Object Tracking and Classification in Weather Radar Images. Case Study: Tracking Birds

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Weather radars have been used for weather forecast for many years. Most of their applications focus on weather forecast. It is assumed that all relevant echoes in images are related to precipitation. New weather radars have also mode of clear air. In this mode, radars aim at detecting other echoes in the atmosphere and use them for evaluation of velocity and direction of wind.

Beside clouds, weather radars detect also other "air targets", such as dust, insects, birds, bats and aircrafts. When the radar works in the precipitation mode, it eliminates most of the other echoes by integrating the received echoes over a large area. As a result, only large flocks of birds might remain after this filtering.

The work suggests a new algorithm for classifying echoes in weather radar images. The algorithm works in two steps; (a) Single Scan Classification (SSC) and (b) Track Based Classification (TBC). At the first step, all objects are labeled and a feature vectors is built for each one. Then a feature vector based classification is applied according to a known parameters found from a bird training set. The second step adds the time dimension to the filtering process, and carries out the classification according to the object movement trajectory.

A block diagram of the algorithm shown in fig. 1:

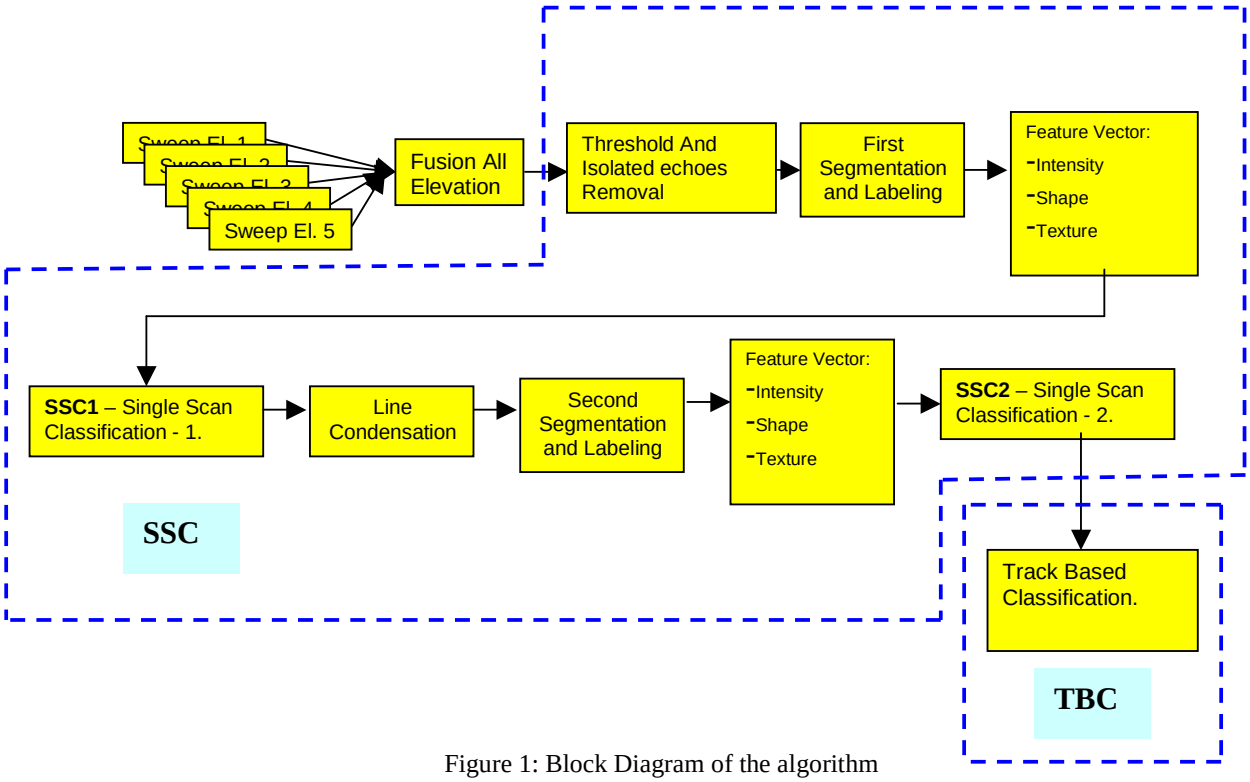

Figure 1: Block Diagram of the algorithm

The algorithm begins with fusion of the radar scans of five 2-D PPI (Plan Position Indicator) different elevations images. SSC stage includes several sub-stages: Thresholding for removal isolated echoes, first segmentation and labeling, building a feature vector for each object, first classification (SSC1), line condensation, second segmentation and labeling, building feature vector and final classification (SSC2).

Figure 2 shows an example for 2-D PPI image, and Table 1 shows the feature vectors calculated out of this image:

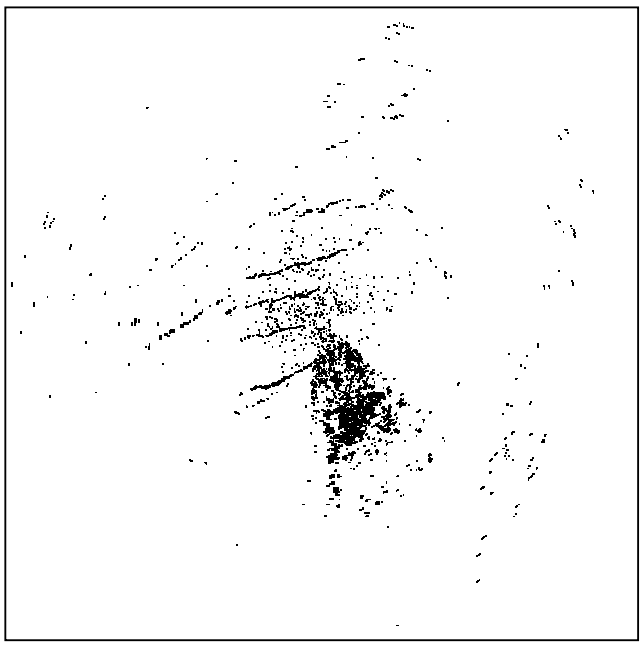

Figure 2: 2-D PPI image of weather radar

Table 1: Example of feature vectors calculated from the above image

Echo No.	X	Y	Surface	Av. Power	Mx. Power	El. Rot.	MainRad	SubRad	Nodes	Complex
1	60.40	408.25	1248	22.69	102	1.23	4.81	1.32	8	1
3	126.18	322.91	1482	35.29	84	-0.80	4.22	1.66	8	1
4	156.87	300.92	5167	8.61	89	-0.95	16.45	1.72	9	2
5	172.67	268.80	857	21.43	87	-1.36	5.06	0.94	8	1
6	215.63	355.44	4033	11.69	78	-0.99	12.53	1.73	8	1
7	232.08	462.83	994	33.13	145	0.88	4.01	0.95	8	1
9	245.57	223.29	348	29.00	72	-0.54	2.01	1.11	8	1
10	260.24	475.12	1042	41.68	97	0.89	2.99	1.81	8	1
11	293.89	312.58	25009	4.55	102	-1.30	30.25	4.26	20	7
12	274.10	402.80	1416	39.33	105	0.73	3.49	1.83	8	1
22	312.86	326.71	332	27.67	69	1.25	2.04	1.09	8	1
23	322.32	354.26	14620	17.33	83	-1.19	14.72	5.93	15	5
24	319.00	268.50	439	36.58	74	-0.88	2.62	0.73	8	1
25	323.50	387.50	344	43.00	74	-0.32	2.16	0.88	8	1
26	340.42	351.62	22642	13.23	93	-0.96	20.64	4.15	9	2
27	328.52	231.90	1221	16.96	91	-0.87	5.39	1.24	8	1

The parameters included in the feature vectors include:

- **Area** – The area of the echo n is the number of pixels in the echo.
- **XY Location** - The centroid coordinates $\overline{X}^{[L]}$ and $\overline{Y}^{[L]}$ of the echo.
- **Main and Sub Radii** of an approximated ellipse calculated for the echo.
- **Echo orientation** – The orientation of the approximated ellipse.

Fig. 3 demonstrates the approximated ellipse attached to the echo:

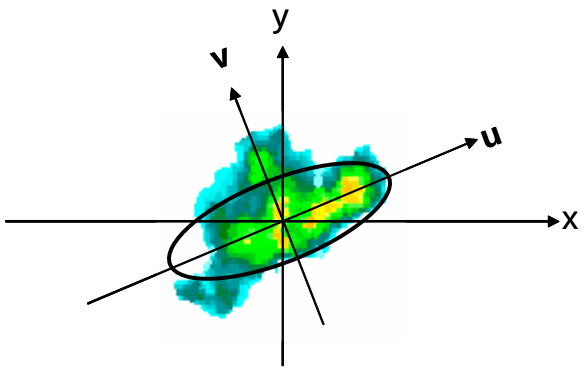

Figure 3: Approximated ellipse calculated for the echo

- **Average/Maximal Power.** Average and Maximal power of each echo are defined as.
- **Tree Complex & Tree Nodes** parameters describe texture of the echo by the number of maxima in it (Complex) and the number of reflectivity levels in the echo (Nodes).

The feature vectors are filtered according parameters which were calculated according a training set. In this work the setting is done for migrating bird echoes, but with appropriate training set the filter can be adjusted for any echo type.

At the second stage, TBC, objects are classified by applying radar tracking technique, the Kalman filter. SSC allows us to make classification only for objects that occupy a large fraction of the image, and therefore form a figure of substantial area to allow calculation its reflectivity, shape and texture parameters. Many bird echoes occupy too small area, and the SSC stage cannot classify them. For classification of those smaller echoes the movement parameters are essential. To find them, a tracker is used. The tracking is made according to the echo location, which is the ellipse center in the echo feature vector.

Table 2 shows example of tracked flocks:

Table 2: Tracks Examples

Track No.	Start Time	Start Location	End Location	Duration	High Quality
10	10:10:07	(154.72,123.79)	(156.46,55.50)	39 min.	7
15	10:10:07	(196.93,219.79)	(252.65,-117.22)	81 min.	7
20	10:10:07	(227.5,177.33)	(208.13,230.82)	48 min.	7
23	10:10:07	(254.95,178.92)	(206.91,-38.78)	71 min.	7
28	10:13:07	(129.13,230.25)	(254.41,-30.27)	66 min.	7
35	10:16:07	(100.32,203.20)	(255.82,38.11)	96 min. *	7
38	10:16:07	(243.30,97.88)	(238.87,117.56)	96 min. *	7
60	10:28:17	(158.35,199.65)	(262.65,31.30)	72 min.	7
74	10:34:16	(185.00,136.75)	(198.81,93.35)	78 min.	7

* The track life is continuing beyond that duration, but the test ended.

The following frames shows example of tracking flocks:

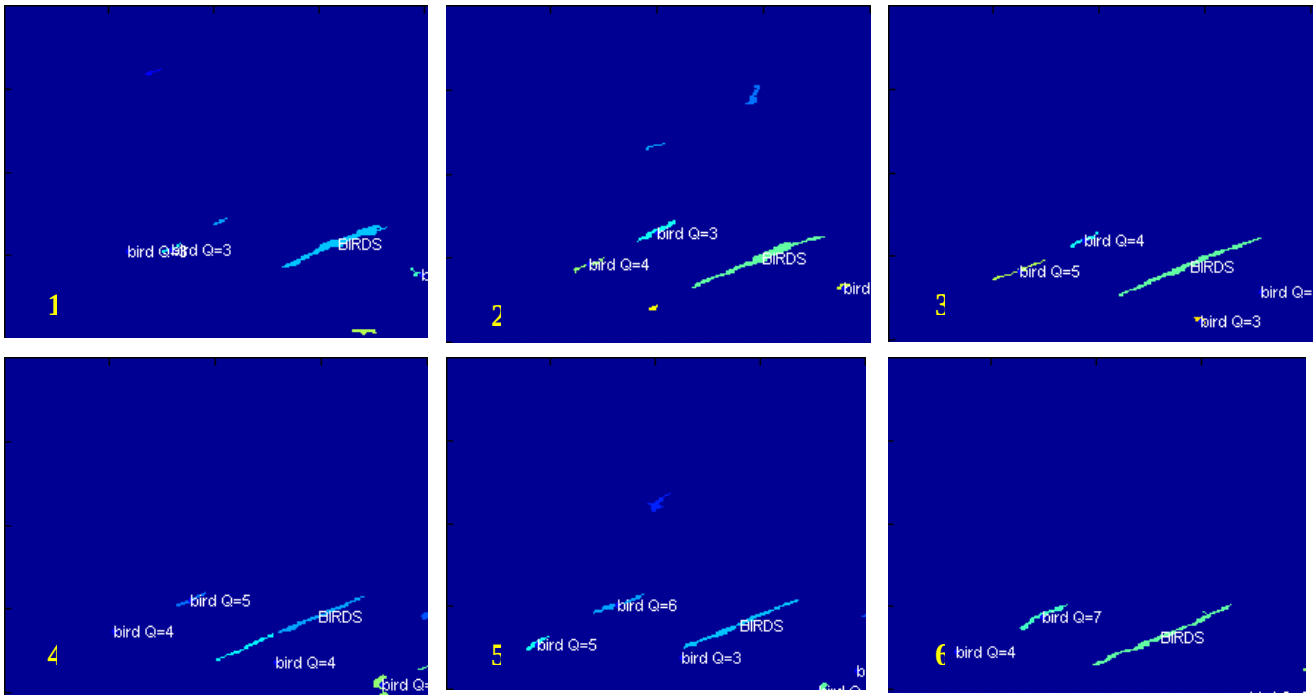

Figure 4: 6 frames showing tracked flocks in the radar images

The results show that the usage of two stage classification – SSC and TBC – secures high probability of detection and low false alarms. This case study is focused on birds, but the technique can be used to classify and track other objects with parameters adaptation.