TECHNICAL DEVELOPMENT IN THE FIELD OF FORENSIC COMPARISON OF TOOLMARKS: THE GERMAN PROJECT TO DEVELOP A COMPUTERIZED SYSTEM FOR ANALYSING AND IDENTIFICATION OF TOOLMARKS

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Recenzavo Lietuvos teisės universiteto mokslo prorektorius doc. dr. **Egidijus Kurapka** ir šio Universiteto Teisės fakulteto Kriminalistikos katedros vedėjas doc. dr. **Hendryk Malevski**

GLOBAL AIM

Considering the increasing number of samples to be analysed in the forensic science laboratories without adequate increase of staff the computerized comparison of toolmarks could solve the problem in supporting the toolmarks examiners to work more effectively. Progress in image processing and pattern recognition as well as the performance of modern computer technology should help to achieve this aim.

Also as an example for forensic research and development management the project work concerning the automatic comparison of toolmarks will be described.

First allow me to give a short overview on the major activities of the Institut PTU, the Forensic Science Institute of the State Criminal Police Office (Landeskriminalamt) of Berlin. The German Capital is a city and one of 16 German states as well. The PTU is the „number one“ of the sixteen German state forensic science institutes and the competence of the staff of about 210 (85 forensic scientists) covers forensic science case work in a very bread area of crime investigation (see fig. 1: organizational structure). Total case work showed a 10 % increase over every of the previous years with more than 60.000 cases delivered in the year 2000.

INTRODUCTION

Now let me present shortly the toolmark laboratory in Berlin and the actual case work situation, which gives the motivation for the development of a computerized comparison system.

The area of responsibility for this laboratory is the examination of toolmarks, shoesole–prints, fractures, lock and key examinations, restoration of erased numbers and vehicle examination. A staff of actually 17 experts in our laboratory is employed for this case work.

In the last couple of years we had an increasing number of applied examinations of toolmarks, which can be seen in the diagram (fig. 2). The influence of the reunification of Germany including the unification of the Eastern and Western Part of Berlin into the Landeskriminalamt Berlin about ten years ago is clearly visible. The part of the lever toolmarks in comparison to all incoming toolmarks has increased rapidly and amounted for nearly 16,000 the year 2000.

The actual volume of our forensic collection of toolmarks from burglaries amounts to about 20,000 marks. This means an enormous time needed for the investigation and comparison in order to search for the toolmark patterns which may be generated by the same tool. In practice a complete examination of all these marks is not possible at the moment, because the actually used data base system only processes criminalistic data (e. g. district and time period of the burglary) and tool specific data, like the width of the blade of the screw–driver.

To increase the effectiveness in case work, the development of a computerized system is desirable which is based on the comparison of surface profiles of the toolmark pattern. This makes it nessessary to digitalize toolmarks taken from the scenes of crime and to store them in a database. A completely comparison of every incoming toolmark with all toolmarks stored in the data base should then be possible.The result of the computerized comparison should be a limited selection of similar toolmarks.

It should be mentioned that such a toolmark comparison system would be a useful tool but never a substitute for the forensic examiner. Therefore finally only the examiner himself decides about the identity of the compared toolmarks.

The advantage of such a system therefore would be an increase in effectiveness and the minimization of the time needed for the comparison investigation. This is a similar way like AFIS is already used worldwide as an important tool for the identification and comparison of fingerprints.

In the last years some efforts have been made to realize a computerized comparison of toolmarks which nowadays is still a problem of the Forensic Science that must be solved:

For example in the Netherlands a system called TRAX has been developed, based on the comparison of marks generated by screw–drivers and which works well under laboratory conditions.

Another system, called ISAS–Tool, is used in a few forensic science institutes in Germany, it serves as a programme for the administration and comparison of some tool specific data.

Other systems which were used for the computerized comparison of toolmark–like pattern are known from the firearms investigation. The IBIS and Drugfire system are based on the comparison of the striations on projectiles.

PROJECT PLANNING

The forensic examination of toolmarks basically consists of two activities:

- First the securing of evidence and taking of the toolmark to the forensic collection
- and secondly the investigation and comparison of toolmarks taken from different scenes of crime and comparison of tools used in the crime with toolmarks stored in the forensic collection.

At request of the Forensic Science Institute of the Bundeskriminalamt (BKA), the Fraunhofer Research Institute for Production Systems and Design Technology (Fraunhofer IPK) in Berlin in cooperation with the Engineer's Office of Intelligence Technologies (INBITEC) in Berlin have deve-

loped a prototype for the computerized comparison of toolmarks. Both institutions have a great competence relating to modern methods of image processing and the pattern recognition and have started projects in other fields of forensic science, too.

The shoeprint and toolmark laboratory of the Forensic Science Institute of the Landeskriminalamt (PTU) in Berlin contributed the special experience and knowledge of the forensic examiners in case work caused by the immense quantity of burglaries in Berlin to this project.

First the Fraunhofer Research Institute and the Engineer's Office carried out a feasibility study in 1997 and 1998 to test suitables analytical methods for the computerized comparison of toolmarks, including data processing and extraction of characteristics in order to improve information quality (e. g. Fuzzy Clustering Algorithm) and data reduction [1, 2].

The next part was the development of a workable prototype and a test under practical conditions in our toolmark laboratory. This second part of the project began at the end of 1999 and has been finished this year.

And at least the development of a commercial system for the use in German and European forensic science laboratories is planned as third, final part of the project.

Now I want to report about the second part of the project: the development of a prototype for the computerized comparison of toolmarks named PAMIR – Pattern based Tool Mark Identification and Recognition. This term is a synonym for the so called Pamir mountains located near the Himalaya, because of the mountain like profile of the pattern.

Which aim should the prototype achieve?

First it should be a workable system which combines all mathematical methods tested before in the feasibilty study to a logical string in a compact system.

The prototype should be adaptable to the specific conditions of a toolmark laboratory and it should be possible to optimize the parameters used in the PAMIR system in practise.

The system should be user–friendly for forensic examiners who are not mathematical experts. And finally the system should be useful in a toolmark laboratory to support the examiners work effectively.

The second project part consists of several working steps which were carried out over a period of 16 month. At each of the milestones of the project meetings were arranged by the project management to discuss the further progress among the project partners.

After the Kick–off Meeting in November 1999 in our institute in Berlin the Prototype (fig. 3) including the PAMIR system, was developed. Working steps like the specification, implementation and further steps to set up the data base followed. Here the toolmark examiners put in their requests regarding the administration of the marks and the user interface. In June 2000 the prototype was installed at the toolmark laboratory of our institute PTU. After the user training selected examiners carried out the practical test with toolmarks taken from the scene of crime. Meanwhile the experts of the Fraunhofer Institute and the Engineer's office continually optimized the parameters of the different methods used in the PAMIR system. Further the used digitalizing systems and the PAMIR system were tuned with each other. The results of the second project part were presented in May 2001 in the ENFSI (European Network of Forensic Science Institutes) meetings in Berlin (Shoeprint and Toolmark Working Group) [3–6] and Prague (Laboratory Directors) [7].

To describe the information flow within the PAMIR data base the structure is shown in the diagram (fig. 4). It starts with the administration procedure and the user has to log in. He has to put in criminalistic data – e.g. the accused and the victim of a crime – as well as tool specific data which both may effectively support the finding of related marks. In addition toolmarks on different carriers have been sent to the laboratory which have been taken from the scene of crime. These toolmarks are digitalized to obtain an image. A suitable part of the image is reduced to a mathematical code which contains the essential characteristics. This code is used for finding similar marks in the data base with different methods of computerized comparison. This gives a selection of the most similar marks („hit–list“). With these results the examiner starts the specific examination of the discovered marks with the help of optical comparison and decides about their identity.

Fig. 1

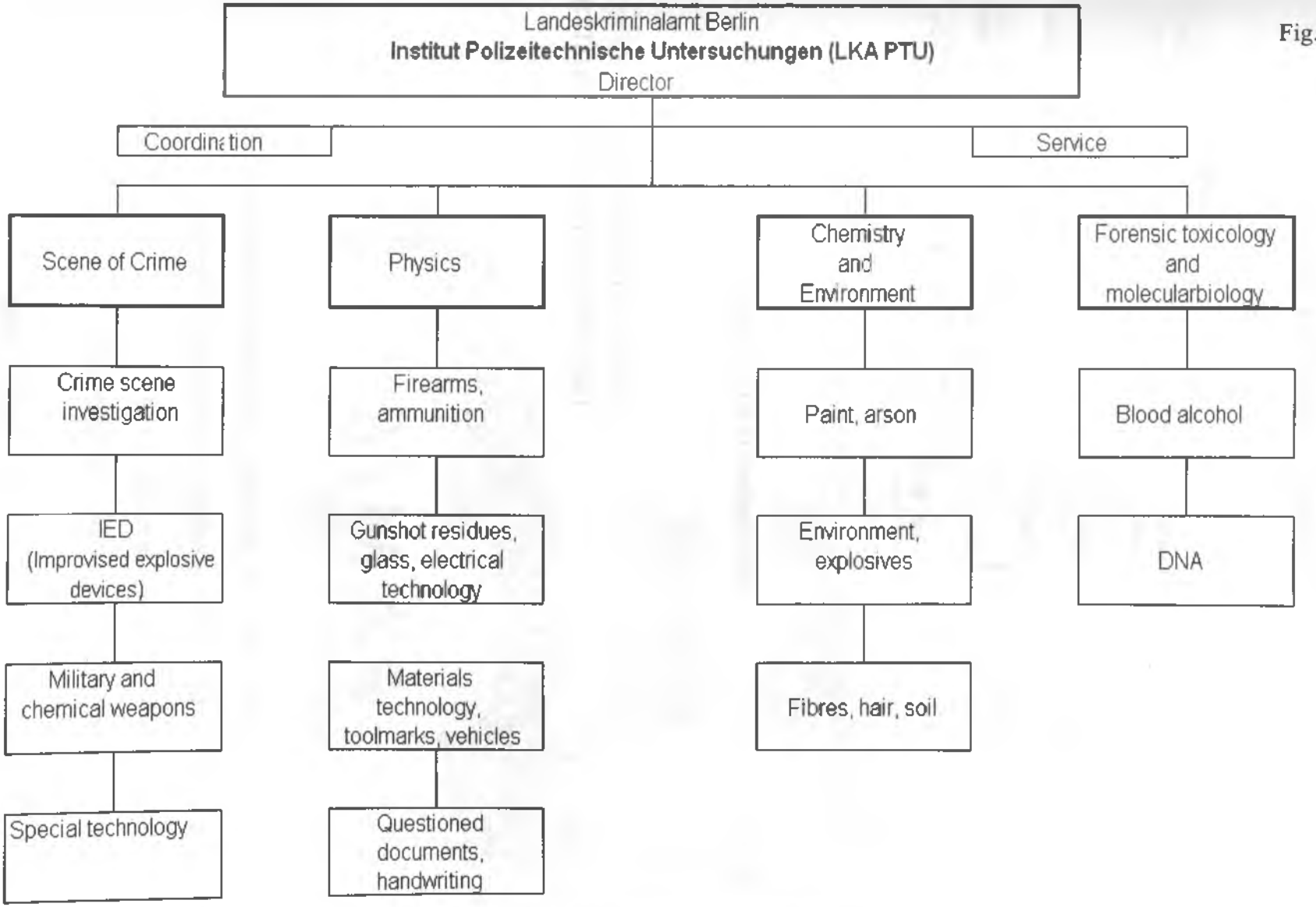

Landeskriminalamt Berlin
Institut Polizeitechnische Untersuchungen (LKA PTU)
Director
Coordination
Service
Scene of Crime
Physics
Chemistry and Environment
Forensic toxicology and molecularbiology
Crime scene investigation
Firearms, ammunition
Paint, arson
Blood alcohol
IED (Improvised explosive devices)
Gunshot residues, glass, electrical technology
Environment, explosives
DNA
Military and chemical weapons
Materials technology, toolmarks, vehicles
Fibres, hair, soil
Special technology
Questioned documents, handwriting

Fig. 2

THE TOOLMARK LABORATORY OF THE FORENSIC SCIENCE INSTITUTE IN BERLIN

Area of responsibility

Examination of

- toolmarks
- fractures
- lock and keys
- vehicles
- restoration of erased numbers

Staff

17 toolmark examiners

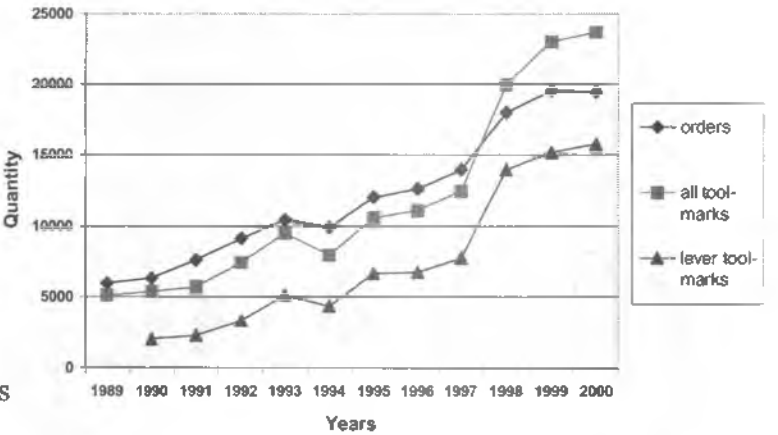
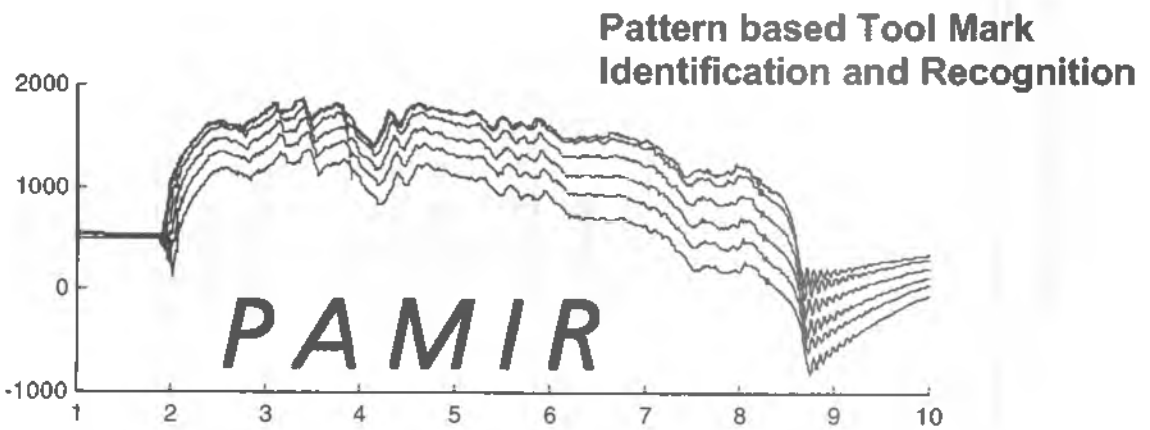


Fig. 3

Development of a Prototype



- Workable system with a logical string of suitable mathematical methods
- Adaptable to the specific conditions of a toolmark laboratory
- User-friendly for forensic examiners
- Useful to support the examiners work effectively

INFORMATION STRUCTURE OF THE PROTOTYPE

Fig. 4 **Procedure of the computerized comparison**

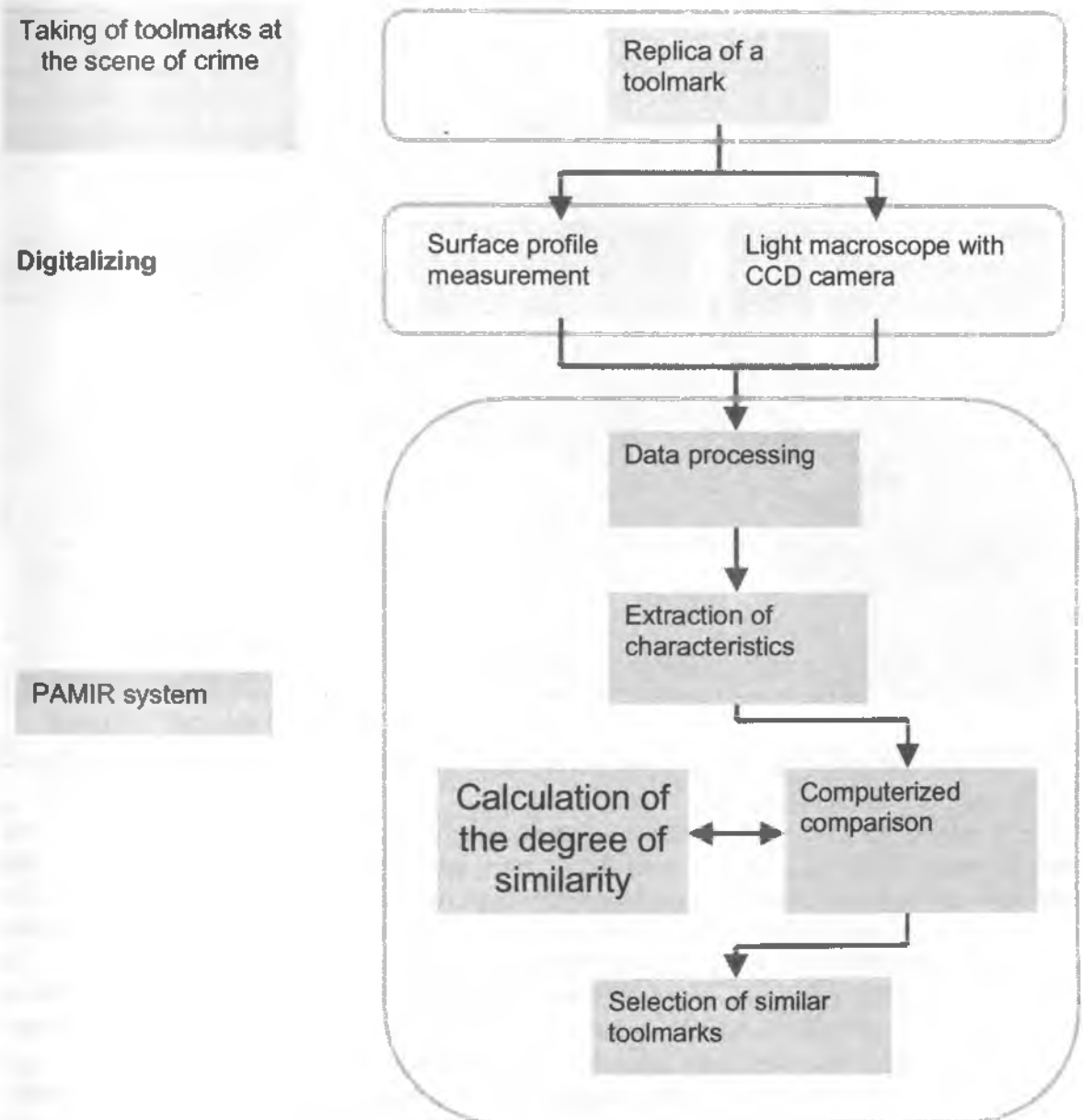
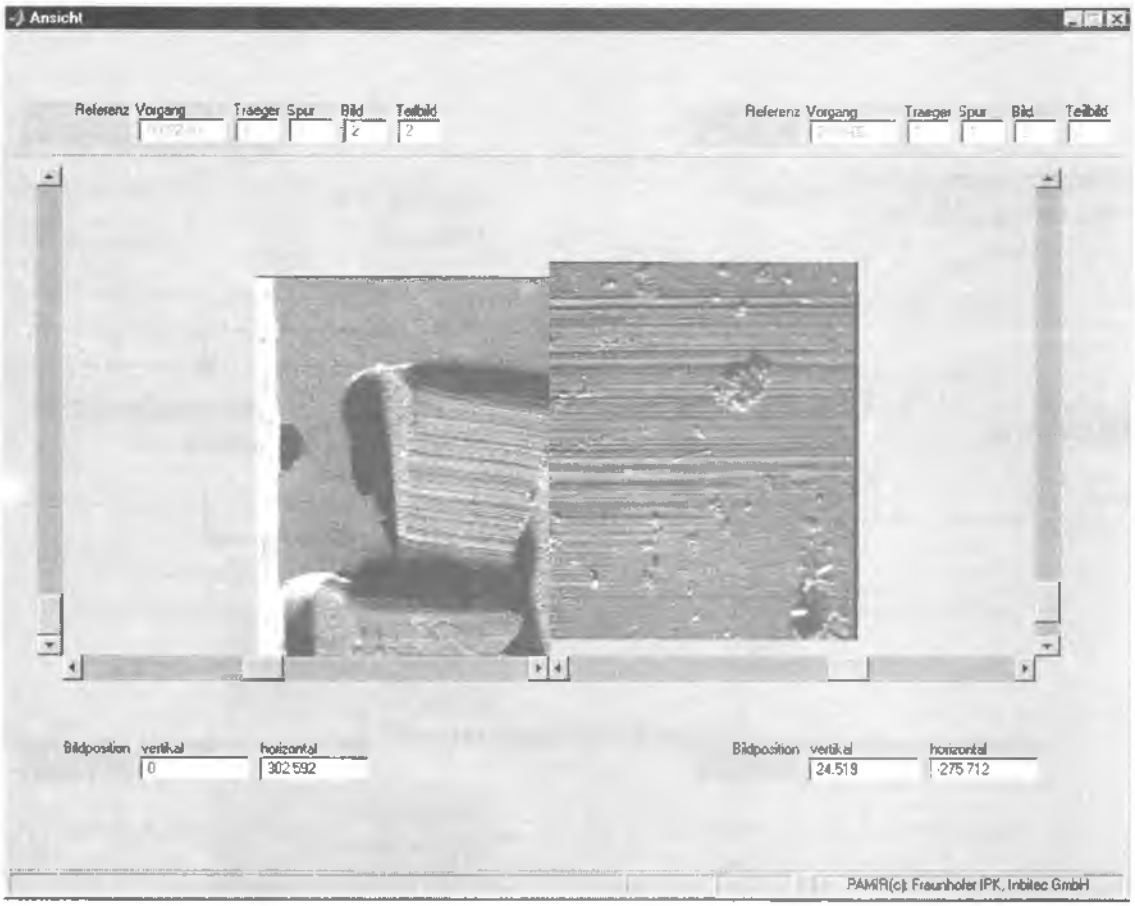


Fig. 4 **RESULTS OF THE COMPUTERIZED COMPARISON**



The total procedure of computerized analysis and comparison consists of several organizational, technical and mathematical steps (fig. 5):

It begins with the preparation of the toolmarks taken from the scene of crime and digitalizing their surface profile. In the project grey value pictures as well as surface profile data were used. The grey value pictures were obtained by a light macroscope in combination with a CCD camera. The profiles of the toolmark patterns were also measured using a three–dimensional measurement system called MicroCad (developed by the company GFMesstechnik).

Then the filtering and data reduction was carried out. The following step – the extraction of characteristics of the toolmark pattern is based on the expert knowledge. Here the toolmark examiners of the Institut Polizeitechnische Untersuchungen had to contribute their experience.

Now the characteristics were coded in order to get essential information of the toolmark pattern for the automatic comparison. The next step is the calculation of the degree of similarity of the coded marks and the comparison. Finally, the most similar marks were selected and appeared as an image on the monitor.

With the prototype each of these steps was realized with different mathematical methods with the aim to obtain a logical string of suitable methods.

The results of the computerized comparison of toolmarks are visualized similar to the pictures you can see using a comparison light microscope. On the left side of fig. 6 there is the original image of a toolmark and on the right side one of the selected marks of the „hit list“ with a high degree of similarity. The examiner is able to shift the image in the vertical position and may decide about the similarity for himself. Then he can use the corresponding marks from the forensic collection for further examination.

Good results with toolmarks taken from the scene of crime have been achieved. Therefore, an increase in the success rate concerning criminal offence series of burglaries is possible by the computerized comparison of the toolmarks.

Now the development of a commercial system is planned as a third step of our project "Computerized comparison of toolmarks" for the use in German and European forensic science institutes. This system must be adapted to the specific conditions of other Forensic Science Institutes, as well. Continued development of the PAMIR program is necessary to achieve a running time efficient and homogeneous data processing environment. Also the interface has to be made more user–friendly. Furthermore a new image processing system that enables an automated extraction and matching of toolmarks, developed by the University of Karlsruhe, Germany [8] should be integrated. And last but not least the commercial system has to be integrated into existing electronic data processing systems and laboratory networks of other Institutes.

At least the development of a commercial system as third step of the German research project "Computerized comparison of toolmarks" is in preparation. I think there will be a good chance also to receive funds of the European Union because of the promising results from the first and second part of our project.

LITERATURE

1. **Ahlhorn T., Katterwe H., Kube E., Vordermaier G.** Computerized Comparison of Toolmarks, 11th ENFSI Meeting. – Moscow/Russia, 1999.
2. **Ahlhorn T., Katterwe H., Braune M., Lisounkin A., Schreck G., Drews F.** Computerized Comparison of Toolmarks, Information Bulletin for Shoeprint / Toolmark Examiners. No. 1. March 2000. Vol. 6. Proceedings of the 3th European Meeting for Shoeprint/Toolmark Examiners. – Stockholm/Sweden, 1999.
3. **Katterwe H., Braune M., Ahlhorn T., Grimmer W.** Image Processing Strategy and Automatic Comparison of Marks. 4th European Meeting for Shoeprint / Toolmark Examiners. – Berlin/ Germany, 2001.
4. **Schreck G.** Computerized Comparison of Toolmarks by the Pamir System, 4th European Meeting for Shoeprint / Toolmark Examiners. – Berlin/Germany, 2001.
5. **Drews F.** Toolmark Comparison and Identification with methods of the Fuzzy Set Theory ant the Image Processing. 4th European Meeting for Shoeprint/Toolmark Examiners. – Berlin/Germany, 2001.
6. **Lisounkin A.** Toolmark Comparison and Identification with Pattern Recognition Methods based on 3D Surface Measurement, 4th European Meeting for Shoeprint/Toolmark Examiners. – Berlin/Germany, 2001.
7. **Ahlhorn T., Katterwe H., Kube E., Vordermaier G.** Modern Management Combined with the Technical Development – a Tool for Forensic Effectivness: Development of the Research Project "Computerized Comparison of Toolmarks". 13th ENFSI Meeting. – Prague/Czechia, 2001.
8. **Heizman F., Puente L.** Automated Analysis and Comparison of Striated Toolmarks, 4th European Meeeting for Shoeprint/Toolmark Examiners. – Berlin/Germany, 2001.

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SUMMARY

This paper focuses on the co-operative development of a computerized system for the comparison and recognition of toolmarks to support the forensic examiner with a "hit-list" of possible mark conformities in a data base. Powerfull tools in the field of image processing and pattern recognition in

combination with special high-tec methods using the increasing performance of modern computer technology enabled to realise a prototype. After this system has been installed at the Institut to Polizeitechnische Untersuchungen of the Landeskriminalamt in Berlin to conduct field tests real samples promising results can now be presented. These results from our project can be used to develop a commercial system providing tournaround times and success rates that law enforcement demands.

LAUŽIMO ĮRANKIŲ PĖDSAKŲ LYGINAMŲJŲ KRIMINALISTINIŲ TECHNINIŲ TYRIMŲ RAIDA:VOKIEČIŲ PROJEKTAS, SKIRTAS TOBULINTI KOMPIUTERIZUOTĄ LAUŽIMO ĮRANKIŲ PĖDSAKŲ ANALIZAVIMO IR IDENTIFIKAVIMO SISTEMĄ

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SANTRAUKA

Straipsnyje dėmesys skiriamas bendram kompiuterizuotos laužimo įrankių pėdsakų lyginimo ir atpažinimo sistemos, leidžiančios kriminalistams sudaryti panašiausių pėdsakų sąrašą su galimais atitikmenimis duomenų bazėje, tobulinimui. Naudojant galingas vaizdo apdorojimo ir modelio struktūros atpažinimo priemones kartu su specialiais patikimos technologijos metodais ir pasitelkiant vis tobulesnę kompiuterių technologiją, buvo galima atpažinti prototipą. Po to, kai ši sistema buvo įdiegta Policijos technikos kriminalistikos tyrimų institute, ją galima išbandyti su tikrais pavyzdžiais ir sulaukti gerų rezultatų. Gauti projekto rezultatai gali būti panaudoti teisėsaugos komercinei sistemai tobulinti.