Coorapid – A Forgotten 22.6 kg Heavy Slide Rule for Coordinate Transformations

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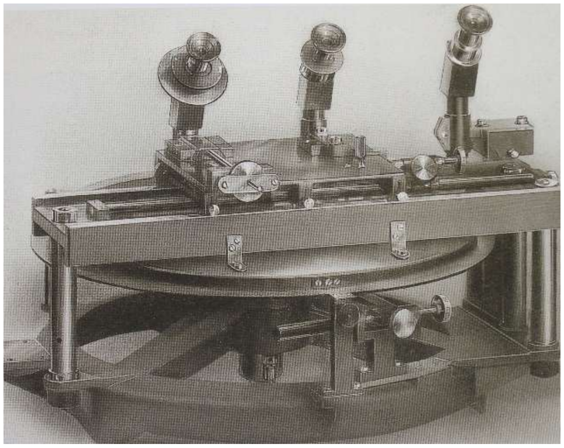

FIGURE 1. First Coorapid Model[29]

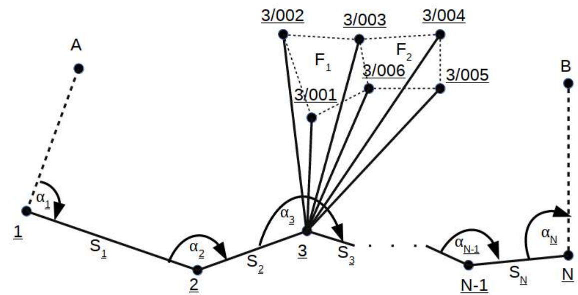

FIGURE 2. Traverse with Star Shaped Net at Point 3.

The Coorapid coordinate calculator is rarely offered at flea markets or online platforms. Most collectors might not even recognize the device as a mechanical calculating device. On one hand, it seems that no input operands can be set, and on the other hand it has three microscopes, the purpose of which is initially not clear. Furthermore, the machine comes with a lamp, but no paper or the like is inserted into the machine. So, what is the purpose of this machine?

1. Traversing in Surveying

To understand the usage of the Coorapid, a look into the mathematical basics of surveying is necessary. In the days before high-precision GPS coordinates, determining coordinates of points on the earth was a complex task. For example, in surveying, the coordinates of a number of subsequent points have been determined, starting from a point with accurately known coordinates. Such a sequence of points together with their connecting lines is called a traverse (see Figure 2).

When measuring the traverse, the subsequent point i+1 is measured from point i. The angle α_i between the previous section S_{i-1} and the section S_i is measured with a theodolite. The distance S_i between i and i+1 is also measured. In the next step, the theodolite is placed on the point i+1 just measured and the coordinate to i+2 relative to i+1 is determined using the same methodology. This is how you proceed to the last point, N.

At the end of the traverse, which can have a length of several kilometers, the coordinates of the second connection point B are determined. Since the point B is precisely known as well, the difference between the newly measured coordinates and the already known coordinates indicates the overall errors introduced during traversing. If the deviation is above an error limit (typically some centimeters) specified by the authorities, the measurement must be discarded and the traverse need to be measured again. The coordinates of the intermediate points of the traverse can only be regarded as sufficiently precise if the error limit is adhered to and the error compensation calculation can be carried out later in the surveying office.

The accuracy of the point coordinates is important, since starting from these points, further points are determined in a star shape net by further angle and distance measurements (see point 3 in Figure 2). The points 3/001, 3/002 etc. measured from point 3 could be corner points of property boundaries (F_1 and F_2). Of course, every owner wants to know that the boundary points are provided with correct coordinates in the property documents.

2. Polar versus Cartesian coordinates

When looking at the measurement method described above, you can see that the traverse points are not recorded in a Cartesian coordinate system. Instead, due to the measurement technology, the measurements are done from the position of the theodolite in a polar coordinate system. The position of the theodolite forms the origin of the polar coordinate system. From this position, all targets are measured by an angle α_i

(based on a reference line) and the distance $S_{\underline{i}}$ from the theodolite. In particular, this also applies to the points in a star shape net. In practice, 20 to 30 such points are often measured in a star shape net.

It should also be noted that with every shift of the theodolite from a point $\underline{i}$ to $\underline{i+1}$, the theodolite is set up at a new position $\underline{i+1}$, which means to a new polar coordinate origin.

This large number of polar coordinates requires a huge number of conversions from multiple polar coordinate systems into a single Cartesian coordinate system, and that is the role of the Coorapid.

3. Theory of Coordinate Transformation

In the previous sections, the surveying application was explained, which requires the polar to Cartesian coordinates transformation. Before we explain how the Coorapid works, let us first have a look at the mathematical conversion from polar to Cartesian coordinates.

Figure 3 shows that each point in a Cartesian coordinate system is determined by unique polar coordinates and vice versa. Point $\underline{1}$ has the Cartesian coordinates $x_{\underline{1}}$ = 4.075 and $y_{\underline{1}}$ = 2.377 (solid blue coordinates). In the polar coordinate system, the point lies on the circle with $r_{\underline{1}}$ = 4,72 at the angle $\alpha_{\underline{1}}$ = 30.31°, respectively 33.67 gon[1] (dashed blue coordinates).

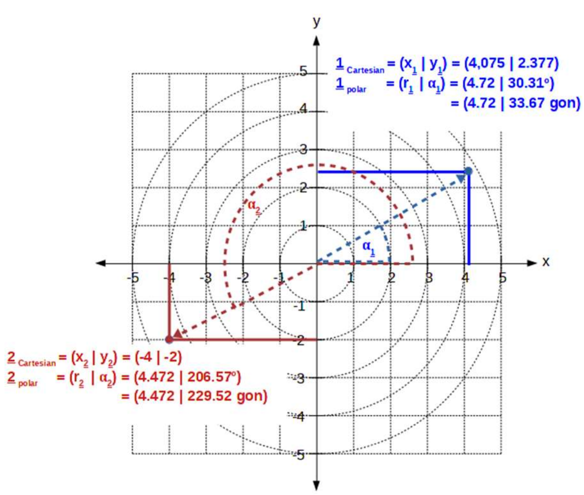

FIGURE 3. Representation of Points in Polar and Cartesian Coordinates.

In order to convert the polar coordinates of point $\underline{1}$ at given $r_{\underline{1}}$ and $\alpha_{\underline{1}}$ into Cartesian coordinates, the following calculations must be carried out:

$$x_{\underline{1}} = r_{\underline{1}} \cdot \cos(\alpha_{\underline{1}}) \quad \text{and} \quad y_{\underline{1}} = r_{\underline{1}} \cdot \sin(\alpha_{\underline{1}})$$

As part of the traverse calculation, a rotated polar coordinate system with the origin in $\underline{i}$ is placed at each point $\underline{i}$ and the associated Cartesian coordinates of the successor point $\underline{i+1}$ are then determined. These Cartesian coordinates represent the $\Delta x_{\underline{i+1}}$ and $\Delta y_{\underline{i+1}}$ coordinates in relation to the point $\underline{i}$. In other words, the distance $\Delta x_{\underline{i+1}}$ in x-direction and $\Delta y_{\underline{i+1}}$ in y-direction have to be added to the point $\underline{i}$ to reach point $\underline{i+1}$. Mathematically, the Cartesian coordinates of $\underline{i+1}$ result from

$$\underline{i+1}_{\text{cartesian}} = (x_{\underline{i}} + \Delta x_{\underline{i+1}} \mid y_{\underline{i}} + \Delta y_{\underline{i+1}})$$

Figure 4 schematically shows the calculation for point $\underline{3}$ at our traverse. The same approach for the coordinate transformation applies to the points measured in a star shape net in relation to the point from which the measurements have been taken.

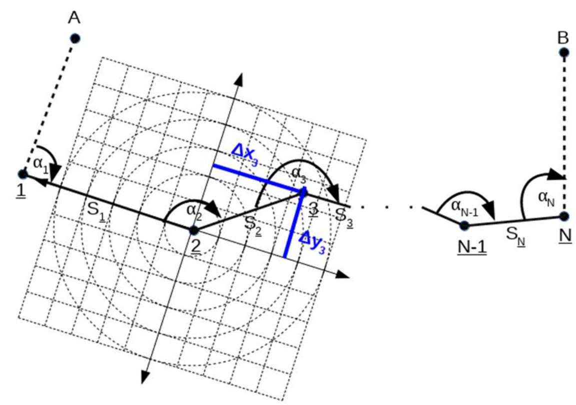

FIGURE 4. Calculating Δx and Δy from Polar Coordinates of the Traverse.

4. Mechanical Coordinate Transformation

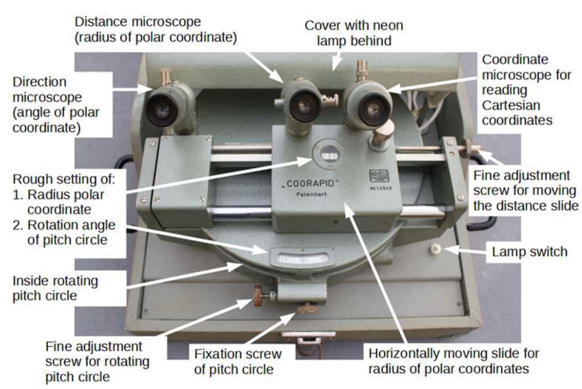

FIGURE 5. Coorapid Serial No. 14942, Later Model (Collection Zerfowski).

Finally, we come to the use of the Coorapid. The machine is not a computing machine that can be used for general calculations, but a special device for the coordinate transformation mentioned above. The device including transportation box weights 22.6 kg with a size of 40 cm width, 30 cm height and 35 cm depth.

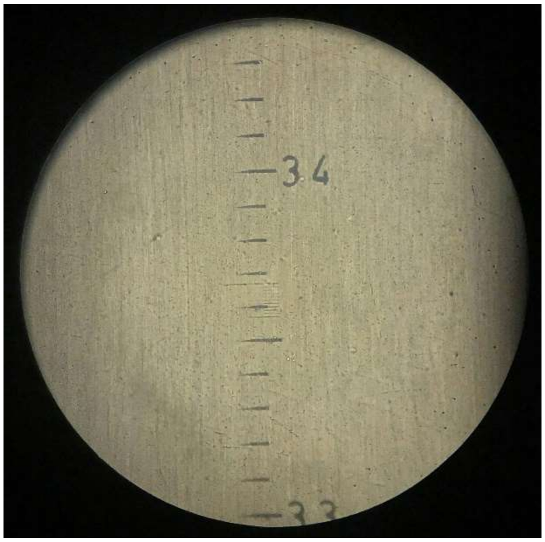

FIGURE 6. View Through the Directional Microscope. Around the mark 33.6 the finer marks for detailed readings is hardly visible. Input value $\alpha_{\underline{1}}$ = 33.67 gon has been set (see point $\underline{1}$ in Figure 3).

FIGURE 7. Top: Rough Setting of the Number Before the Decimal Point of the Distance Coordinate $r_{\underline{1}}$ = 4.72. Bottom: View Through Distance Microscope. Decimal Places of $r_{\underline{1}}$ = 4.72 of Point $\underline{1}$ in Figure 3.

The Coorapid contains a very fine, incised grid on a glass plate (Figure 10), on which the rectangular coordinates to be determined can be read with an accuracy of 0.01mm using the Cartesian coordinate microscope (Figure 8).

The polar coordinates are entered in two steps (see Figure 5). The directional angle of the polar coordinate is set by rotating the pitch circle (Figure 11). The radius of the polar coordinate is entered by means of a drive screw that moves the distance slide horizontally. The settings are checked using the directional microscope (Figure 6) and the distance microscope (Figure 7). Figures 6 through 8 show the coordinate transformation of point $\underline{1}$ in Figure 3.

To get a better understanding of the device's operation, consider the explanation model created by R. & A. Rost (Figure 9). The previously mentioned grid lines of the rectangular coordinates are shown on a disc. On the circular edge, the angular divisions are plotted on the outside in centesimal degrees (0 - 400 gon) and on the inside in degrees (0 - 360°). The radius of the polar coordinate is plotted on the white cursor, which can rotate over the disc.

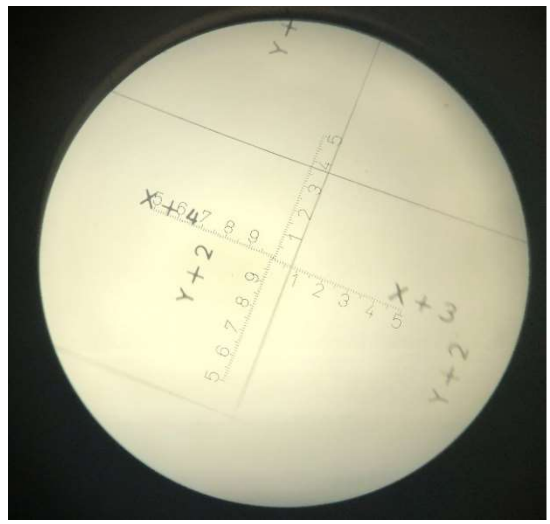

FIGURE 8. View through Cartesian Coordinate Microscope. Reading the Cartesian coordinates gives $x_{\underline{1}}$=4.075 and $y_{\underline{1}}$=2.377 for the point $\underline{1}$ in Figure 3.

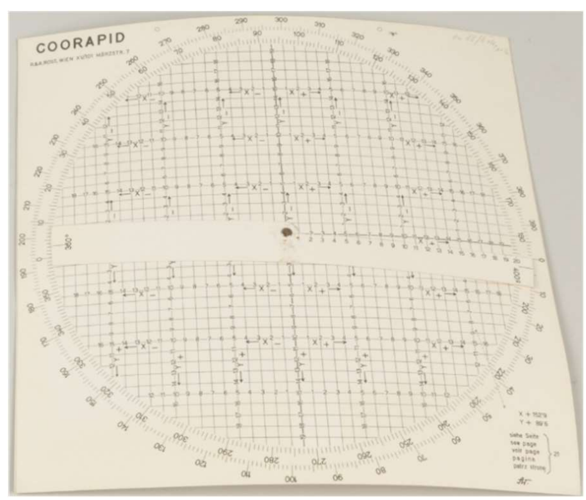

FIGURE 9. Principle of the Coorapid. (Source: Deutsches Museum, Munich, [1988-0414_T002_ 2013.12.16 005_D0005_ND_JD]).

The mode of operation of the Coorapid can now easily be explained by using the model. Turning the pitch

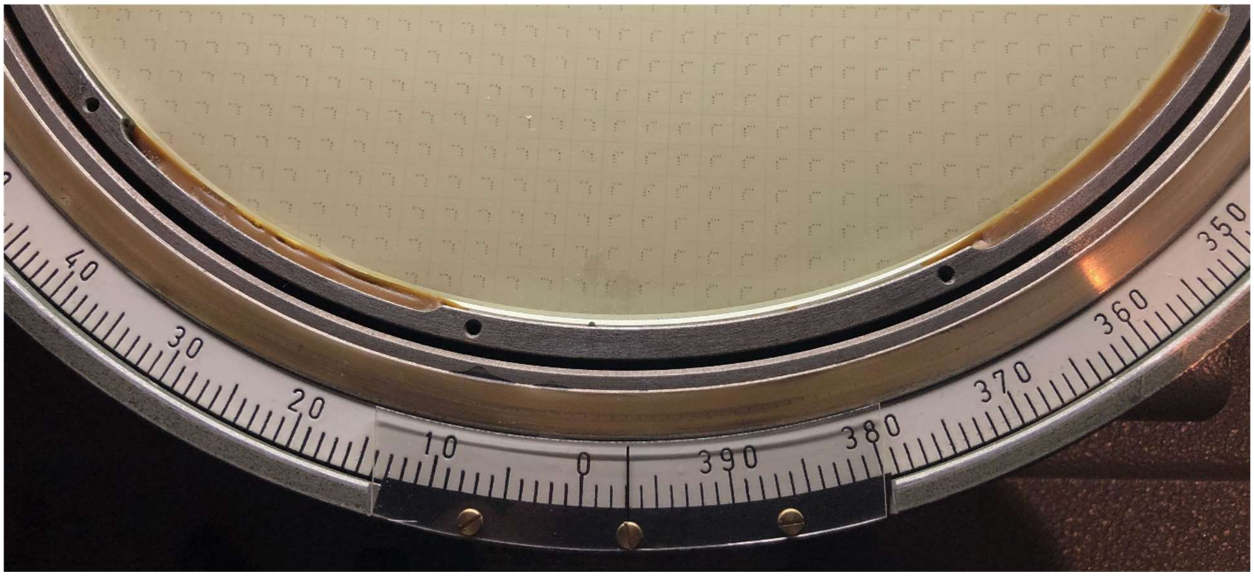

FIGURE 10. View Into the Opened Coorapid on the Pitch Circle. Without the Microscope, the Finely Engraved Cartesian Coordinate System is Hardly Visible.

circle on the Coorapid corresponds to rotating the disc under the cursor. The angle value to be set, can be read at the arrow on the cursor's end pointing on the circular edge on the disc. In the Coorapid, this is done with much higher accuracy and by using the direction microscope. The sliding part of the Coorapid and thus the setting of the radius of the polar coordinate, corresponds to a movement along the cursor. The Cartesian coordinates can now be read at the corresponding mark of the cursor.

In the Coorapid, this is again done with a high accuracy using the coordinate microscope. It should be noted that the grid lines in the Coorapid on the glass plate are much smaller and finer than on the model shown.

Figure 10 shows a part of the real pitch circle within the opened Coorapid. The outer ring is used for the rough setting of the angle. The inner brass ring carries the finely engraved high-resolution angle values, which are looked at through the direction microscope. The inner area of the pitch circle carries the fine structure of the Cartesian coordinate system, which has to be viewed through the coordinate microscope (see Figure 8).

In summary the approach behind the Coorapid can be explained as a two-dimensional slide rule that enables high setting and reading accuracy using mechanics and microscopes (see also Ref. 27). The entire mechanism realizes a miniaturization of an incredible huge and non-operable circular slide rule while ensuring high precision calculation results.

FIGURE 11. Grip Recesses for Turning the Pitch Circle. The Left Setscrew is used for Fine Adjustment, the Right one for Fixing the Pitch Circle.

With the assumption that the microscopes are operated with a magnification factor of 10, then an equivalent device without magnification would have to be about 10 times the diameter, which means more than 2.5 meters.

5. Advantages of the Coorapid

The coordinate transformation derived in Section 2 requires the determination of two trigonometric values, $\sin(\alpha_i)$ and $\cos(\alpha_i)$, as well as two multiplications for each conversion. Before the first scientific calculators in the 1970s, this meant time-consuming and error-prone look-up of the angle functions in corresponding tables and the manual execution of the multiplications. Towards the end of the 19th century, the use of calculating machines for multiplication was already being propagated. In 1898, Jordan[16,17] described the use of Burkhardt's arithmometer in the traverse calculation. Jordan suggested the use of calculating machines in conjunction with sine and cosine tables and the use of corresponding calculation form sheets to guide the employees through the individual steps of the calculation. The algorithm presented was not optimized for use by computing machines. Nevertheless, Jordan mentioned a time saving of 25% due to the use of calculating machines. Further literature references on the use of calculating machines for geodetic calculations can be found in Ref. 33.

In order to get a feeling for the number of calculations carried out at that time, note that Jordan[16] stated: *„E.g. in Baden cadastral surveying, about 1 to 2 million traverse points according to s sin α and s cos α have been calculated since 1852 [to 1898] with the help of Ulffer's coordinate table..."*

Later in the article it is mentioned *"... that in Germany annually a few hundreds of thousands of traverse points are calculated..."*.

A similar statement can be found in Rinner's article[25] from 1949, in which it is stated *"... that by 1939, 250000 to 300000 points had to be transformed annually in the Austrian Federal Office for Meteorology and Surveying."*

This enormous amount of required coordinate transformations is the reason why Rinner recommended the usage of the Coorapid. Due to the simple handling of the Coorapid, the user of the device does not need any measurement or mathematical knowledge to carry out the transformation. Rinner goes as far as saying[25] that *"... the machine can be operated like a typewriter by less qualified personnel."*

A corresponding test lasting several hours gave the following results: *"A lady without geodetic knowledge converted 94 points in the first hour, 116 in the second and 122 in the third, thus an average of 113 points per hour. A graduate surveying engineer, on the other hand, converted 99, 119 and 102, i.e., an average of 107 points each Hour."*

Unfortunately, we have no comparable values for the number of transformations done with a calculating machine.

6. Inventors & Production

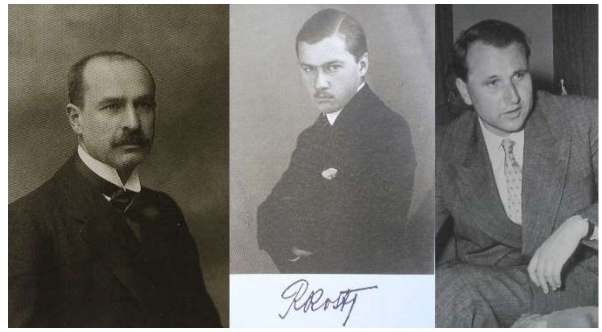

FIGURE 12. Three Generations of Leaders of R. & A. Rost (from left to right): Rudolf Rost Sr., Rudolf Rost jr., Peter Schlög[29].

Since the Coorapid was manufactured exclusively by the company R. & A. Rost in Vienna, we take a look at the history of the company. It was founded in 1888 by Rudolf Rost (born August 26, 1860 in Vienna, died December 14, 1933 in Vienna), after his education as an instrument maker at Starke & Kammerer, in Vienna. Eight years later, on January 17, 1896, August Rost (Rudolf's younger brother by three years) joined the company Rudolf & August Rost, which subsequently successfully manufactured and sold geodetic instruments.[22,29]

At the beginning of the 1920s, the two brothers left the company and their sons, Rudolf jr. and August jr., took over the management. However, August jr. left the company after a few months due to internal differences. Until the Second World War, the company was successful manufacturing geodetic instruments and was able to compete in the market against increasing competition.

The invention of the Coorapid also coincided with this period. The inventors were Hugo Bohrn and Leander Avanzini, both located in Linz, Austria. The first patent application[5] was made on January 30, 1937. In 1938, corresponding applications had been applied for in other countries,[6,7,8,9] some with more images than in the first patent.

Country & Patent no.	Application date	Ref.
AT 154964B	30.01.1937	5
CH 208012	28.01.1938	6
GB 512661	28.01.1938	7
US 2198757	28.01.1938	8
FR 832780	29.01.1938	9

Leander Avanzini worked as a graduate engineer from 1929 to 1939 at the Federal Office for Calibration and Surveying. During this time, the patents for the Coorapid had been filed. After the Second World War, Mr. Avanzini worked at the Innsbruck Surveying Office from 1949 to 1967 and took over its management in 1958. From 1967 onwards no further information about Mr. Avanzini is known.

In 1948, Hugo Bohrn, engineering consultant for surveying (Alpenphotogrammetrie GmbH in Wels, Upper Austria), reports[10] that he and the co-inventor Avanzini asked the instrument maker Franz Pachner of Starke & Kammerer to manufacture the first machine, which at that time was still called Koorapid.

With the dissolution of Starke & Kammerer during the Second World War, R. & A. Rost took over parts of the production facility. Mr. Pachner, who was the last owner of Starke & Kammerer, also moved to R. & A. Rost. At the same time, the patent owners handed over the exclusive manufacturing rights to R. & A. Rost,[12] so that Mr. Pachner was able to play a decisive role in the development of the Coorapid, which was ready for series production. In the company publication on the 100th anniversary of R. & A. Rost,[29] it is emphasized, that the Coorapid was only ready for series production after the Second World War.

The first model, shown in Figure 1, was tested by the Experimental Institute for Geodetic Instruments and Timepieces of the Austrian Federal Office for Meteorology and Surveying, and received a very favorable test report[10]: *"From the results, the quality and usability of the construction has been recognized, since the performance with this apparatus went far beyond the performance of experienced machine calculators. The apparatus is therefore highly economical."*

Furthermore, it is mentioned that variants with old degree graduation (360°) and with new graduations (400 gon), as well as for meter and yard distances had been manufactured.

Rudolf Rost jr. died at the end of 1951 and 24-year-old Peter Schlögl, nephew of Rudolf Rost jr. and grandson of the company founder, took over the management of the company and ensured the further distribution of the Coorapid. The company name, Rudolf & August Rost, disappears from the market on October 1, 2007. The R. & A. Vertriebs GmbH and R. & A. Produktions GmbH are merged into the Swedish company Hexagon AB.[31]

7. Market Penetration

The main sales regions of the company R. & A. Rost had been in Austria, Yugoslavia, Hungary and other Eastern European countries. Being a very specialized tool for a single application, the Coorapid was primarily used in surveying offices and authorities. Subsequently, the company R. & A. Rost advertised the Coorapid over several years, especially in Austrian and Swiss magazines. Advertisements of the Coorapid appeared in the Austrian journal for surveying until April 1961 (Figure 13).

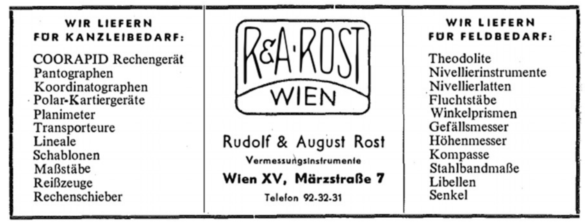

FIGURE 13. Advertisement by R. & A. Rost, April 1961.

Overseas the Coorapid was sold through dealers (see Figure 14). Currently it is not known whether or how successful the sales had been in the US markets. In addition to the above advertisements, specialist articles in German,[15,18] Swiss,[25,26] Polish,[32] and Czech[19] magazines, as well as in the widely read book "Marktscheidekunde"[20] by Schulte & Löhr, created awareness of the Coorapid.

FIGURE 14. Coorapid Advertisement in "Survey and Mapping", January-March 1954.

The successful delivery to German land consolidation offices (German: Flurbereinigungsämter), which had a very high need for coordinate transformations, led to further market success of the Coorapid.[29] Recent research confirms this statement from a user perspective.[30] For example, in the state of Baden-

Württemberg, Germany, before the data center of the State Office for Land Reconciliation and Development in Ludwigsburg was converted from Zuse computers to IBM computers, there was a decree that polar coordinate calculations should be carried out on the newly acquired Coorapid instead of centrally available Zuse Z11 computer systems. Unfortunately, the exact date of this decree is not yet known. Corresponding Coorapid machines were subsequently purchased and centrally used. So, the machines had not been distributed to the 24 surveying offices in the state of Baden-Württemberg. The introduction of the Coorapid required a multi-year training program to train employees and newly hired personnel to operate the machines in a reliable manner. Only later were the machines distributed to the surveying offices. The time when this happened is currently unknown.

Until the mid-1960s, surveying articles on the use of the Coorapid were reported. Afterwards the use of the device seems to decrease. In a small advertisement[21] of the magazine for surveying (from the year 1971) 13 well preserved Coorapid are offered for a price of 600 DM each. With this information, the end of production of the Coorapid can be estimated to the approximate period from the late 1960s to the early 1970s.

8. Existing Coorapids

The authors are aware of the following existing Coorapid machines with the serial numbers shown (when known) and locations.

Serial no.	Location / reference (centesimal degree)
12118	Ebay auction, 04.12.2011
12160	Dorotheum Online Auctions 17.05.2017[12]
12532	Deutsches Museum Munich (400 gon)
12772	Geodätisches Institut, Leibniz University of Hannover, Germany (Ref 14, page 91)
?	Archive R. & A. Rost
13263	Archive Förderkreis Vermessungstechnisches Museum e.V. Dortmund
13909	Norsk Kartmuseum Digital Museum,[23] (400 gon)
14921	Ebay auction 26.01.2020 (400 gon)
14942	Collection Zerfowski (400 gon)

The first four devices are from an early model series, which seems to be very similar to the first Coorapid (see Figure 1). This model series was manufactured until at least 1954, as a corresponding device was shown in an American advertisement (Figure 14). The other five known devices belong to a revised, newer model series. The newer models (Figure 5) differ from the older ones (Figure 1 and Figure 15) by the outer design. The most obvious difference is the additional top mounted lamp. This ensured uniform illumination of the frosted glass pane and thus significantly improved readability through the microscopes. In the manual,[28] probably from the late 1950s, three variants are mentioned:

- Nr. 610 Coorapid with single graduation (360° or 400 gon),
- Nr. 611 Coorapid with double graduation (360° and 400 gon),
- Nr. 612 with additional cold light lamp.

Any other existing technical differences may require further investigation.

Unfortunately, there are no manufacturing data related to the serial numbers and it cannot be estimated how many Coorapid were manufactured. Due to the value of the serial numbers and the fact that many of the other R. & A. Rost products have comparatively high serial numbers[2], it can be assumed that R. & A. Rost did not use separate serial numbers for the Coorapid, but continuously numbered different types of products.

9. Summary

In summary, the Coorapid can be considered as a miniaturized 2.5-meter, 22.6 kg heavy circular slide rule for transformation of polar to Cartesian coordinates. The device has a fixed cursor and rotating glass disc encapsulated within a heavy metal frame. The precisely engraved structures and the use of microscopes made the Coorapid a miniaturized huge circular slide rule. The very narrow market segment and area of application has led to Coorapid machines rarely appearing among collectors. Most of the surviving specimens are likely to be found in archives of geodetic university institutes and surveying authorities and, unfortunately, do not attract much attention.

The authors would be happy for any additional information about this interesting computing device and references to other existing machines.

FIGURE 15. Coorapid Serial No. 12532 (Source: Deutsches Museum, Munich, [1988-0414_T001_2013.12.16_003_D0005_ND_JD]).

10. Note of Thanks

We would like to thank Mrs. Dr. Michaela Schlögl (great-granddaughter of the company founder Rudolf Rost Sr. and daughter of Peter Schlögl), Mr. Jürgen Weber (a former user of the Coorapid), Ms. Katja Rasch, and for kindly supporting and providing information material on the Coorapid, Ms. Krutsch (German Museum Munich, in particular for the rights to use the photos), Professor Tegeler (who volunteers for the collection of the Geodetic Institute of the University of Hanover), and Nico Schulze (member of the club of office machine calculators "Internationales Forum Historische Bürowelt e.V., IFHB, https://www.ifhb.de), who made us aware of the Coorapid).

Notes. All Internet links tested and working as of 20 Feb 2020. Some sources listed below are not referenced in the text, but they are included here for bibliographic completeness.

1. In surveying typically, centesimal degrees (400 gon) are used instead of degrees (360°).
2. Based on internet research by the authors.
3. Abb, Wilhelm, *Die Beschleunigung des vermessungstechnischen Verfahrens der Flurbereinigung in Bayern*, Dissertation, Technische Hochschule München, Fakultät für Bauwesen, 23. März 1956. Auch veröffentlich als Bayerisches landwirtschaftliches Jahrbuch: Sonderheft 3, 1956.
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6. Bohrn, Hugo and Avanzini, Leander, *Verfahren und Vorrichtung zur Bestimmung der rechtwinkeligen Koordinaten von Geländepunkten, insbesondere von Polygonzügen und dergl*., January 28, 1938, Linz, Swiss patent 208012. Application date 28.01.1938. Patent granted 31.12.1939. Published 16.03.1940, 6 pages, 6 figures.
7. Avanzini, Leander and Bohrn, Hugo, *Apparatus for Transforming Polar into Rectangular Coordinates*, January 28, 1938, Linz, Austria, British patent 512661. Application date 28.01.1938. Serial number 2830/38. Complete specification accepted 22.09.1939, 3 pages, 3 figures.
8. Bohrn, Hugo and Avanzini, Leander, *Means for Determining Coordinates*, January 28, 1938, Linz, Austria, U.S. patent 2198757. Application date 28.01.1938. Patent granted 30.09.1940, 3 pages, 3 figures.
9. Avanzini, Leander and Bohrn, Hugo, *Procédé et dispositif pour déterminer les coordonnées orthogonales de points de terrain, notamment de chaînes de polygones, etc.,* January 29, 1938, Austria, French patent 832780. Application date 29.01.1938. Patent granted 04.07.1938. Published 03.10.1938, 8 pages, 10 figures.
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12. Dorotheum Online Auctions, "*Seltene Koordinaten Rechenmaschine COORAPID Patent Bohrn Avanzini*", Lot No. 139-060259/0001 on 17.05.2017. https://www.dorotheum.com/de/l/843728/
13. Grabner, Klodwig, *Der Coorapid*, Vermessungstechnische Rundschau, No. 12, 1953.
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17. Jordan, W., *Zur Polygonberechnungen mit der Rechenmaschine*, Zeitschrift für Vermessungswesen, Vol. 27, No 12 June, 1898, pages 343. Note: Supplement to Ref. 16.
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