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Video image analysis of coral reefs in Saudi Arabia: a comparison of methods

Video-Bildanalyse an Korallenriffen in Saudi Arabien: ein Methodenvergleich

by

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Abstract

A video system for quantitative analysis of coral reef communities was employed for counts, length measurements and area calculations of corals and other reef species. At Karan Island three transect lines of 50 m were placed on the reef at 2, 4, and 6 m water depth and recorded by a SCUBA diver with a S-VHS-C camera in an underwater housing. For comparison reasons all transects were also recorded in situ with the line intercept transect (LIT) - method. In Manifa Bay the video system was employed for counts and measurements of the diameters of the sea urchin *Echinometra mathaei*.

In order to assess the accuracy of area calculations, the areas of coral skeletons were measured on a digitizing board. The corals were then placed on an even sea floor and recorded with the video camera and a stereophoto apparatus. Area calculations were also performed on the same set of images used for the counts and length measurements.

For image processing a Macintosh IIsi computer with an installed frame grabber card was employed. Image analysis was conducted by the use of the NIH Image programme. In order to scale the video images quadrats, marks on the lines and laser beamers were applied.

A chi-square test for homogeneity of the pooled data accepts the null hypothesis that no difference exists between the transect method and the video methods in the number of species counted. A comparison of the length measurements of the reef species indicated little difference between the two methods. The area calculations of coral skeletons based on video images proved to be acceptable in comparison to both the results of the outlining on the digitizing board as well as to photogrammetry. A comparison between the results of area calculations based on video images scaled by laser beamers and by marked lines, indicated large differences in the absolute figures but little variation of the percentages.

The main difference, however, is the time factor. The use of video images saves considerable amounts of expensive underwater working time. Nevertheless a substantial amount of time is needed during image analysis. Further advantages and disadvantages of the video system, as well as its future use are discussed in detail.

This study is a result of a larger programme which used video recordings to assess the health situation of coral reefs after the Gulf War. The more comprehensive findings of this programme are reported elsewhere (VOGT, 1994).

Zusammenfassung

Ein Videosystem zur quantitativen Analyse von Korallenriffgemeinschaften wurde für Zählungen, Längenmessungen und Flächenberechnungen von Korallen und anderen Riffarten eingesetzt. In einem Riff nahe der Insel Karan wurden drei 50 m lange Transektleinen in 2, 4 und 6 m Wassertiefe ausgelegt und von einem Taucher mittels einer S-VHS-C Videokamera in einem Unterwassergehäuse gefilmt. Zu Vergleichszwecken wurden alle Transekte ebenfalls in situ mit der Transektmethode (LIT) aufgenommen. In Manifa Bay wurde das Videosystem zu Zählungen und zur Berechnung von Durchmessern des Seeigels *Echinometra mathaei* eingesetzt.

Um die Genauigkeit von Flächenmessungen abschätzen zu können, wurden zunächst die Flächen von Korallenskeletten auf einem Digitalisierbrett ermittelt. Die Korallen wurden dann auf ebenen Meeresgrund ausgelegt und sowohl mit der Videokamera, als auch mit Stereophotokameras aufgenommen. Darüberhinaus wurden Flächenberechnungen von Korallen an dem gleichen Bildmaterial durchgeführt, das auch für die Zählungen und Längenmessungen verwendet wurde.

Die Verarbeitung der Videobilder wurde mittels eines Macintosh IIsi Computers mit installierter Digitalisierkarte und dem Bildanalyseprogramm NIH Image durchgeführt. Zur Skalierung der Videobilder dienten Quadrate, Mar-

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kierungen auf den Transektleinen, sowie Laserstrahler. Ein Chi-Quadrat Test zur Homogenität akzeptierte die Nullhypothese, daß kein Unterschied besteht zwischen den Zählungen mittels Transektmethode und Videobildanalyse. Der Vergleich der Längenmessungen von Riffarten erbrachte ebenfalls nur geringe Unterschiede zwischen den beiden Methoden. Die Ergebnisse der Flächenberechnungen von Korallenskeletten ergaben im Vergleich zu den Ergebnissen des Digitalisierbrett-Verfahrens und der photogrammetrischen Auswertung gute Übereinstimmungen. Ein Vergleich der zur Skalierung verwendeten markierten Leinen bzw. Laserstrahlen ergab drastische Unterschiede in den absoluten Werten, aber sehr geringe Unterschiede in den prozentualen Anteilen.
Trotz geringer Unterschiede in den Ergebnissen bestehen gravierende Unterschiede in den Zeitaufwendungen. Das Videosystem ermöglicht erhebliche Einsparung von teurer Unterwasserarbeitszeit, erfordert allerdings viel Zeit für die Bildanalyse. Weitere Vor- und Nachteile des Videosystems sowie dessen zukünftige Einsatzmöglichkeiten werden diskutiert.
Diese Untersuchungen wurden im Rahmen eines umfangreicheren Programmes zur Evaluierung der Auswirkungen des Golfkrieges auf die Korallenriffe durchgeführt. Über die umfassenderen Ergebnisse dieses Programmes wird an anderer Stelle berichtet (VOGT, 1994).

1. Introduction

In order to study changes in coral reefs accurate measurements of important biological factors like e.g. coral cover are essential. For this purpose various labour and time intensive methods using transect lines (e.g. LOYA, 1978; ROSS & HODGSON, 1981; SY et al., 1981) and quadrats (e.g. SCHEER, 1974, 1978; GOMEZ et al., 1981; MERGNER & SCHUHMACHER, 1974; SCHUHMACHER & MERGNER, 1985) are currently in use. All these methods require that the measuring of corals is conducted in situ. DONE et al. (unpublished 1989) were the first to use video recordings for a survey in a coral reef area. In their study the video tapes were stopped and the species in the middle of the screen were scored. Since then video recordings have contributed to the monitoring of threatened reefs on Hawaii (HUNTER & STEPHENSON, 1991). Information about video technology, including the use of video for quantitative surveys, image analysis using computers and time lapse video were provided by MANEY et al. (1990). Estimations on coral cover based on video images were compared with traditional methods by UYCHIAOCO et al. (1992).
So far the use of video in coral reef studies has been limited to the counting of specimens and estimation of coral cover. This study demonstrates and introduces the calculation of coral areas and the measuring of distances using digital image processing. Most of the fieldwork for this investigation was conducted in the framework of the 'Establishment of a Marine Habitat and Wildlife Sanctuary for the Gulf Region'-project. The major findings, including the analysis of more than 1500 video images, are reported elsewhere (VOGT, in prep.). This presentation focuses on the methodological aspects of the video method and provides comparisons to currently used recording techniques.

2. Material and Methods

Areas and times of investigations

Most fieldwork was conducted at three parallel transect lines of 50 m at Karan Island in Saudi Arabia during June 1993 (Fig. 1). However, the data of the sea urchin counts derive from fieldwork conducted in Manifa Bay, Saudi Arabia, during August 1991 (Fig. 1). The comparison study between the areas of corals obtained with a digitizing board, the video method and stereophotography was conducted at the Australian Institute of Marine Science during August 1990.

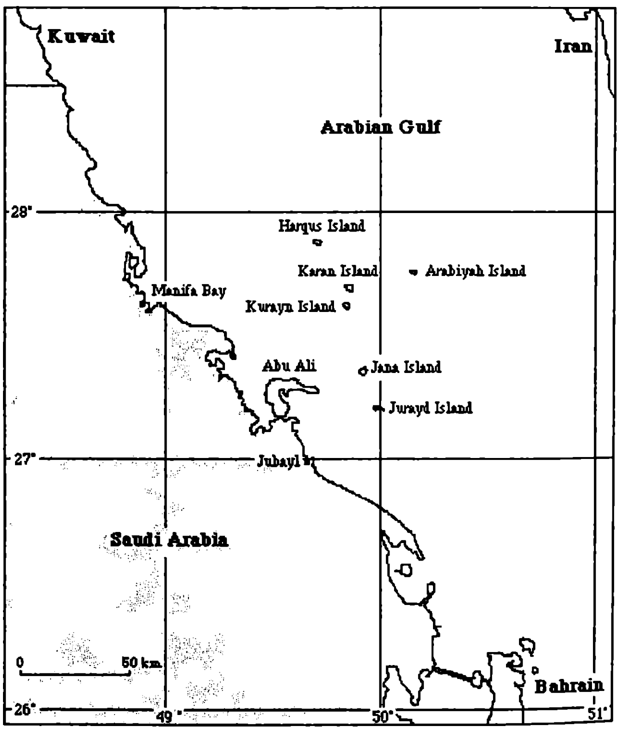

Figure 1: Important Saudi Arabian islands with surrounding coral reefs.

The video recording and image analysis system

Most of the video recordings were obtained by using the Super-VHS-system which provides visibly superior image quality to the ordinary VHS-system and allows copies to be made without noticeable quality loss. A Panasonic S-VHS-C camera in an underwater housing (mb sub, Ingenieurgesellschaft für Unterwassertechnik mbH, Xantenerstr. 105, 5000 Köln 60, Germany) was employed for all fieldwork in Saudi Arabia; in Australia a VHS-system was used.

The recording distance was approximatly 0.5 m for all fieldwork in Saudia Arabia and 1 m in Australia.
The analysis of the video images was conducted by the use of a Macintosh IIsi computer with an installed 'Screen Machine™' frame grabber card. The public domain software 'NIH Image' (LENNARD, 1990) was employed for image processing and analysis. All measurements were exported for data processing to the programme 'Ms Excel' The video images were temporarily stored on the computer as black and white pictures. Parallel to the computer images colour pictures were available from a S-VHS video recorder and a TV-monitor.

Scaling the images

Marked lines or quadrats with defined areas were placed on the reef to supply scales. In order to position a maximum number of quadrats in a minimum amount of time, a 'ladder' like structure was employed. It consisted of aluminium bars stretched between two cords which provided quadrats with two flexible and two solid sites. For easy underwater handling these quadrats could be rolled upon a plastic tube. The 'ladder' consisted of 20 squares with each covering an area of 50 x 50 cm. This 'ladder' is a modified version of a similar structure used by DONE (pers. comm.). Although its use allowed the comparatively fast positioning of defined areas, considerable amount of time was still spent on placing the scales. Therefore in a first trial, it was attempted to project a known distance onto the reef. For this purpose laser light was used because laser beams travel in parallel lines. Therefore it can be expected that the distance between two projected points is always the same. For this study two low cost laser pointers projected red dots of 0.5 cm in diameter. Both laser beamers were fitted in two separate underwater housings (Gesellschaft für Telemetriesysteme, Wulfsbrook 36, 2300 Kiel, Germany) which were attached parallel to each other in the closest possible distance. The laser beamers were joined to the video housing in a way which allowed adjusting underwater.

The video method used for counts and length measurements

The video method was employed to count the number of the sea urchin *Echinometra mathaei* observed in Manifa Bay. For this purpose the 'ladder' was twice unrolled on the reef and filmed. During image analysis the specimens of *Echinometra mathaei* inside of 40 squares were counted and their diameters measured. The aluminium bars served to scale the images. It was assumed that the sea urchins inside and outside the quadrats were of the same size. Video recordings without scales were taken in the surrounding parts of the reef. From this video tape 20 images were stored randomly. The average diameter obtained from the measurements inside the quadrats was then used to scale these images.
At Karan three 50 m long transect lines marked in distances of 10 cm were placed on the 2, 4 and 6 m depth contour line. The coral cover underneath the lines were analysed for a comparison between the results of the traditional LIT-method, the video analyses using marked lines and video recordings with laser beamers. The LIT-method (LOYA, 1978) was employed to measure the intercepts of all species underneath the 3 transect lines in a total length of 150 m. All three transects were recorded with the video system in full length. The tapes were then stopped 150 times at regular intervals and the images analysed in two different ways. Firstly the lengths of all species intercepting the transect lines were measured using the marks on the transect lines to scale the images. Secondly the same set of images was also analysed by identifying the species between the laser dots. The distance between the dots was constant therefore measuring was only required if two species occurred.

Video used for area measurements

In August 1990 an assessment of the accuracy of area calculations based on video images was conducted. In a comparison study the areas of 19 coral skeletons of different size, shape and species were measured by outlining the corals on a digitizing board. At John Brewer Reef (Great Barrier Reef) the corals were placed on an even sea floor inside of rectangles with a known dimension. Each colony was positioned in 4 different locations inside rectangles in varying combinations with other corals. The corals were then recorded by both a VHS-video system and stereophotography (DONE, 1981). The corals on the video images were outlined by using the 'NIH Image' programme. The areas of the corals were computed by using the known size of the rectangles as reference areas. The stereophotos were analysed at the Australian Institute of Marine Science following the method described by DONE (1981).
The 150 images taken at Karan were also used to calculate the coral areas. All species and substrate types visible on each image were outlined and their areas computed. The images were initially scaled by using the 10 cm marks on the transect lines and then scaled again by applying the distance projected by the laser beamers.

3. Results

Counts and length measurements

Within 40 quadrats of each 50 x 50 cm 343 specimen of *Echinometra mathaei* were counted inside an area of 10 m^2. The average diameter of the sea urchins was 4.7 cm. The amount of time spent on placing and recording the quadrats was about approximately 15 min for two divers. Counting the sea urchins at the TV-monitor took about another 15 min.
In the second part of the exercise video recordings were obtained without scaling bars. For these images the sea urchins served as scaling bars and were used to calculate

Species and substrate types	Line transect no	%	Video, marked lines no	%	Video, laser scaling no	%	Total no	Chi-square	DF	Inference
Acropora spp.	28	19	24	16	24	16	76	0.42	2	accept
Montipora spp.	5	3	4	3	6	4	15	0.40	2	accept
Pocillopora damicornis	0	0	1	1	2	1	3	2.00	2	#accept
Porites spp.	3	2	1	1	2	1	6	1.00	2	#accept
Platygyra daedalea	4	3	1	1	1	1	6	3.00	2	#accept
Lythophyllum kotschyanum	42	28	36	24	38	25	116	0.48	2	accept
coral rock	37	25	44	29	41	27	122	0.61	2	accept
rubble	25	17	33	22	29	19	87	1.10	2	accept
sand	6	4	6	4	7	5	19	0.11	2	accept
Total	150	100	150	100	150	100	450	9.12	16	

critical value = chi-square c = 5.991 (v = 2, alpha = 0.05); #accept = Please note, that if fi-values are very small, then there is a tendency to reject the null hypothesis because the calculated chi-square value is larger than the theoretical chi-square value (ZAR, 1984). However, in these examples the null hypotheses were accepted.

Table 1: Comparison between the counts of species recorded with the line transect method and video recordings using marks on the lines and laser dots for scaling.

the reference area. In this manner 302 sea urchins were counted outside the quadrats within an area of 8.4 m^2 with an average density of 36 specimens m^{-2}. The time needed was about 5 min solely spent on recording by one diver. About 1.5 hours was spent on the analysis of the 30 video images.

The results of the comparison between the traditional LIT-method and the approaches using video image analysis are presented in Tab. 1. The number of the corals were compared as well as the length measurements. In order to achieve an equal sample size of 150 counts, only about every second count of the line transect method was included. From the two ways of video image analysis only the largest distance was counted. The distance between the laser dots was 4.6 cm therefore two species occurred in only 2 % of 150 images.

The counts obtained with the three methods were compared individually for each species and substrate type using separate chi-square tests. The chi-square test for homogeneity of the pooled data (ZAR, 1984) accepts the null hypothesis that no difference exists between the three methods in the number of species counted ($x^2 = 9.12$, $P > 0.05$, DF 16).

The absolute figures of the length measurements are difficult to compare (Tab. 2) because of varying sample sizes. However, the percentages indicate little variation between the different recording methods. The maximum difference for the coral and algae species varied between 0–5 %. Larger differences were observed between the percentages of coral rock and rubble with 11 and 9 % respectively (Tab. 2).

The amount of time spent underwater using the LIT-method was about 4–4.5 h for the 3 transects. 2 hours were then spent transferring the data from the underwater writing sheets to a notebook and then to a computer. The recording with the video camera took between 45–60 min. and image analysis required about 8–9 h regardless of the type of scaling used.

Area calculations

The results of the comparison of corals outlined on a digitizing board and then recorded on the sea floor by stereophotography and video recordings are presented in Tab. 3. The results obtained with the digitizing board are regarded to be the most accurate ones and were therefore used to assess the accuracy of the other two methods. The

Species and substrate types	Line transect [cm]	%	Video, marked lines [cm]	%	Video, laser scaling [cm]	%	max. difference %
Acropora spp.	2377	16	522	14	110	17	3
Montipora spp.	472	3	83	2	27	4	2
Pocillopora damicornis	0	0	10	0	9	1	1
Porites spp.	198	1	34	1	9	1	0
Platygyra daedalea	111	1	30	1	5	1	0
Psammocora contigua	115	1	0	0	0	0	1
Tubastrea aurea	2	0	0	0	0	0	0
Lithophyllum kotschyanum	4029	27	1084	29	163	24	5
coral rock	3006	20	1164	31	178	27	11
rubble	4189	28	722	19	133	20	9
sand	501	3	94	3	31	5	2
Total	15000	100	3743	100	665	100	

Table 2: Comparison between the length measurements of species recorded with the line transect method and video recordings using marks on the lines and laser dots for scaling.

coral no.		1	2	3	4	5	6	7	8	9	10
digitized area	[cm²]	71	100	109	111	117	121	128	134	141	147
stereophotos, difference	[%]	–11	–2	18	–1	24	16	18	5	2	–6
video, difference	[%]	–6	–8	3	–7	12	–4	10	–16	–12	–16
coral no.		11	12	13	14	15	16	17	18	19	average
digitized area	[cm²]	177	186	216	235	263	350	382	417	848	224
stereophotos, difference	[%]	–1	–9	19	4	17	–7	2	–9	14	5
video, difference	[%]	1	–21	10	–10	–8	–18	–1	–7	22	–1

Table 3: Comparison of areas of coral skeletons obtained by outlining on a digitizing board and by analysis of video images and stereophotography. All area calculations are average values with n = 4.

average figure for all 19 corals using video analysis was 0.6 % below and for stereophotography 5.2 % above the average figure for digitized areas.

The area measurements of corals at 2, 4 and 6 m water depth are provided in Tab. 4. The figures suggest that using lasers as scales results in considerably higher area values compared to the figures obtained by using the marked lines. This result can be explained by the fact that the laser beamers also project the dots into crevices which cannot be reached by the transect line. However, it does not follow that the laser approach is more accurate because the corals may occur in all levels which includes being above or below the projected laser dots and the transect line. Nevertheless, with some caution it may be followed that using transect lines as scales leads to underestimated figures, whereas the opposite can be the case when lasers are used. However, the percentages for both ways of scaling provide very similar results.

4. Discussion and Conclusions

Comparison with traditional method (LIT)

In this investigation the frequently used LIT-method was compared to a new method using video image analysis. The findings in respect to counts of species and length measurements indicate similar results. The comparison of corals with 'known' areas and calculation based on video images and stereophotos suggest that both methods provide acceptable results. However, it is important to note that the corals were recorded on an even seafloor. As the study on scales indicated, the positioning of scales in relation to the objects is of vital importance. In a reef situation the scales obtained from lines or bars will frequently lie above the corals causing underestimation of the specimens underneath the scales. Stereophotography can compensate these short comings by applying the principles of photogrammetry. The video method still lacks this option, but a comparable approach using only one video camera but pairs of video images is in preparation by the author.

UYCHIAOCO et al. (1992) compared estimations of coral cover based on video recordings with the line transect method and in situ mapping on plastic slates. The video estimations proved to be very efficient and provided a good documentation of the area but required special equipment and some familiarity with the site for accurate identification. The line transect method was found to be very simple to use and moderately time efficient but the least accurate method. In situ mapping yielded slightly better results with a permanent record, but was very time-consuming.

The prospects for video image analysis

Coral cover of the transects areas was recorded in a width of 50 cm. Species cover was calculated and colour coded maps of all transect were drawn (VOGT, 1994). The results of the study proved to be reproducible and indicated only very limited change within the range of the recordings inaccuracies.

Water depth	2 m				4 m				6 m				Total			
Species and	transect		laser		transect		laser		transect		laser		transect		laser	
bare substrate	[cm²]	%	[cm²]	%	[cm²]	%	[cm²]	%	[cm²]	%	[cm²]	%	[cm²]	%	[cm²]	%
Acropora spp.	471	1	800	1	4175	11	5201	9	10210	39	19848	38	14856	17	25849	16
Montipora spp.	0	0	0	0	482	1	1015	2	531	1	734	0	1013	1	1748	1
Pocillopora damicornis	121	1	720	1	3016	8	3841	7	171	2	249	1	3308	3	4809	3
Porites spp.	257	0	290	0	323	1	547	1	0	0	0	0	580	0	837	0
Platygyra daedalea	0	0	0	0	1138	3	1290	2	289	1	1923	4	1427	1	3213	2
Favites sp.	0	0	0	0	98	0	174	0	0	0	0	0	98	0	174	0
Tubastrea aurea	0	0	0	0	0	0	0	0	0	0	32	0	0	0	32	0
Lithophyllum kotschyanum	31140	72	43621	71	9112	23	11425	20	1587	6	2296	4	41839	34	57342	32
coral rock	9350	22	13029	21	13011	33	19507	34	3124	12	5738	11	25484	22	38274	22
rubble	0	0	0	0	8198	21	15071	26	8870	34	18788	36	17068	18	33858	20
sand	1901	4	2766	5	39	0	91	0	1123	4	3262	6	3064	3	6119	4
Total	43240	100	61225	100	39592	100	58161	100	25906	100	52870	100	108738	100	172256	100

Table 4: Comparison of coral area obtained by the video method using marks on the transect line and laser projected dots as scales.

Future improvements of the video method are planned especially as the quality of the laser beamers is concerned. In the strong sunlight of the very shallow waters the dots projected by the standard laser pointer were not always visible. Therefore either more powerful laser beamers or more costly lasers operating in the blue light spectrum will be used in future. The use of lasers to project dots suitable for scaling shows great potential because no time is lost on placing reference bars onto the reef. Therefore this approach is ideal in the sense that constant recording is possible. Since the distance between the dots is constant, the analysis process may be reduced to only identifying and counting the species. After the counting is completed the total length of all specimens of each species can be calculated easily. Very rarely do two corals occur between the dots if the distance is small. In these cases the images may either not be included or the visibly larger species may be counted. Overall an approach including lasers has the advantages of being extremely fast and also comparably cheap because the costs for an image analysis system are saved.

Further simple improvement of the video system can be made by attaching a depth gauge to the housing in a way that the water depth is constantly displayed. In cases where the total recorded distance is of importance a flowmeter may be connected to the camera housing. MINGOA & MENEZ (1988) used a flowmeter for *Tridacna* counts. A comparison with the numbers counted along a line transect provided encouraging results. Future studies may use a combination of lasers, depth gauge and flowmeter. Video recordings could than be obtained on a chosen water depth for a selected distance without any time lost on placing scaling bars or measuring distances.

Advantages and disadvantages of the video method

One of the major advantages of the video system is the large amounts of images stored. Up to 700 different images could be recorded on an 45 min. tape in high quality mode if the diver swam at an average speed of about 0.3 m/sec. Video tapes of 2 h length are available with the comparable Hi 8 system.

Due to the large number of images the video system is extremely time efficient. UYCHIAOCO et al. (1992) found that within one hour spent underwater a video system can record 300 m^2, whereas in situ mapping covers only 10 m^2 and the line transect method records 40 m in length (or 0.4 m^2, if the line is assumed to have a width of 1 cm). Although the video method saves expensive underwater time, it requires large amounts of time for video image analysis.

Video image analysis always involves taxonomic identifications. Since the difficult field of coral taxonomy sometimes requires coral skeletons for definite species identification, neither photos nor video images may always be sufficient. However, many studies do not necessarily require all specimens to be identified to species level. For both, photos and video images the recording distance to the objects is of vital importance for any identification. Therefore one has to choose between large areas with reduced capabilities of species identification or a rather small area which allows close up pictures with good chances of identification. The decision will strongly depend on the research question and will be made on a case to case basis. In comparison to a photo film, video tapes provide far larger number of images but require a VCR and a TV-monitor to be viewed. The most significant disadvantage is still the poor quality of hard copies. Although costly video printers are available, the print out quality is far below the ones of photos.

Another disadvantage are the high cost especially if a digital image analysis system is purchased. However, the video system saves expensive diving time and if often used, it may pay off in the long-term. The use of an electrical system automatically causes the risk of technical failure as well as the dependency on electricity. Compared to the use of a simple line and measure tape, a complete video set is fragile, heavy to carry and may become a nuisance if it has to be used in countries with strict import regulations. The use of video also requires a period of training before the first useful pictures are obtained.

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