Automatic archaeology

Digging in the dirt in search of clues to the past has churned up millions of pieces of pottery. Haim Watzman unearths the new technologies being developed to sift through them all.

Vered Rosen is an artist. For the past few years, she has made her living drawing pieces of pottery using a simple sketchpad and a pencil, for a team of archaeologists excavating Tel Dor on the northern Mediterranean coast of Israel, south of Haifa. But now her employers are retraining her. They have sent her to the Weizmann Institute of Science in Rehovot to learn to draw using a profilograph, a device that can produce digital images of pottery fragments — images that can be analysed and classified by a computer.

For archaeologists, the ability to sift automatically through pottery samples is fast becoming a necessity. A typical excavation site might disgorge hundreds of thousands of pieces of broken clay pots — the favoured all-purpose vessels from ancient times until well into the Middle Ages — all of which need to be washed, sorted, labelled and analysed. The pots' shapes, dimensions, texture and style can help to date the layers of soil through which the archaeologists are digging, and can even reveal when and where different societies were trading with each other. Pottery shards are, to an archaeologist, as important as microfossils are to a palaeoclimatologist — the crucial clues that are used both to date a stratum and to understand the conditions that prevailed at the time. But there are not enough trained people to deal with the flood of pottery finds, and there are doubts in the community about whether the conventional method of hand-drawing is the best way to study them.

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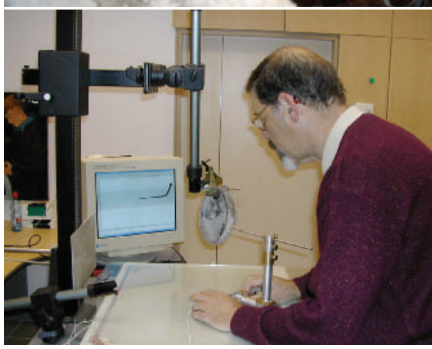

Helping hand: Uzy Smilansky (left) aims to use a drawing device called a profilograph to record the wealth of pottery shards (right) unearthed at sites such as Tel Dor (above and above right).

Artistic difference

Rosen's metamorphosis from artist to technician began when Uzy Smilansky — a physicist at the Weizmann Institute and an archaeological hobbyist — celebrated his sixtieth birthday three years ago. On that day he took his entire family to an excavation at Ein Gedi, on the northwest coast of the Dead Sea. "At the time I was looking for something new to do in the last phase of my career," says Smilansky. His experience as an amateur archaeologist meant that he was aware of the problem of comparing and analysing vast quantities of pottery. And his excavation holiday drove that home. "I thought it was time to harness the computer to the profession of archaeology," he says.

With that goal in mind, Smilansky was directed to Ilan Sharon of the Hebrew University of Jerusalem. Sharon, one of the chief excavators at Tel Dor, has a similarly mixed background, having done two years of undergraduate work in mathematics before switching to archaeology. Sharon was enthusiastic about Smilansky's idea, and knew of a Hebrew University undergraduate named Avshalom Karasik who was doing a double major in archaeology and mathematics. Together with Ayelet Gilboa of the University of Haifa — the Tel Dor excavation's pottery expert — they made a perfect team.

Together, they soon learned that others have been in hot pursuit of new ways to study pottery in bulk. Statistician Clive Orton of University College London was one of the first to outline the potential benefits of speed and objectivity that an automated system could offer[1]. In the late 1980s, Orton began to work on one of the first computer programs that can analyse and compare information about large quantities of shards. But measurements for each piece had to be painstakingly taken and entered into the computer by hand.

Drawing on technology

Smilansky's team focused its efforts on eliminating that problem with the help of a profilograph. The device, invented years ago for use by architects, designers, artists and scientists, resembles a cross between a drafting table, a caliper and a computer mouse. To use it, a piece of pottery is clamped above the table in a position such that the central axis of the pot, if it were whole, would run parallel to the table. Then a delicate metal pointer attached to a computer mouse is used to trace the outline of the pot, clicking every few millimetres. This forms a series of data points in three-dimensional space that the computer then connects to create an image of the shard's surface.

Rosen is still learning how to use the device. At this point, she says, it takes her about an hour to trace a single piece — much longer than the 20 minutes it would take to do a simple pencil drawing of the fragment. But the end result is much more accurate and objective than any freehand drawing.

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Smilansky's role, meanwhile, has been to program the computer to interpret these drawings. His program creates a 'curvature function' from the lines — a mathematical representation of features such as the shape and size of the pot. For the moment, his program emphasizes the shape of the top few centimetres and rim of the pot — a diagnostic characteristic that many archaeologists think is the best indicator of when and by whom the pot was made.

The technique's great advantage is its objectivity. "Hand drawings are inevitably biased, no matter how objective they try to be," says Gilboa. "The artist will often have the excavator's theories in mind when looking at a piece, and when the archaeologist reviews the drawing he'll often tell the artist to emphasize a feature that he thinks is important."

"Most drawings are not accurate," agrees Robert Sablatnig, a computer scientist at the Vienna University of Technology in Austria. "Archaeologists somehow classify their findings in their mind and then draw what they think they should draw to make the classification correct. When you examine the original fragments, they often don't have the same features as in the drawing."

To test the usefulness of the profilograph, Gilboa, Karasik, Sharon and Smilansky turned their attention to an ongoing dispute about evidence of trade between Hazor, a site north of the Sea of Galilee that was a major urban centre during the Iron Age, and Tyre, a city in modern-day Lebanon that was once a major Phoenician port. A large bulk of evidence points to the fact that these two nearby cities were engaged in trade. But there have been arguments about whether there is additional evidence for this in the large collections of 'torpedo' jars found at both sites. These long, cylindrical vessels, used in the northern Kingdom of Israel and Phoenecia during the Iron Age IIB period, about 2,800 years ago, were made to carry anything from grain to wine in commercial trade.

One of the Hazor researchers argues that all of these jars were manufactured in Hazor, and that some were exported to Tyre[2]. But the archaeologist who found the jars in Tyre claims that, if anything, they went in the opposite direction — the Hazor jars were imported from Tyre[3]. A third study, by Gilboa, argued that the existence of tiny, but consistent, morphological differences between the Tyre and Hazor jars indicates that the jars are not the same at all, but were each made in their own home city[4]. Tests using the profilograph backed up Gilboa's contention — the jars from each city are far more similar to each other than to those from the neighbouring area. The discovery might not help to clear up any confusion about trade between the two cities, but it does show that archaeologists can benefit from a standard, objective system to judge similarities and differences in pottery.

Subjective view

But even Smilansky's technique cannot remove all subjectivity from the process — someone had to decree that rim shape is among the best deterministic factors, for example. "We began with a great deal of respect for archaeologists," Sharon says. "Our assumption is that the computer's job is to provide an emulation of the archaeologist's intuitive processes — with a grain of salt."

Nor will something as simple as an equation describing the rim of a pot ever completely replace the watchful eye of a trained archaeologist. "There's a lot more to identifying pottery than looking at drawings," says Jodi Magness of the University of North Carolina at Chapel Hill, an expert on Roman pottery. "It also involves familiarity with the fabric, which means things like colour and texture. You have to handle a lot of pottery to become familiar with it. Some pottery experts even taste pot shards to identify them."

"There's something about the human mind's ability to deal with data that so far computers don't do," says Aren Maier of Israel's Bar-Ilan University, who excavates at Tell es-Safi, a site southwest of Jerusalem. Maier is so far sceptical of the value of the simple drawings produced by computer programs such as Smilansky's. But, he adds, "it could be that that's enough — especially given our need to save time, space and resources".

That is exactly what the profilograph technique promises to do. "What do you do when you have 100,000 pot shards?" asks Gilboa. There are simply not enough artists to cover that much work. "There's no question that there's a ton of pottery and not

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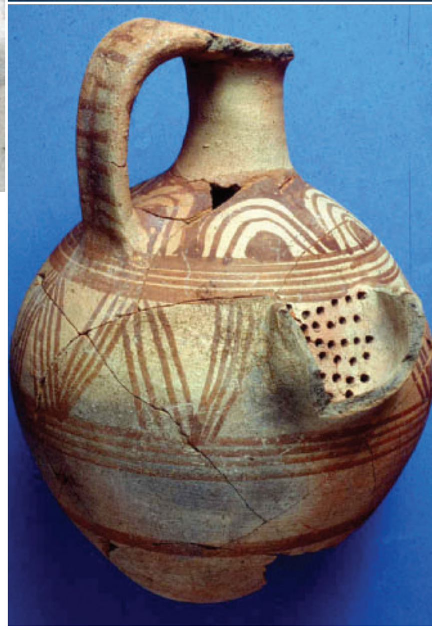
Given the wealth of findings from Tel Dor (above and right), a computer log of pottery shape will be a huge bonus. Future databases will also aim to incorporate information on clay type and colour.



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enough people who can work on it," says Maier. Part of the problem is that drawing and comparing bits of pottery is seen as an unglamorous job. "It's the kind of work you generally do for a doctorate and then never touch again," says Gilboa. "The general feeling in the field — it's totally mistaken, of course — is that the study of pottery is for wusses," adds Maier.

But that means that masses of pottery from a site such as Tel Dor are never drawn or analysed, potentially leaving interesting facts undiscovered.

One reason that Tel Dor was chosen as a laboratory for automatic analysis is that the pottery in the area changed relatively rapidly over time, with fashions in the city shifting every few decades. During Israel's iron age, around 3,200–2,600 years ago, the profiles of pots shifted from looking like bent femur bones — with knobs and indentations adorning the top — to simpler S-shaped profiles resembling the horn of a longhorn cow, passing through myriad styles in between.

An archaeologist who chooses to publish drawings and studies of only one or even a handful of these pieces will probably miss something that could provide excavators at another site with crucial information about relations between the two communities, says Gilboa. Even if all the pottery is drawn and analysed by hand, it is likely that few people will bother to look them up in the weighty excavation reports — a process so slow and laborious that it is seldom carried out, she adds.

An automatic technique, together with a computerized database of the results, would solve these problems. But the profilograph is not the only possible technological solution. Sablatnig, for example, is working on a different experimental system that uses photographs to form a three-dimensional computer image of a broken pot. This process is faster than using a profilograph, so Sablatnig does not restrict himself to looking at the tops of pots. As a result, he gains a more complete picture of the reconstructed piece. But so far it is unclear which method will prove more powerful in comparative studies. Smilansky points out that his own curvature functions are more versatile than Sablatnig's, as archaeologists can use them to specify the aspect of a pot's shape in which they are most interested. The pair plan to collaborate to devise the best possible method — one option that Smilansky is already investigating is the possibility of using lasers to image the pieces.

Shaping up

Others, including research teams at Brown University in Providence, Rhode Island, and Arizona State University in Tempe, are also tackling the problem.

But many of these systems suffer from the fact that they address only one element of the pottery — its shape. What's more, to reconstruct the image of a pot from a few shards, they assume that the vessels they are looking at are basically symmetrical. Prudence Rice, an archaeologist at Southern Illinois University in Carbondale, points out that people from the Americas did not use potter's wheels, so this assumption does not apply to pieces from the New World.

Instead, archaeologists rely more heavily on other criteria, such as colour or the composition of the clay, to identify such pieces. "I don't see how these three-dimensional images are going to replace that," says Rice. Smilansky and Sablatnig are working together to develop imaging methods that can capture features such as painted pictures on the pots. And Orton, one of the pioneers of automated comparative archaeology, is working on adding information about colour, texture and clay type into his databases of pottery shards. But he has not been able to automate the collection of that kind of data — he is still doing it all by hand.

In the end, even if these teams succeed in establishing profilographs or laser-imagers as standard equipment on archaeological digs, the kind of comparisons that Gilboa wants to carry out will also require backlogging information from previously published excavations into a computer format — an immense amount of work that Rosen and her colleagues could never achieve. Gilboa nevertheless dreams of an international and comprehensive pottery database that will make serious comparative work not only possible, but a pleasure. Maybe then, she thinks, archaeologists can begin to answer questions that they have not yet been able to address, such as whether pot shape changed over time because of fashion trends, new technologies or both. Who knows? Maybe working on pottery will even become glamorous again. ■

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1. Orton, C. *Sampling in Archaeology* (Cambridge Univ. Press, Cambridge, 2000).
2. Geva, S. *Bull. Am. Sch. Oriental Res.* **248,** 69–72 (1984).
3. Bikai, P. M. *Bull. Am. Sch. Oriental Res.* **258,** 71–72 (1985).
4. Gilboa, A. *Qedem Rep.* **2,** 15 (1995).