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WSR-88D PRODUCTS AND STANDARD DATA STRUCTURES

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1.0 INTRODUCTION

The WSR-88D Open Radar Product Generator (ORPG) includes a system architecture that has already provided an opportunity to increase the pace of technology infusion and the deployment of new algorithms into the operational weather radar. The first operational ORPG was deployed in 2001. A second major ORPG software release (Build 2) was deployed later last year with future releases planned to occur approximately every six months.

The WSR-88D Common Operations and Development Environment (CODE) has enabled teams of developers at NWS Systems Engineering Center, NWS Office of Hydrologic Development, and MIT/Lincoln Laboratory to participate in the "production development" of new algorithms. Algorithms completing production development already use the native systems services of the WSR-88D ORPG (the algorithm API) and have undergone initial testing on the system. This expanded participation in the development of production algorithms has helped increase the pace of new science development and employment for the WSR-88D.

2.0 CONCERNS ARISING FROM NEW RAPID TECHNOLOGY INFUSION

During the past year more than half a dozen new products have been added to the WSR-88D (Istok, 2003). WSR-88D products include defined data packet types that are used to encode product data. These packets represent character data, special symbols for display, and geographical arrays of meteorological data. Algorithms added for Builds 2 and 3 have already exceeded the capabilities of existing data packet types. As a result, one new data packet type has been defined and the use of other data types modified. The general concern is the ability of WSR-88D product users to adapt to this rapid change. A system that receives the product must be able to read or decode the data whether for display for a forecaster or for use as input data into another system for further processing. This paper introduces two topics:

1) The development of formal rules for use of existing data packet types in order to support standard product decoders that only need minor configuration to support new products.

2) The definition of a set of data types that have the flexibility to support a wide range of new products.

The goal is to avoid a rapid increase in the number of defined data packet types, each needing a new decoding module and to avoid changing the way a defined packet is used which requires a change in existing decoding software.

The scope of this discussion is limited to rules for use of existing data types and in defining additional useful data packet types within the current WSR-88D product structure. Technologies exist for partially self-describing array data formats such as netCDF by the Unidata program at the University Corporation for Atmospheric Research (UCAR) and the Hierarchical Data Format (HDF) by the National Center of

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Supercomputing Applications (NCSA). Abstract Syntax Notation number One (ASN.1) is an international standard for encoding data for telecommunications. We have not concerned ourselves with the broader topic of possibly changing the nature of WSR-88D products that might involve these technologies.

3.0 WSR-88D PRODUCT STRUCTURE

A review of WSR-88D product format and terminology will aid in understanding the issue (NWS Radar Operations Center, 2002). First, a product is composed of several defined blocks. All graphical products include two major header sections. The *Message Header Block* (MHB) provides information about the transmitted message: source (radar site) and destination of the product message, the date & time of transmission, and message size. The *Product Description Block* (PDB) contains information concerning the radar that produced the product (location, height, operating state, etc.) and the product-specific header information. A third block common to all graphical products (whether for display or data arrays) is the *Symbology Block*. The *Symbology Block* contains the actual product data in the form of defined data packet types.

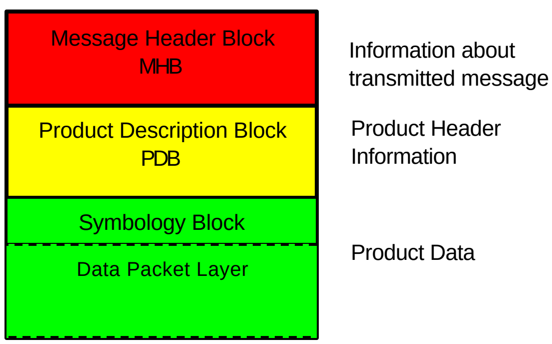

Figure 1. Structure of WSR-88D Graphic Product

For this discussion we will ignore the layering of data in the Symbology Block and the purpose of the other optional blocks (GAB – Graphical Attribute Block and TAB – Tabular Attribute Block).

The topic of this paper is related to two very specific portions of the graphical product. The product-specific information in the PDB and the definition and use of the individual data packet types used in the *Symbology Block*.

3.1 *Product-Specific Heading Information*

There are two types of product specific header information. Each product contains 10 product-dependent parameter (PDP) fields and 16 data level threshold fields. Use of these fields by legacy products (products prior to the ORPG) was fairly consistent and their use is described in the Interface Control Document for RPG to Class 1 User (NWS Radar Operations Center, 2002).

The contents of the 10 PDP fields include: elevation angle for elevation based products, altitude for altitude based products, contour interval, beginning and ending azimuth and range for cross section products, etc. For new algorithms (subsequent to Build 10 RPG), the Radar Operations Center (ROC) Engineering Branch has changed the use of these 10 parameters to be consistent with the 6 product parameters in the product request message. This provides for a consistent request message for new and legacy products of similar types and allows new products to be easily added to the WSR-88D with simple configuration file changes.

The purpose of the 16 threshold level fields was originally to explicitly encode the threshold values used to assign a color value for the legacy 8 and 16 level products. These products are compressed with a run-length encoding scheme and are intended to be displayed by the WSR-88D display system. Other products (sometimes called digital data array products) are intended to provide raw data for use by other systems. Digital products can contain up to 256 data levels with each individual data value encoded into a byte. Several of the 16 threshold level fields are used to partially describe the encoding of this data.

3.2 *Data Packet Types*

The *Symbology Block* contains the data packets that encode the actual data. There are more than 30 data packet types defined for WSR-88D products (NWS Radar Operations Center, 2002). Some data packet types encode a single special symbol, a line vector, or a character string while other data packet types encode arrays of meteorological data.

Many of the recently added products are not intended for an 8 or 16 level color display but are high resolution data arrays. Packet code 16, the digital radial data array packet, is used for these products and contains a polar coordinate data array centered on the antenna location of the source radar. The structure of this packet is depicted in Figure 2.

The packet contains useful header information including the packet code used to identify the packet type, the number of radials contained in the array, the number of data points (or bins) in each radial, and the starting azimuth angle and the width of each radial. Each data point representing real numerical data is encoded into a single byte. It is the decoding of this data point that is the first topic of this paper.

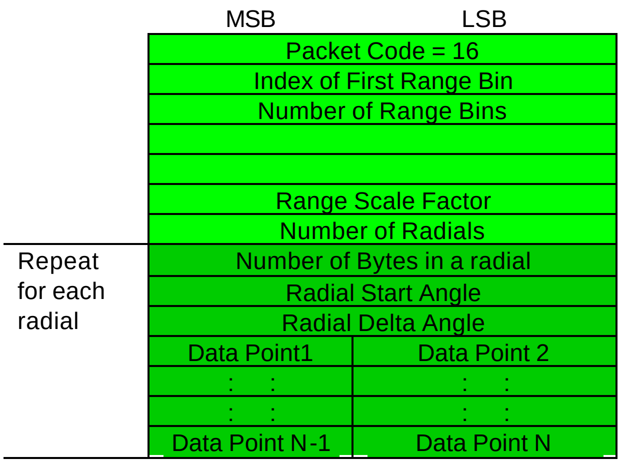

Figure 2. Data Packet Code 16

4.0 DECODING EXISTING DATA PACKETS

For discussing the development of rules for use of existing data packets, a useful example is the digital data array product (using packet code 16). Our objective is to develop the ability to completely decode these products using information contained within the product.

4.1 *Packet Code 16 and Existing Products*

By convention, the first three threshold fields in the *Product Description Block* (PDB) have been used to provide a partial description of the encoding of the data. For the ITWSDBV product the thresholds are:

Threshold	Description	Value for ITWSDBV
1	Minimum value	-635
2	Increment between encoded values	+5
3	Number of data levels	256

In order to decode each data value from the byte value ranging from 0 through 255 into the real data, additional information is needed. First the parameters for minimum value and increment are scaled by a factor of 10. Scaling is required because like the data bins, the threshold fields are integer type fields. The minimum value is actually -63.5 and the interval between data values is +0.5. The third parameter implies that there are 256 data values that would lead us to conclude that the maximum value is 64.0.

However, the first two-byte values represent special cases or flag values. Binary value 0 represents "below threshold" and binary value 1 represents "range folding". Now we have sufficient information to decode the data points. inary 3 encodes -63.5, binary 4 represents -63.0 and the maximum value is +63.0 (binary 255).

Existing products have a variable number of flag values, some flag values are at the higher binary values, and one product has different scaling of the minimum value and the increment. In order to decode existing products, using additional threshold level fields in the PDB could easily provide the following information:

1) the minimum value
2) the increment
3) the number of data values
4) scale factor for the minimum value
5) scale factor for the increment
6) the number of leading flags
7) the number of trailing flags

To completely understand the product we would also need to know the unit of measure of the data and the meaning of the flag values. In addition, the use of the third parameter must be clarified. Existing products have the value of 256 in threshold field 3 regardless of the number of flags or the actual number of data values that can be produced by the algorithm. This field must be redefined to either provide the total number of data values (including flags) or the number of values excluding flags.

There are two rules implied by the above parameters.

1) First, the flag values must be either at the beginning (just before the first encoded numerical binary value) and or be represented by binary values just above the binary value representing the maximum real data value.

2) Second, the encoded real data values must have a constant interval.

4.2 *Modified Use of Packet Code 16*

Due to the nature of the data, a recent product, Digital High Resolution Vertically Integrated Liquid (HRVIL), could not follow the second rule. The data are linearly described for low values and logarithmicly described for higher values and, in order to provide the necessary precision and range of values, a constant interval was not used. A simple decoder using the 7 derived parameters could not decode this product. Another option for the new product would have been the definition of a new data packet type using floating point fields. Either choice requires a new decoding module by the user system.

The developers of HRVIL did attempt to provide information in the header that a user with a priori knowledge could use to decipher the digital values. This involved creating a 16-bit (2 byte) version akin to the IEEE standard for 32-bit floating point arithmetic (ANSI/IEEE Standard 754-1985) to encode the slope and intercept associated with the linear and logarithmic equations used to digitally code HRVIL. Obviously, this does not lend itself nicely for universal application.

Another new product, Enhanced Echo Tops (EET), is soon to be provided for a Build 4 targeted release. One issue regarding echo top heights is whether the radar was able to scan above a storm so as to ensure the storm top was actually within the scanned radar volume for any particular range and azimuth. In many instances close in to the radar, the storm top is above the scanning pattern of the radar. Thus, the echo top is said to be "topped". This is useful information to some users of this product. A typical portrayal of "topped" information might be a polar mapping with a binary depiction (1/0) representing "yes/no topped".

The developers of EET do not want to create a second product for, in essence, a binary mapping of a particular characteristic, or data quality issue, relating to the main EET product. Since the dynamic range of EET will be from zero to 70 kft in 1 kft increments, only 7 bits of a byte are necessary to describe the range. The 8^{th} bit could be used as the binary toggle thus providing a single product with layered information: the true data plus some binary mapping relaying a data characteristic to interested users. Of course, some header parameter might be needed to self describe that this product is bundled in this manner.

Many NEXRAD products might be candidates for this type of layered final product information. For instance, users may want to know if a particular grid point in a Cartesian composite reflectivity product involved disregarding some values due to identification of AP. It may be useful to define a data packet to accommodate the concept of a layered information product codified in single bytes.

5.0 NEW DATA PACKET TYPES

With the ability to field new algorithms at a pace that is several times greater than in the past and with more than one organization contributing to their implementation, there is a potential for rapid change in the structure of products. The design for HRVIL could have involved the definition of a new data packet type that is more suitable to the data.

Another recently added product, Super Ob, has resulted in the definition of a special packet type. Super Ob is unique in several ways. It is geographical in nature but data are sampled over cells that are large with respect to the radar sample bin and sampled over a specified period of time. The location is converted to degrees Latitude and Longitude and the height of the cell is specified in feet above MSL. Each cell has multiple data attributes including a velocity vector (speed and direction), standard deviation, and a time factor. This data packet structure and content limits the packet's usefulness to other applications. This is not a major concern since the data contained, which are input to NWS models at the National Center for Environmental Prediction (NCEP), are not of general interest. If in the future NCEP wanted other data sampled in large three dimensional cells, for example precipitation, this data packet would not be ideal.

Even though the Super Ob product probably lends itself to a unique data packet type, establishing some generic methods for representing 2 and 3 dimensional meteorological data before new products are developed would provide another useful consideration for the design process.

Most WSR-88D products are two dimensional geographic data arrays. These two dimensional arrays are commonly either polar coordinate arrays (based upon the WSR-88D data radials) or have been transformed into Cartesian coordinates. Some two-dimensional products have no altitude associated with them, some have an elevation angle associated, and others have a constant altitude factor. Another aspect of geographical data arrays is the type of projection to the surface that may have been used. All of these factors should be specified by the data packet header information if the data structure is to be self-descriptive.

Any taxonomy would obviously include character and string data that may or may not be associated with a geographical location or three-dimensional position.

Existing WSR-88D products include tabular data. Most tabular data are not geographical in nature. On the other hand, some geographical data that consist of non-regularly spaced data points or are usually sparsely populated arrays may be better handled by a tabular structure rather than a geographical data array. In addition, there are two-dimensional cross section products where one dimension is altitude.

Another aspect of both the tabular data and the two-dimensional geographic arrays is the type of data container. Currently a byte is often used for most data points, whether digitally encoding real data or run-length encoding basic 16-level data. This has obvious advantages in product size. However, with recent advances in network bandwidth and the new WSR-88D product compression capability, other containers should be considered. Possible types are characters (individual byte and new International standards), strings, individual integers (byte, 2-bit, 4-bit), and floating point.

6.0 SUMMARY

In order to support the rapid pace of technology infusion in the form of new products, standards for encoding data must be defined and generic self-describing data formats developed.

Rules for use should be established for the most common or useful existing data packet types, including packet code 16. This would include the data encoding / decoding aspect discussed in paragraph 3. In addition, the use of the 10 product dependent parameters could be reviewed to determine if any existing conventions should be formalized.

For the benefit of WSR-88D algorithm developers, the definition of standard data structures should also be applied to WSR-88D intermediate (or internal) products and to internal structures used by algorithms.

The goal is to ease the burden of having to create custom software in order to decode new WSR-88D products. There are always tradeoffs during product design which include processing efficiency for the primary user and product size (transmission bandwidth). Consideration should also be given to keeping the number of defined data packet types to as few as practical while supporting the needs of multiple users.

7.0 REFERENCES

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