Navigating the Rhine on a dark and foggy night requires an experienced hand at the helm. If there is any visibility at all, distinguishing the navigation lights from the barrage of other ship and shore lights can be a formidable task. **ERNST DIETER GILLES** and his colleagues at the **MAX PLANCK INSTITUTE FOR DYNAMICS OF COMPLEX TECHNICAL SYSTEMS** in Magdeburg have developed an integrated navigation system that gives barge skippers a much clearer perspective in such situations. In fact, in the future, the system is intended to steer the vessel automatically.

Right, now she’s on her own,” says Ernst Dieter Gilles, as his Falke drones on. Straight ahead, right down the middle of the river. The autumn sun is low in the sky, its rays glancing off the gentle waves that ruffle the Elbe. It’s hard to even focus on the water, let alone pick out the bobbing marker buoys. The boat is oblivious, chugging ahead with speed and determination, past the gray eminence of Magdeburg’s venerable cathedral and the crunched Hundertwasser building. Hardly any other vessels are under way and only a few people are strolling along the banks. From a bridge high above us come the faint hum of traffic and the screeching of trams. It’s quiet on the river. This Wednesday afternoon feels more like a Sunday. The round brick hut on the bank that houses the water depth gauge was quite different.

**Computer at the Helm**

The researchers started by sinking imaginary lines along the channel, steering the ship accordingly. It takes a ton of technology – including a GPS receiver for satellite navigation, a radar system, a mobile radio receiver to update water depth data and a turn indicator that records the ship’s turning motion. And of course it also takes intelligent mathematical models that know what to do if the current drags at the hull, or if there is traffic coming the other way. So far, the autopilot is not for sale. The scientists still have to optimize it, making it safe and accurate enough that it can handle even the trickiest situation. The most sophisticated version is currently on board the Friedrich List.

Perhaps soon to be a common sight on inland waterways: Ernst Dieter Gilles takes a rest on the foredeck while the computer steers the Friedrich List.

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FOCUS

The Friedrich List and the Falke are floating laboratories. Ideas born on dry land are tried out here for the first time. So far, only the Friedrich List can avoid obstacles all by itself. The Falke is semi-autonomous – operated via a joystick. A quick flick left or right and the launch turns to swing onto a course parallel to the ideal line, around the obstacle. Not bad at all.

This joystick-operated automatic system has since been fitted to other ships. The researchers have prototypes on board the Sachsen-Anhalt, one of the “Weisse Flotte,” the White Fleet of river cruisers based in Magdeburg, as well as on the Lahn-Stein, a huge push tow that almost 200 meters long. This blunt-nosed bulldozer packs a push tow almost 200 meters long. It has made light work of the traffic jams made by fellow river vessels on the Rhine between Rotterdam and Duisburg. So far, the navigation system – albeit without the automatic guidance or autopilot – has been used primarily on the Elbe and the Rhine. Kilometer by kilometer. The rotating radar antenna produces a black radar image, the chart itself appears on the screen. The system receives reports of current water levels by radio and marks them as channel markers, such as buoys with radar reflectors, and includes these in the chart. The system receives reports of current water levels by radio and adjusts the chart accordingly. The current radar image is superimposed on an unobtrusive green. A red line symbolizes the ideal course through the channel – the shortest and most economical route. The river kilometers and speed appear on the edge of the screen.

Staff from the Stuttgart-based section of the working group have since started their own business to market this first stage of the navigation system – albeit without the automatic guidance or autopilot. So far they have sold 400 combined chart and radar packages. Even though the software is not yet capable of keeping ships on course on its own, it has its uses. It calculates not only the vessel’s position and direction of travel, but also those of other vessels. This is achieved through stochastic analysis of consecutive radar images. In this way, captains can detect in good time whether another ship is likely to come dangerously close. The navigation system also recognizes other channel markers, such as buoys with radar reflectors, and includes these in the chart. The system receives reports of current water levels by radio and adjusts the clear channel on the monitor accordingly.

But what use are these detailed charts to an experienced skipper? Some of them have been sailing the Rhine or the Danube for a quarter of a century, and they know every shallow and rock, and can safely navigate all of the narrows, always with a hand’s breadth of water under their keel. So why do they need an electronic chart? “Because it makes the master’s job easier, especially when the river narrows,” says Gilles. Or at night. In the dark, the helmsman is sometimes faced with hundreds of lights – buoys, the navigation lights of other ships and lights on shore. With tired eyes, it’s hard to distinguish between them, and watching the flickering radar doesn’t help much.

Things can become really bad if you become disoriented in the fog. Consider the fate of the captain of the push tow Maudriaul on the Mohile River in Alabama back in 1993. Despite his radar, he mistakenly turned into a narrow, unnavigable branch of the river. The fog was so thick that the captain couldn’t even see the front of his train of barges. The heavy rig slammed into a railway bridge and the rails buckled. Minutes later, a passenger train thundered over the bridge, derailing the locomotive and several cars, toppling them into the river. Forty-seven people died. Fortunately, an accident on this scale has not happened on Germany’s rivers. However, ships do still manage to collide in the fog.

AUTOPilot MAKES SHIPPING SaFER

The integrated navigation system is intended to prevent accidents. There are, however, some reservations. Barge skippers fear that automatic systems will one day rationalize their jobs away. “That certainly won’t be the case, because a skipper always has the last word,” says Gilles. And there is always the possibility of computer failure. One press of the emergency stop button and the ship is back under the control of the good old wooden wheel. Gilles is confident that, in 10 years, the autopilot will be commonplace. The authorities are supportive of the idea, having already given permission for a vessel the size of the Lahn-Stein to mix with the milling mass on the Rhine on semi-automatic.

There can be no dispute that Gilles’ invention will serve a purpose to make shipping safer. It has survived the lean years for river shipping and has matured at a time when traffic on the Danube, Main and Rhine is becoming denser. The German Federal Ministry of Transport, Building and Urban Af- fairs estimates that about 40 vessels transport on Germany’s inland waterways will rise by 20 percent between 1997 and 2015, while freight traffic will increase by 64 percent. The barges have long been carrying more than just bulk commodities such as coal, oil and steel up and down river. In a united Europe with overcrowded highways, more and more containers loaded with electronic equipment and other high-value goods are being shipped by water. In the future, with the integrated navigation system, these goods will follow an ideal line non-stop from place to place. The onboard computer ensures that the ship sticks to its route like an obedient dog. “The key to the system is a Kalman filter,” says Ralph Bittner, a control systems engineer and specialist in guidance systems.
control at the Max Planck Institute in Magdeburg: "Using the data from sensors such as the GPS and radar, this mathematical model makes up its own mind about the status of the ship’s position, speed and drift."

**A DUMB COMPUTER STEERS A SERPENTINE COURSE**

Then the control system takes over, and the mathematical models are activated. The control system notices errors and deviations from the norm—due, for example, to the ship's head drifting off course under the effect of current or wind. One mathematical model (the direct model) couples this information with the stored description of the ship’s behavior, design or current overall weight. Bittner explains: "The model answers the question of how the ship will respond if the rudder angle is changed in a particular way." The control system then knows what to do and the ship stays on course.

The challenge was to select the model and the parameters in such a way that they could be easily adapted to new vessel types—with no need for costly test runs. It is actually sufficient just to create a bar model of the ship. Even turbulence around the hull can be largely ignored...

The second part of the control system is the inverse model—the rever- sion of the direct variant. "The inverse model answers the question of how the navigation system needs to adjust the rudder angle in order to follow specific points," says Bittner, "or in other words, the circuitous ideal line along the river." An unintelli- gent computer without mathematical support would respond only when its sensors detected an error and the ship had already departed from the ideal course. To put it simply: with a dumb computer, the ship would steer a serpen- tine course weaving around the ideal line. Not so with the model- controlled concept. This combines the ideal route with knowledge of the ship’s behavior and calculates the cor- rect rudder commands right from the outset.

Despite the sophisticated soft- ware, the autopilot has, in the past, had difficulty in maneuvering par- ticularly large vessels around tight bends in a strong current. The sci- entists have since optimized the programs and solved the problem.

In long-term use on commercial vessels, the upgraded mathematics now have to prove whether they are really the master of every situation. The autopilot generally allows the Falke to stray no more than a max- imum of one meter from its track. For shipping purposes, that’s good enough.

**ULTRASONICS HELP WITH DOCKING**

There is something else the integrat- ed navigation system is due to learn: how to dock. A doctoral student is already working on the problem. In the future, with the aid of ultrasonics and even more precise position rec- ognition, docking a ship will be as natural as parking a luxury-class car. For now, however, Ernst Dieter Gilles has to do it himself on the Falke. He eases back on the throttle and switches off the autopilot. Then he swings the wheel hard over to port to excur- sive a U-turn on the Elbe. Slowly the Falke chugs toward the white pontoon by the bank.

Gilles stares ahead with calm con- centration. Jacket open, his hair an iron gray. You could easily take the 71-year-old for an experienced sail- or. In fact, he has spent countless hours on board ship, not just since he began to research his electronic nav- igator. He sailed on the Rhine in the 1940s and 1950s, when his father ferried pilots to the passing ships. In those days, paddle steamers chugged up and down the river, whizzing black and white clouds between the tight and towering rocks of the Rhine valley. Gilles’ father was a ferryman in Kaub am Rhein, where the gorge is rugged and sheer, beautiful and steeped in history. Where the rock known as the Pfalzgrafenstein stands in the river, he carried cars, homet- drawn carts and cyclists across to the left bank, past the ancient customs fortress.

In those days, the Rhine was haz- ardous between St. Goar, Kaub and Bingen—especially the narrow stretch by the Lorelei, and the rocks of Binger Loch, stone obstacles in the middle of the river. Above Bingen, the Rhine was just 27 meters across until, in the 1970s, the river bed was blasted to widen the channel to 120 meters. Sailors were well advised to take a pilot on board. Small boats took them out to the steamers in mid-river. Ernst Dieter Gilles sometimes went alone, since the small pilot boats also belonged to his father. Of- ten it was he who steered into the river, out to the large and weighty tugboats that hauled as many as 10 ships behind them.

Maybe it was these memories that, in Stuttgart, sparked the idea for a navigation system, and for a modern version of these chains of ships on tow. In the future, multiple vessels equipped with autopilots should be able to follow in line. Only the master of the lead ship will need to watch the traffic; the rest of the skippers can rest easy. The Falke and the Friedrich List have already demonstrated the principle. The system naturally detects the ship in front and the autopilot copies its movements and adapts its own performance accord- ingly. Some years ago, experiments were carried out in the US to test the ability of cars fitted with adaptive cruise control and other assistant sys- tems to drive automatically in convoys. Gilles has now proven that it works with river boats as well.

**COMMUNICATING IN A CONVOY**

For around five years now, it has been obligatory for ships at sea to carry an Automatic Identification System (AIS). Each vessel is fitted with a transponder that transmits informa- tion regarding the cargo and port of destination, as well as current speed and position. Experts are cur- rently discussing the introduction of AIS on inland waterways. "AIS would make it even easier to travel in con- voy, as the ships would be transmit- ting the relevant data to and from another," says Alexander Lutz, one of Gilles’ team members working on the project.

AIS on the river would also facili- tate the ship’s behavior with the "lookout" systems. Thus far, human intervention has been required to control the traffic passing through the narrows. Now, ships could deter- mine directly via AIS which of them has the right of way. Before that hap- pens, however, Ernst Dieter Gilles and his colleagues will have to travel many more kilometers up and down river.