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The secret language of the internet

What happens when we access a website? In the Software Lab of the Technical University of Darmstadt, researchers are looking for errors in the programs running unnoticed in the background. Their aim is to make the internet more secure and reliable.

By Boris Hänßler

The online service Alexa maintains a list of the most popular websites worldwide. The names at the top, such as Google, YouTube, Facebook, Amazon or Twitter, are familiar to us all. As users of these sites, we rely on the fact that they work perfectly and are secure. But even on these familiar websites, errors in scripts are ever-present, and we are often only aware of them once serious damage has been done.

Michael Pradel from the Software Lab at TU Darmstadt and his team took on the top 100 websites according to Alexa, resolving to search them for any weaknesses. The researchers developed different methods of analysis, which they could use to test a great many websites automatically. „Most people just cannot imagine how many scripts are running in the background all the time as soon as we access an internet site," says Pradel. Scripts are small programs that allow us to interact with website. „And every one of these programs can contain or cause errors. Most of them are harmless, but some are expensive to users."

"We have a lot of ideas on how to extend and refine our methods."

Pradel has his offices on the fourth floor of a building that also houses the Fraunhofer Institute for Secure Information Technology. From his window, he looks out over the city of Darmstadt up to the Mathildenhöhe. His team communicates in English. He did his doctorate in 2012 at ETH Zurich and then was a postdoctoral researcher at the University of Berkeley in California. He moved to Darmstadt in October 2014, to set up the Software Lab.

His focus is on program analysis, and there are three aspects to this as far as he is concerned: reliability, efficiency and data security in web applications. For Pradel, a website is reliable if it acts as the operator intends and does not crash. It is secure if the data of the operator and the site visitors are protected against attack. In addition to this, an ideal site is fast and does not perform any unnecessary calculations.

Pradel's team checks these aspects by means of so-called runtime analyses. "We have developed programs that act like a human being," says Pradel. "But unlike a human user, they systematically trigger all the processes on a site – that is, they simulate all the possible interactions. If a person were to do this, it would sometimes take days or weeks."

Websites have an initial state, so to speak, and that sometimes changes as soon as we move the mouse cursor over a picture. The picture is given a frame, for example, it increases in size, or the mouse cursor becomes a magnifying glass. In these cases, the site moves to a different program state, which in turn allows new interactions. "This produces a huge search space where we can hunt for errors," says Pradel. "The more programs there are behind a site, the more there is to go wrong. Our software cannot explore every script for all known errors, so in each analysis, we concentrate on a specific problem." An example of one such problem is the time it takes the sites to load, which depends to a large extent on how efficiently the scripts are executed. But browsers are not patient. Their limits lie between five and ten seconds. Once this time is exceeded, the browser announces that the site in the window is not available. For the operator, the result can be that a potential customer is annoyed, and takes their business to the competition.

The programmers of websites struggle to detect this type of error early on. They sometimes only occur under certain circumstances, such as when the user takes a number of steps in a fixed order. So the errors are overlooked during a routine check of the site. The Software Lab analysis software keeps calling up the program codes in a different order, so that nothing escapes the test.

Errors in connection with JavaScript are among the most common security risks on the internet. "JavaScript is an accident waiting to happen", says

An invitation to hackers

Cases of problematic weaknesses that can be exploited by hackers keep being made public:
Two years ago, when Twitter introduced a new layout, the programmers overlooked the fact that users could send links with JavaScript instructions. As soon as the Twitter users moved their mouse cursors over these links, the problematic tweets were forwarded from the individual account to all its followers – so that vast numbers of the links were circulated within minutes, before Twitter found the loophole.

In 2014, the auction platform eBay also fell victim to this so-called cross-site-scripting (XSS): A user had an iPhone for sale. But when those interested in buying clicked on the site link, they were diverted to an external, fake website, where they were asked to enter their eBay login data again. This data was intercepted by the hackers. At the start of 2016, eBay again had to admit to having discovered such a loophole, and closed it.

Information

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Photo: Katrin Binner

Dr Michael Pradel, Head of the Software Lab research group.

Pradel. "The language was introduced more than 20 years ago. At the time, a Netscape engineer had ten days to develop a language for interaction with the browser. As the language is backward compatible, all its shortcomings from those times are still present." JavaScript is popular because the language is easy to learn and websites do not crash if there are errors in the script – the browsers simply ignore the errors. Other programming languages need compilers, which stop the program immediately in the event of an error and indicate the relevant point in the code. They force programmers to work more carefully.

Not all shortcomings are caused by the carelessness of developers. Sometimes scripts from other sources such as advertisements, or embedded videos are loaded onto the websites. The programmers cannot see these scripts in advance. Other errors that often do not come to light during routine checks are caused by "data races". Two parts of a JavaScript program get in each other's way, because they can be executed in random order and store different data in the same memory. The subsequent calculation can change, depending on which part of the program is first. So it can happen that a book in a shop suddenly costs 2,000 Euros, instead of 15 Euros.

These are just a few examples. "We are nowhere near finishing all the analytical work", says Pradel. "We have a lot of ideas on how to extend and refine our methods." Pradel's team has already written to some of the top-100 website operators to point out errors. A few companies have remained silent, while others have been quick to correct the weaknesses. Although we are unaware of all that goes on, we thank the Software Lab for saving us from bother on the internet.

The author is a technology journalist.

Cybersecurity profile area

The Software Lab is a research group in the Department of Computer Science at TU Darmstadt led by Dr Michael Pradel. Its research scientists explore tools and techniques that help to develop reliable, efficient, and secure software. The Software Lab is part of the cybersecurity profile area at TU Darmstadt. Teams from eight of the thirteen university departments work here on challenges related to cybersecurity and privacy protection.

Turbo for the broadband network

Installing new optical fibres is expensive. So network operators want to make better use of their existing capacities. A new type of laser diode from Darmstadt could help. It has now been put into practice with the industry.

By Christian Meier

Light floods through the extensive office windows on the sixth floor of the Hans Busch Institute at the Technische Universität Darmstadt. Franko Küppers is at his desk, holding a gleaming grey fibre as fine as a hair up to the sun. Light flows through these fibres as well, although not for lighting, but to carry data.

Light as a communication medium has occupied the thoughts of this electrical engineering professor for a long time. He knows the unrivalled strength of optical fibres: thousands of gigabytes shoot through them every second. On the other hand, the copper cables which nowadays often still span the so-called „last mile" to the households, only transmit data at a thousandth of this rate.

„Optical fibres are also used for data transmission in computing and data centres, which are becomingly increasingly important in this age of cloud computing."

As the former head of a respective research department at Deutsche Telekom, Küppers knows well what is hindering the spread of optical fibres. New infrastructure costs a lot of money. So network operators try to make better use of their existing capacities. A well-known way of doing this is so-called multiplexing, which combines up to 80 signals and simultaneously directs them though a single optical fibre. Think of it as a sort of inverted prism. This normally splits a beam of white light into its component colours. It also works in reverse: if beams of different colours enter the prism, it combines them to make a beam of white. As different signals can be carried by means of different coloured light, it is possible to combine more information in a white beam than it would be in a beam of a component colour.

„Multiplexing was the key innovation, as without it, neither the broadband internet we know today nor the mobile internet would be possible", enthuses Küppers. His team from the Department of Electrical Engineering and Information Technology has crucially improved this technology, thus opening up a „vast market", as the researcher puts it. A joint project involving the team from Darmstadt and three industrial companies and sponsored by the Federal Ministry of Education and Research (BMBF), recently got the technology ready for field tests.

The key part came from Darmstadt: A microelectromechanical system (MEMS), integrated with a laser diode, to which it gives a new and unusual feature. Laser diodes usually emit light of a specific wavelength. They inject light pulses of this colour into the optical fibres. In optical multiplexing, you need up to 80 different laser diodes of different colours. This is because each information channel transmits with a different light wavelength. „This causes a lot of expense", says Küppers. Because for one thing, it requires extremely precise manufacturing to ensure that the diode emits exactly the required wavelength. „There are a lot of rejects", acknowledges Küppers. There must also be spare diodes available for all 80 channels.

Küppers is now offering an alternative – a laser diode that can be tuned in wavelength. The wavelength emitted by the diode can be chosen anywhere within a certain range. The advance can be compared to a stringed instrument. Previously, so to speak, guitars never used to have frets, so every string could only produce a single sound. The Darmstadt invention provides the frets, and thus the opportunity to elicit many sounds from every string.

Rejects are reduced. The wavelength can be changed on the finished product, so the standard that has to be maintained during production is not ridiculously strict. „It is also no longer necessary to keep 80 different spare parts available", adds Küppers. A further advantage of the new diodes: „Networks can be more flexible", says Küppers. Even during operation, it is possible to change the wavelength in a matter of seconds. The bandwidth of each colour channel can be constantly adapted to meet current needs. „So optimum use is made of the total bandwidth of the optical fibre", stresses Küppers.

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The basic idea behind the Darmstadt technique is simple. Imagine that a laser is like a tube with a mirror at each end, between which light is reflected to and fro. The distance between the two mirrors, rather like the length of a string, determines the colour of the light emitted by the laser. Julijan Cesar and Sujoy Paul, who are studying for their doctorates at Küppers' Institute, show how it works in the clean-room laboratory: Put a movable mirror at one end of a conventional laser diode. This consists of a highly reflective membrane of silicon oxide and silicon nitride, about a tenth of a millimetre in diameter. Four supports resembling spider's legs hold it parallel above the surface of the actual diode. „If you direct a low current through these little legs, they expand and the mirror moves a bit further away from the surface of the diode", explains Küppers. This change in the distance shifts the default wavelength used in optical fibres of 1,550 nanometres (millionth of a millimetre) by up to 100 nanometres. The technical jargon calls this technique: Vertical-Cavity Surface-Emitting Lasers, or VCSEL for short.

A laboratory prototype has now been developed by the Darmstadt team, together with an industrial consortium. „We enjoyed a very close collaboration", enthused Küppers. And it was worth it. The new technology now achieves an extremely fast data rate of around 12 gigabits per second. „We also found it a particular challenge to keep the wavelength adjustment stable for operation", explains Küppers. The joint project has developed a prototype that is suitable for mass production, and it is to be tested in the industrial environment of one of the partners.

The consortium will then be able to open up a vast market. The backbone of the internet consists of optical fibres. „But optical fibres are also used for data transmission in computing and data centres, which are becoming increasingly important in this age of cloud computing", realises Küppers. It may well be that an invention from Darmstadt will soon become part of the basic internet configuration.

The author is a science journalist with a doctorate in physics.

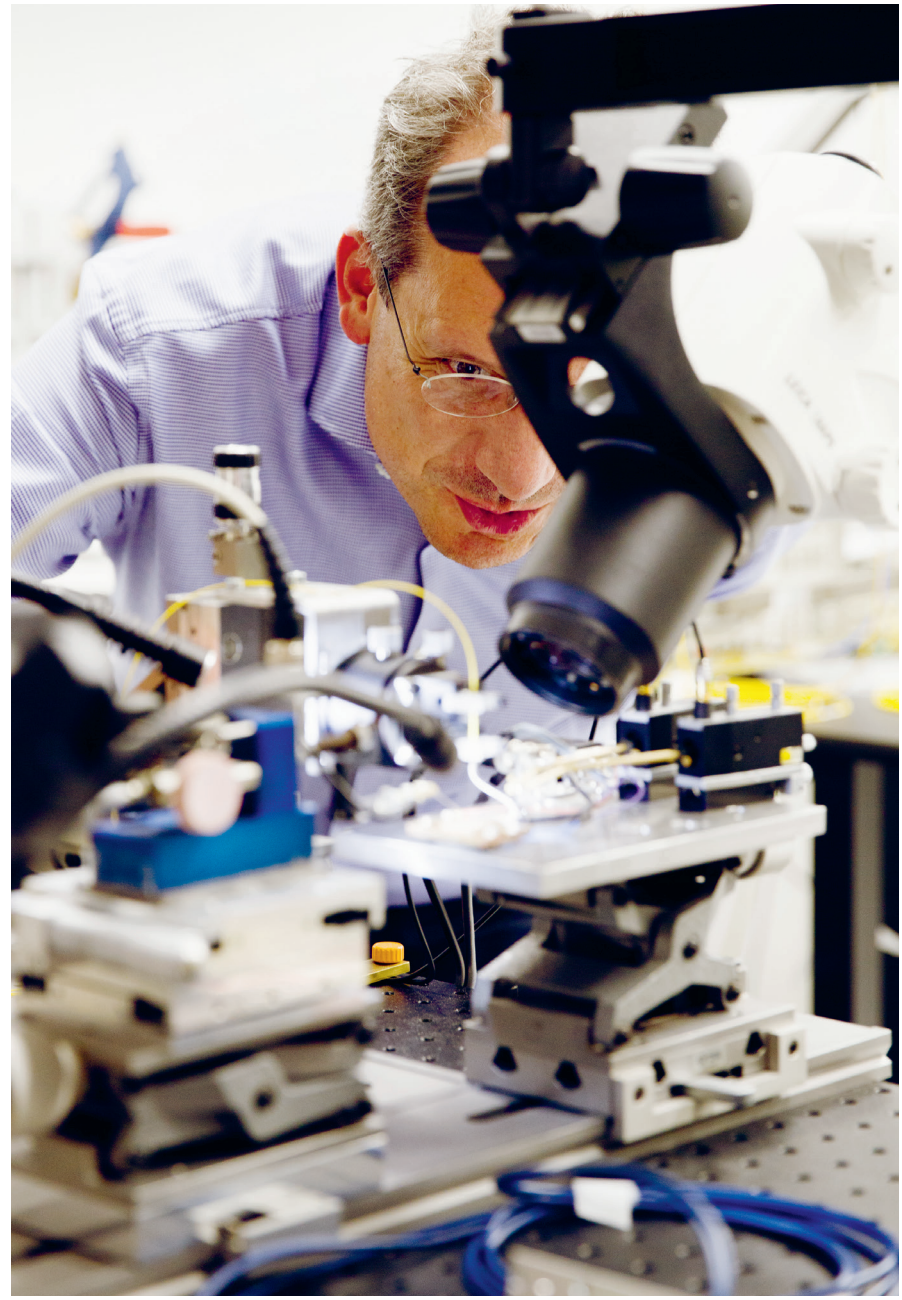

Photo: Katrin Binner

Professor Franko Küppers in the optical laboratory.

Laser diode

Conventional laser diodes are semiconductor components a few millimetres in size, similar in design to LEDs, but emitting concentrated light with a fixed wavelength, that is, laser light. The wavelength is defined by the choice of semiconductor material, e.g. indium gallium nitride. Laser diodes cover a wide light spectrum: from infrared to ultraviolet. In addition to data transmission, other typical uses for laser diodes include DVD or Blu-ray players, bar-code readers or gas sensors.

The project

In the VCSEL-based transceivers for telecommunications and data networks (VCSEL-TRX) project, TU Darmstadt worked together with Vertilas (Garching), DEV Systemtechnik (Friedberg) and ADVA Optical Networking (Martinsried). The BMBF supported the research to the tune of approx. 1 million Euros in three years. The companies are mapping the entire exploitation chain: from specialists for high bit rate RF solutions and optical modules to the producers of high-performance and energy-efficient lasers and industrial end users.

It doesn't always have to be platinum

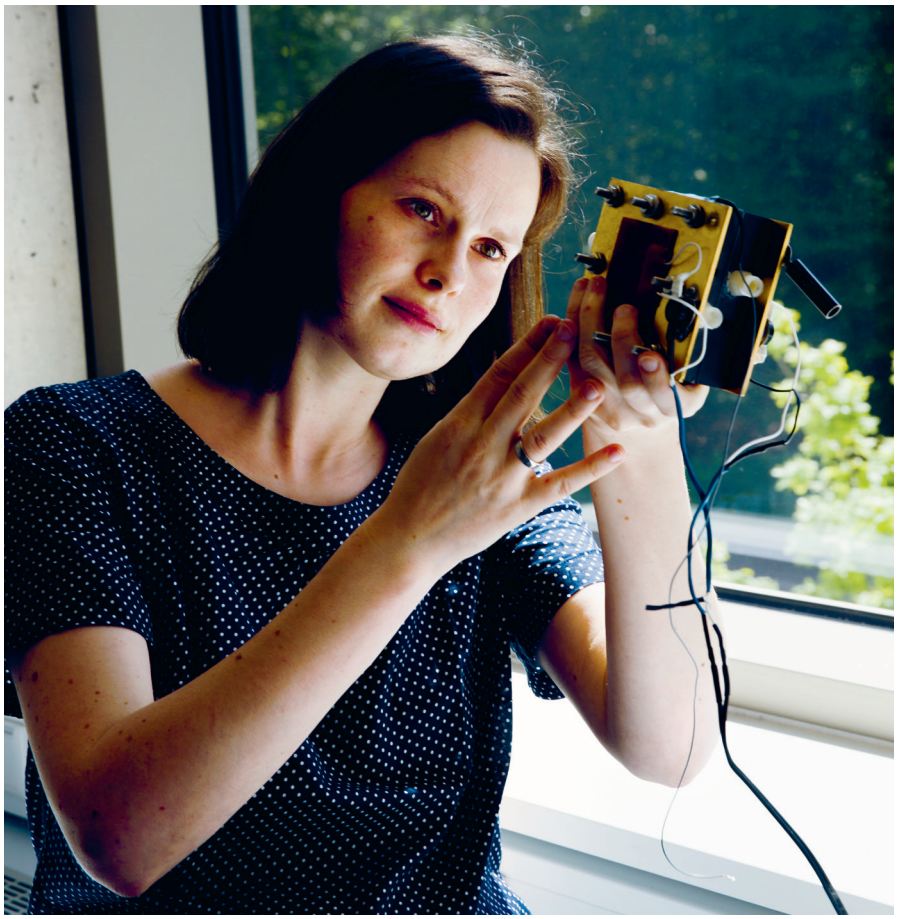

Photo: Katrin Binner

Researcher at the interface of materials science and chemistry: Ulrike Kramm.

Junior Professor Ulrike Kramm develops catalysts for fuel cells. They are modelled on nature and are similar to haemoglobin.

By Uta Neubauer

Even some green technology is still worth improving: Fuel cell vehicles, for instance, qualify as a clean issue, because they only produce steam instead of environmentally damaging exhaust gases. But current low-temperature fuel cells contain platinum – and this is „not only in rare and expensive, it can also be extracted under questionable conditions", emphasizes Ulrike Kramm, Junior Professor in the Chemistry and Materials and Earth Sciences departments at TU Darmstadt.

In the fuel cell, platinum is the catalyst ensuring a „cold combustion" of hydrogen and oxygen, i.e. that the chemical reaction takes place under temperate conditions. As the two gases make a highly explosive gas mixture, a thin membrane in the fuel cell keeps them apart. Both sides of this membrane are coated with graphite electrodes containing finely dispersed platinum. Although the membrane is impermeable to the non-charged hydrogen molecule H2, it does allow protons, the tiny, positively-charged hydrogen ions H+, to pass through.

And this is how the fuel cell works: On one side of the membrane, hydrogen is oxidised to protons under the release of electrons. The protons migrate through the membrane to the other side, where they react with the oxygen to form water. The electrons released on the hydrogen side are required as well for this so-called oxygen reduction. So when the circuit is closed, a usable electric current flows. The platinum catalyst accelerates both the hydrogen oxidation and the oxygen reduction. However, the precious metal does

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have certain disadvantages – apart from the availability problem and the cost: „A perfect catalyst specifically accelerates just one reaction", explains Kramm. „But in the fuel cell, the platinum is the catalyst for both reactions." The problem with this is that when a fuel cell vehicle starts up, there is also some air, and therefore oxygen, on the hydrogen side initially. So if oxygen reduction and hydrogen oxidation now take place there at the same time, undesirable side-reactions occur, which might destroy the catalyst.

So the hunt is on for alternative catalysts. They have to be selective, low-cost and durable. Nina Erini, the postdoctoral researcher in Kramm's team has already made a start in researching catalysts for hydrogen oxidation – with nothing to report so far. But Kramm has already made a name for herself internationally with her work on catalysts for oxygen reduction. „The basic requirement is the adsorption of oxygen on the catalyst, as the oxygen then reacts more easily with the electrons and protons", explains Kramm. Nature has at hand a substance that has virtually been made for oxygenation: haemoglobin. At its heart is an iron atom, surrounded by four nitrogen atoms. Kramm's catalysts also contain an iron-nitrogen unit like this. But unlike haemoglobin, it is not incorporated in an organic molecule, but surrounded by carbon in the form of graphene layers. The initial scientific publications on iron-nitrogen-carbon catalysts come from the nineteen-sixties, but a broader interest in this idea has only surfaced in recent years, comments Kramm.

„If all goes well, it should take us about five years to understand what is limiting the stability of the catalysts, and how this can be improved."

It might be difficult to find anyone in the whole of Germany who is more familiar with iron-nitrogen-carbon catalysts than the Junior Professor from Darmstadt. She was working with the substances more than ten years ago in the course of a cooperation between the Helmholtz Centre in Berlin (HZB) and Toyota. In her doctoral thesis, she examined their structure and then developed a cleaning process to improve the performance of the catalyst. „These catalysts are very close to platinum in their activity", says Kramm. However, there are still a few hurdles to overcome.

One of the problems concerns long-term stability: Ioanna Martinaiou, a doctoral student in Kramm's working group, is currently investigating whether the catalysts work longer if they contain a metal other than iron – such as copper or nickel, and Martinaiou has also tested manganese, chrome, molybdenum and cobalt. The analysis is ongoing. Iron is unsurpassed with regard to activity, but combining it with another metal may perhaps improve the stability, without losing the positive properties of iron as a catalyst. „If all goes well, and based on the planned projects supported by the Federal Ministry of Education and Research, it should take us about five years to understand what is limiting the stability of the catalysts, and how this can be improved", says Kramm. With the involvement of an industry partner, sufficiently stable catalysts without precious metals should be developed for fuel cells ready for the market in ten years. The aim is for the catalyst to lose only a maximum of ten percent of its performance in 5,000 hours of operation. Car manufacturers such as VW, Toyota and General Motors, as well as the Umicore materials technology group are already showing an interest in Kramm's catalysts. Umicore, for instance, is the industry patron of a young researcher group, for which Kramm has just acquired funding from the Federal Ministry of Education and Research.

Industrial scale production of the catalysts should not be a problem, but Kramm is still looking to make a few adjustments. In a current synthesis process, for example, the catalyst is treated with ammonia to increase activity. But this causes so-called iron nitrides to form, which are disruptive in the spectroscopic structure determination, which means that after the ammonia treatment, it is no longer possible to examine the structure of the catalyst in detail. Knowledge of the structure, however, is the basis for further optimisation. The ammonia treatment also reduces the life of the catalyst. Kramm has set herself some demanding objectives: She wants to understand the structure of the catalyst and the mechanisms of catalysis in detail, in order to optimise the substances and their synthesis accordingly. „It is often the case in research that resolving one problem will give rise to many new questions", says Kramm. She is trying to „keep an eye on the big picture". Her Junior Professor and the separate group that has been assembled at TU Darmstadt are her best chance of doing so.

The author is a science journalist with a doctorate in chemistry.

An exemplary career

Ulrike Kramm took up her Junior Professorship under the Excellence Initiative in March 2015. She studied physical engineering at the University of Applied Science Zwickau, with the focus on applied physics (environmental science), and followed this by working on the optimisation of new fuel cell catalysts in an industrial cooperation between the Helmholtz Centre Berlin (HZB) and Toyota. In her doctoral thesis at HZB, as well as in her postdoctoral research at the Canadian Research Institute INRS-EMT in Varennes, at HZB and at BTU Cottbus-Senftenberg, she also dealt with the struc-ture determination of these catalysts, which are one of the main foci of her current work. The Federal Ministry of Education and Research promote Kramm's investigations on the stability of the new catalysts in a joint project with Kaiserslautern University and with the Karlsruhe Institute of Technology and, from 2017 onwards, with a young researcher group.

Current publications

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Dr Karina Becker

Photo: Katrin Binner

The precarius care market

Care work in German families is increasingly being taken over by female migrant workers. Their precarious situation is now analysed in an industrial and organisational sociology study from TU Darmstadt.

The resources of power
Sociology distinguishes between structural, institutional and social power, as well as organisational power. Structural power counts as a primary resource, in the form of the individual power to negotiate in the event of a workforce shortage, for example. The others are secondary power resources. They are based on trade union freedoms, legal regulations, independent regulatory control, or lobbying by non-governmental organisations, amongst other things. Migrant workers currently have none of these resources at their disposal.

By Jutta Witte

Support, care and welfare in your own home: „The obligation of care" in the family used to be taken on mainly by female relatives, but nowadays, increasing numbers of female migrant workers from Central and Eastern Europe are being employed – because a care home is out of the question, or because many of us cannot or do not want to do the job ourselves. Those affected and their relatives save money by hiring staff from Romania or Poland, and in many cases, secure themselves 24-hour care, seven days a week.

Nobody knows exactly how many female migrant workers are currently working in German households. „It is estimated that a great many cases are unreported", says Karina Becker, research scientist at the Institute for Sociology at TU Darmstadt. In her study „Migrant care workers in German households between structural powerlessness and individual primary power", our expert has looked more closely at the care worker situation, carrying out a total of 27 quality interviews in nine households with carers, those dependent on care and relatives, as well as obtaining expert opinions from advice centre professionals.

„In all cases there was a distinct lack of symmetry with regard to power, to the detriment of the care workers", she reports. In the majority of cases, the hours of work are not regulated, neither are health protection and safe working necessarily guaranteed. A lack of regulation means that the care workers had to negotiate their own working conditions. At the same time, because private households were not subjected to close, public scrutiny, standards such as being constantly available or the expectation that the job will be done for little money but „with passion" became established – and these standards were no longer being questioned. Those affected have hardly any room for negotiation, because the size of the potential workforce means that they are easily replaced.

„If they do not work and behave as the family expects them to, they will be sent back home", observes Becker. In her study, our expert identifies four types of precarious and unregulated employment: illegal workers; supposed home helps coming to Germany under the freedom of movement for workers, but actually working in the „grey area of care"; women sent by a service agency outside Germany, and the pseudo self-employed. This last group is getting bigger, according to Becker. „But there is no legal lever with the power of negotiation to monitor the households where the self-employed are working". There are currently no „powerful" institutions to represent the interests of migrant workers either, so the sociologist recommends that those affected concentrate on developing better communication and networking.

It is her conviction that a lasting solution can only be found if the problem is made public, and migrant workers in Germany are granted a lobby. Her research should also help to achieve this: „This issue must lose its niche status."

The author is a science journalist with a doctorate in history.

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