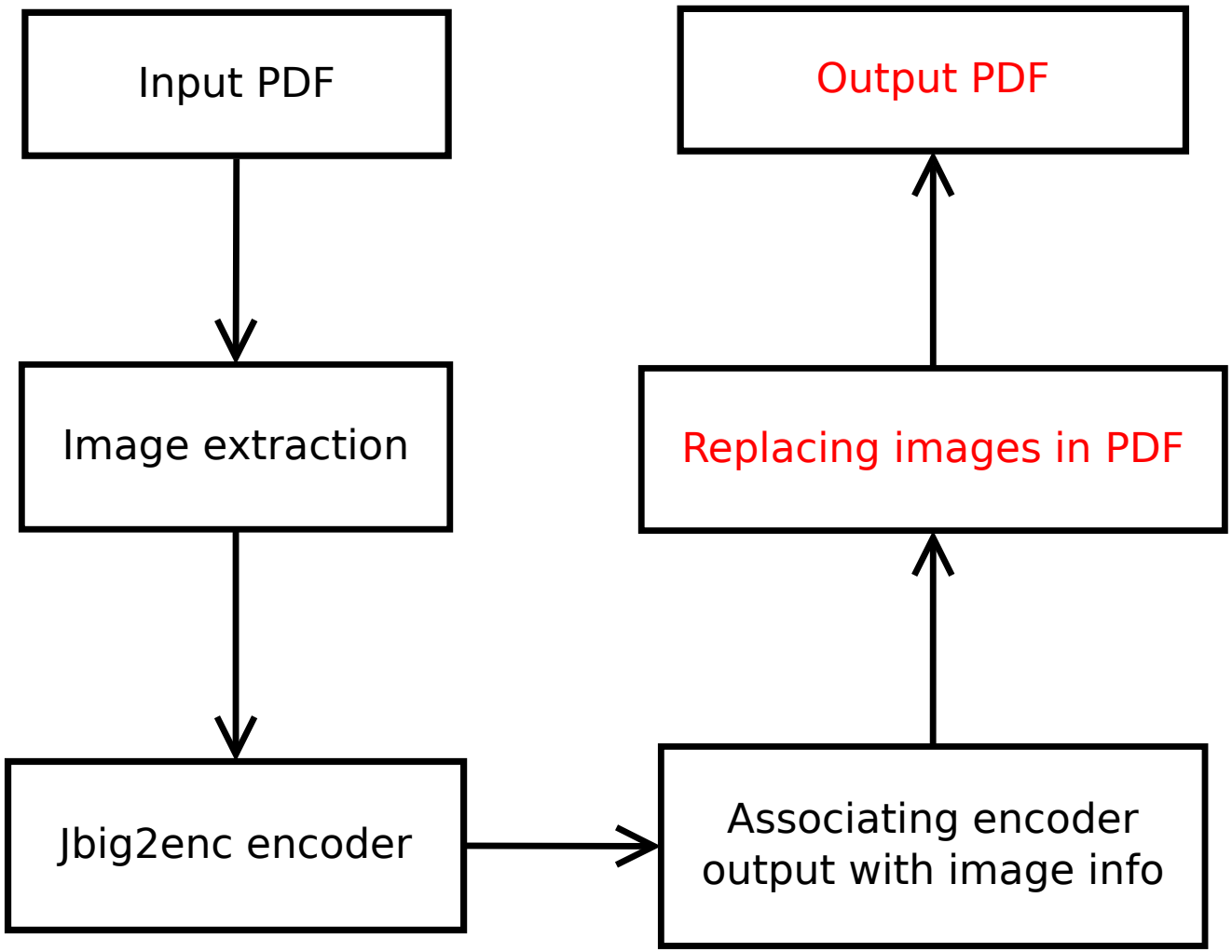
PDF recompressor via encoder jbig2enc



PDF recompressor: associating output with image info



PDF recompressor: output PDF



JBIG2 and `jbig2enc` basic principles

- Page segmented to several regions based on type of data (text, image, generic)
- For each region is used specific coding
- Text area segmented to connected components (symbols)
- For each new symbol is created a representive one and instances of this symbol are just pointers to this canonical representative

JBIG2's symbol encoding

- The idea of symbol encoding is to encode what a letter *A* looks like and, for all the *A*'s on the page, just give their locations (lossy encoding).
- However, assuming that we group the symbols correctly, we can get great compression this way. Remember that the stricter the classifier, the more symbol groups (classes) will be generated, leading to bigger files. But, also, there is a lower risk of cootoots (misclassification).

JBIG2's symbol retention

Symbol retention is the process of compressing multi-page documents by extracting the symbols from all the pages at once and classifying them all together. Thus we only have to encoding a single letter .a. for the whole document (in an ideal world).

This is obviously slower, but generates smaller files (about half the size on average, with a decent number of similar typeset pages).

One downside one should be aware of: If generating JBIG2 streams for inclusion to a linearised PDF file, the PDF reader has to download all the symbols before it can display the first page.

Improvement of `jbig2enc`—motivation

- Number of symbols recognized for a page is several times greater than of born digital documents
- Our improvement reduces size of output image in average for further 10 percent without visible loss

Improvement of `jbig2enc`

- Comparison of representative symbols
  - Two symbols are considered equivalent iff there is not found a big enough difference to form a line or a point
- Key idea: safe unification of two equivalent symbols to one

Image before and after compression

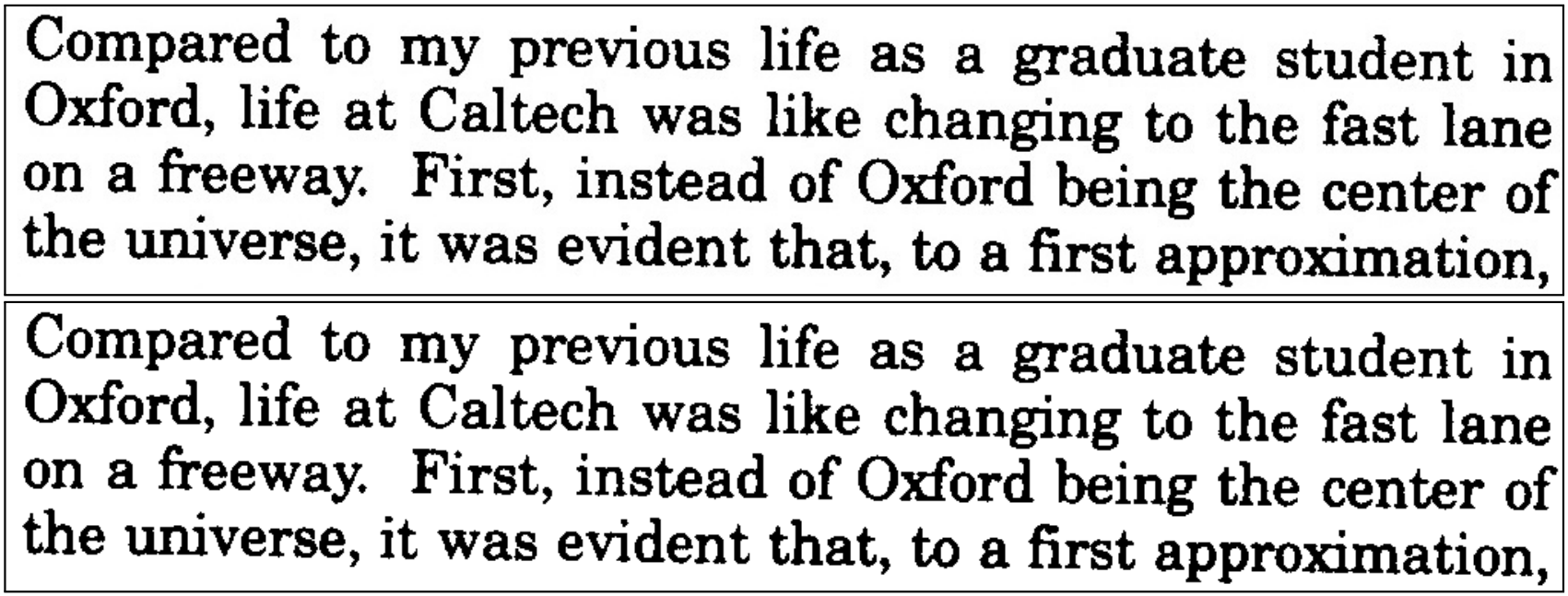


Image before and after compression: differences

PDF tools: `pdfsizeopt.py`

- Generic PDF optimizer written in Python by Péter Szabó (Google)
- Uses best practices and Unix tools to optimize size of PDF document (e.g. image compression, font unification)
- Uses `ghostscript`, `Multivalent`, `sam2p`, `pngout`, `jbig2enc`, ...
- Uses only generic coding of `jbig2enc`
- Images compressed using different compression methods and chooses one with the best result

Results: description of data used to create statistics

- PDF files of 11 journals retro-digitized in DML-CZ
- PDF files contain scanned text (bitonal page images originally compressed by CCITT-G4)
- Applied at PDF documents from digitized journal `Archivum Mathematicum` from years 1965–1991
- 6,641 pages in 665 papers in total

Results: different parts of PDFs

	Original PDF	After using PDF recompressor	After using `pdfsizeopt.py`	After using both
Total size (in kB)	7,123 (100%)	4,702 (66.01%)	3,962 (55.62%)	2,717 (38.14%)
Font data objects (in kB)	1,525 (100%)	1,525 (100%)	103 (6.74%)	103 (6.74%)
Image objects (in kB)	4,717 (100%)	1,915 (40.6%)	3,529 (74.83%)	1,904 (40.37%)
Other objects (in kB)	545 (100%)	926 (169.76%)	31 (5.63%)	411 (75.38%)

Results: single vs multi page PDF

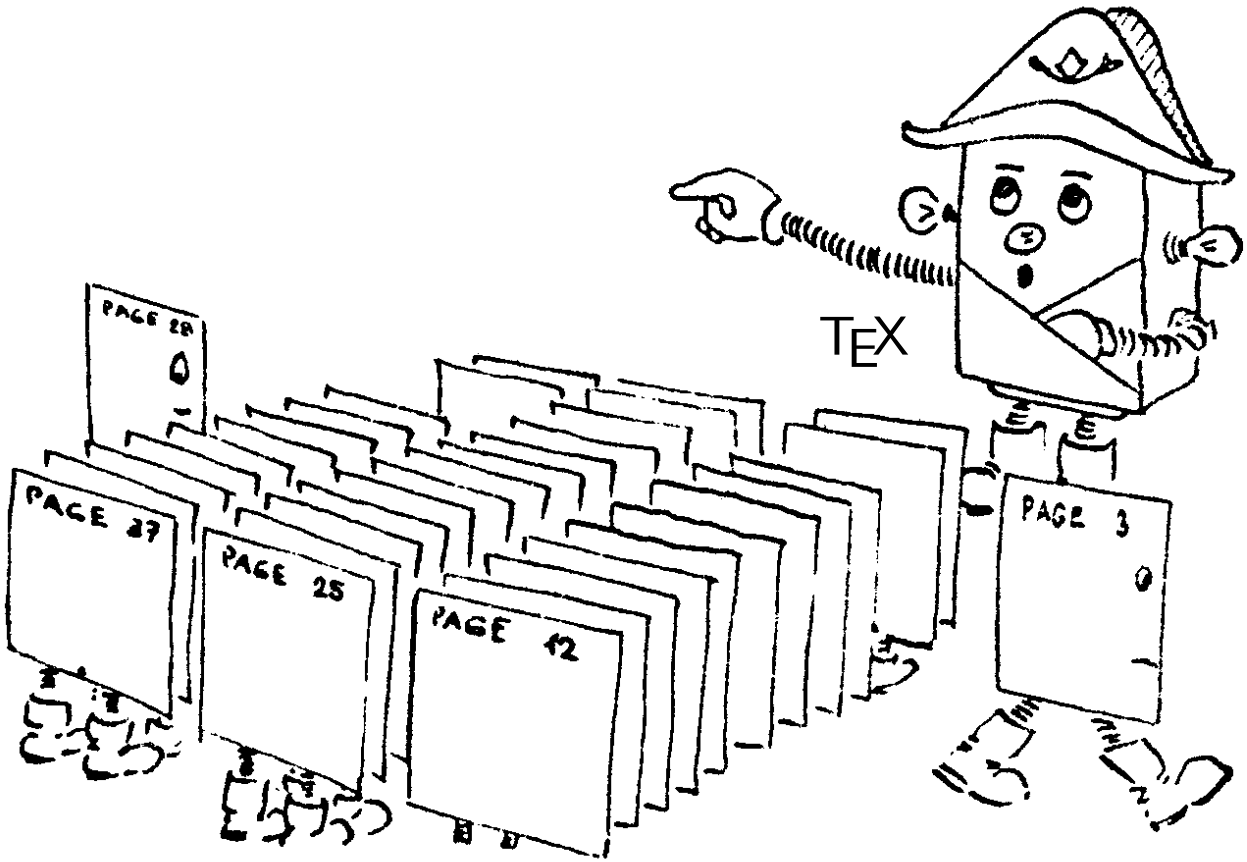
Single page documents (655.83 MB in total)			
	By using PDF recompressor	By using `pdfsizeopt.py`	By using both
Saved globally	77.37%	52.22%	46.68% (396 MB)
Saved in image and other objects	70.46%	60.30%	52.97%

Multi page documents (723.47 MB in total)			
	By using PDF recompressor	By using `pdfsizeopt.py`	By using both
Saved globally	66.01%	55.62%	38.14% (276 MB)
Saved in image and other objects	53.99%	67.66%	44.00%

Summary

- Verified complex DML-CZ digitization workflow and proven technologies and tools for math DL
- PDF size reduction of sixtytwo percent of original already CCITT-G4 compressed PDFs using PDF recompressor with improved `jbig2enc` and `pdfsizeopt.py`
- EuDML: Towards wordwide digital mathematical library, based on DML-CZ know-how and tools developed at Masaryk University during last $\approx$ 6 years
- DML workshop series, join us at DML 2011 c/o CICM Bertinoro, Italy, July 18th–23rd, 2011

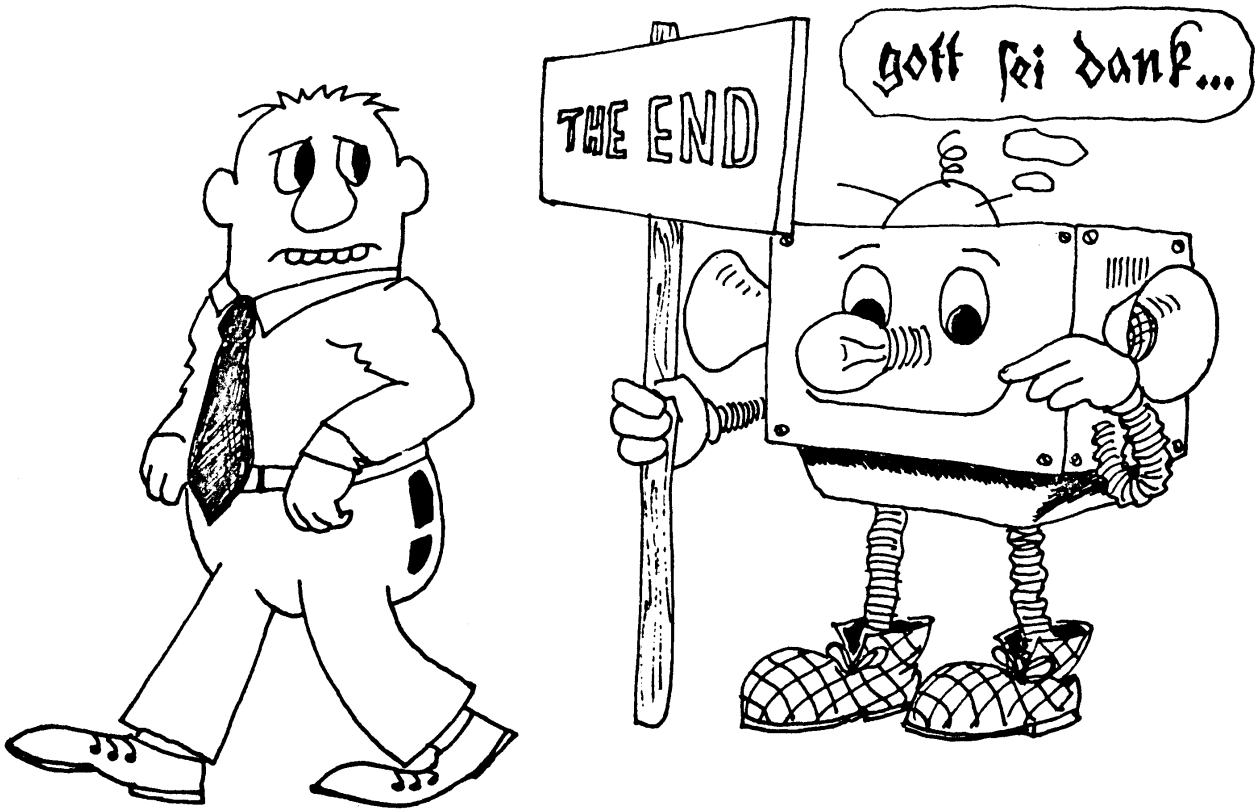
Yes, you can!



Future work

- Adding OCR tools to PDF recompressor to increase compression ratio of bitonal images even further
- Optimize subimage lookup and storage in PDF recompressor
- Pursue research in mathematical document classification, math indexing and retrieval, OCR for math, document similarity
- Design alternative and novel user interfaces for the digital library
- Improve metadata validation procedures in ME
- Interfaces for export and conversion for projects on European or worldwide levels
- Other challenges: multilingual math retrieval, MathML indexing and search, math common sense
- Cooperation "wanted!" for problems above, `fixfont`, math OCR

End of the talk



Questions? Comments? Cooperation offers?

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