Variable Rate Technology (VRT) for Site-Specific Agriculture

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Reading Assignment:

1. Variable Rate Technologies. In: The Precision Farming Guide for Agriculturists by Deere & Company, pages 79 to 93.

2. Chapter 12 in NRC – 180 publication

Generalities:

- VRT is the implementation of gathered information and decisions or "the printer" for site specific agriculture.
- VRT consists of the machines and systems for applying a desired rate of crop production materials at a specific *time* (and, by implication, a specific *location*).
- Materials:
  - Seed
  - Fertilizer
  - Pesticides
- By definition, VRT implies that the rate *varies*, although sometimes simply maintaining a constant rate is a challenge.

Map versus Sensor:

The text discusses map – versus sensor – based systems. Regardless of how the *desired rates* are determined, the VRT system must respond by *applying that desired rate*. The application hardware is similar, often identical in each case. However, there can be some differences in that map-based systems can "look-ahead" or predict when desired rates may change. Similarly, some sensor-based systems operate on very small areas and therefore may require a much faster response time of the VRT system.

Background on Application Rate and Materials Handling in Agricultural Applications:

By rate, we generally mean:

$$\text{Application rate} = \frac{\text{mass (or volume)}}{\text{area}}$$

and is usually expressed as (lb/acre, gal/acre, kg/ha, l/ha)

And typically we consider this as:

Application rate = flow rate of material / rate of land coverage = material discharge rate / land rate

$$= \frac{\text{mass (or volume)} / \text{time}}{\text{area} / \text{time}}$$

And note that "land rate" is the product of *implement width* and *ground speed*.

Land rate = width(length) * speed(length / time)

Width is usually *fixed* by the machine or vehicle but *ground speed* is highly variable and therefore, must be sensed and VRT must compensate for such changes. This is often a significant challenge, when desired application rates and ground speeds may be changing quickly and over a wide range..

Think:

1. We often wish to adjust the application rate.
2. The application rate is defined as flow rate / land rate.
3. So we can rewrite our equation as:

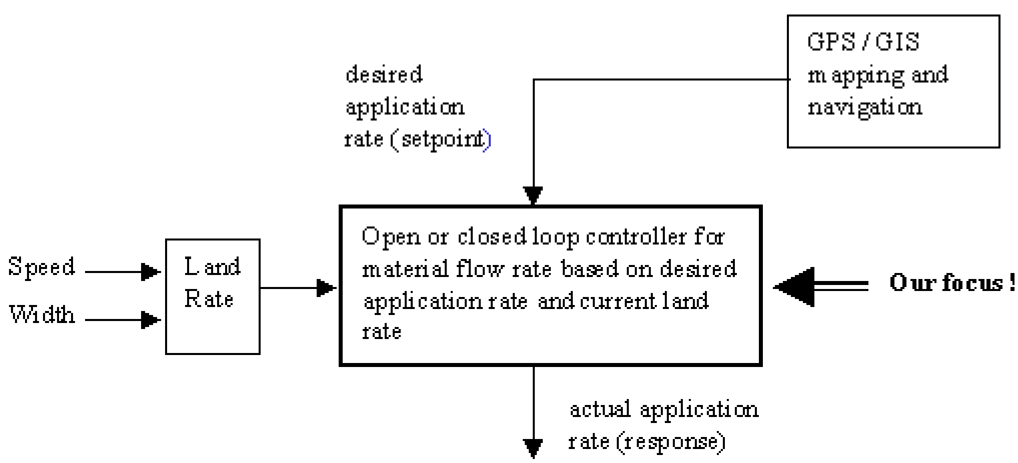
Desired Flow rate = desired application rate * land rate

Desired Flow rate = desired application rate * implement width * ground speed

Since width is usually fixed (or can be sensed), ground speed is variable but can be sensed, when we wish to achieve a desired application rate, we must adjust the *flow rate of material.*

Therefore, the basic task of a VRT system is to *maintain a desired flow rate of material.*

In concept:



Definitions and Considerations:

The desired application rate (usually from the GPS/GIS system or the sensor, depending on the basis for VRA) is called the *setpoint application rate*. From setpoint application rate and the current land rate, the *setpoint flow rate* is determined.

The VRT system attempts to achieve the setpoint flow rate, and correspondingly, the setpoint application rate. The flow rate at any given time is the *actual or response* flow rate which correspondingly determines the actual or response application rate.

The application rate *error* is the difference between the setpoint application rate and the actual application rate. It is almost always nonzero.

Spatial resolution is the smallest area which can receive a distinct and desired application rate. It is the product of *lateral resolution* and *longitudinal resolution*. Lateral resolution is normal to the direction of travel. Lateral resolution is simply the width of each individually controllable element of the application machine. Longitudinal resolution is the smallest travel distance in which a desired application rate can be achieved and maintained. It is the product of the travel speed of the vehicle and the minimum time required for the control system to achieve and maintain the desired application rate. This minimum time is often called the *response time* or *dynamic response* of the rate control system. Longitudinal resolution is along the direction of travel.

Principles of the VRT Controller:

The core of the VRT system is the flow rate controller. Everything you know (or don't know) about control systems, the underlying mathematics, the principles of dynamic response and error management, common algorithms and process hardware applies.

Essentially, the flow control system receives the *setpoint* flow rate from the application system (likely a GPS / GIS system on-board the vehicle and then manipulates a number of actuators in an attempt to adjust the *actual flowrate* to match the setpoint. At this point the error would be zero.

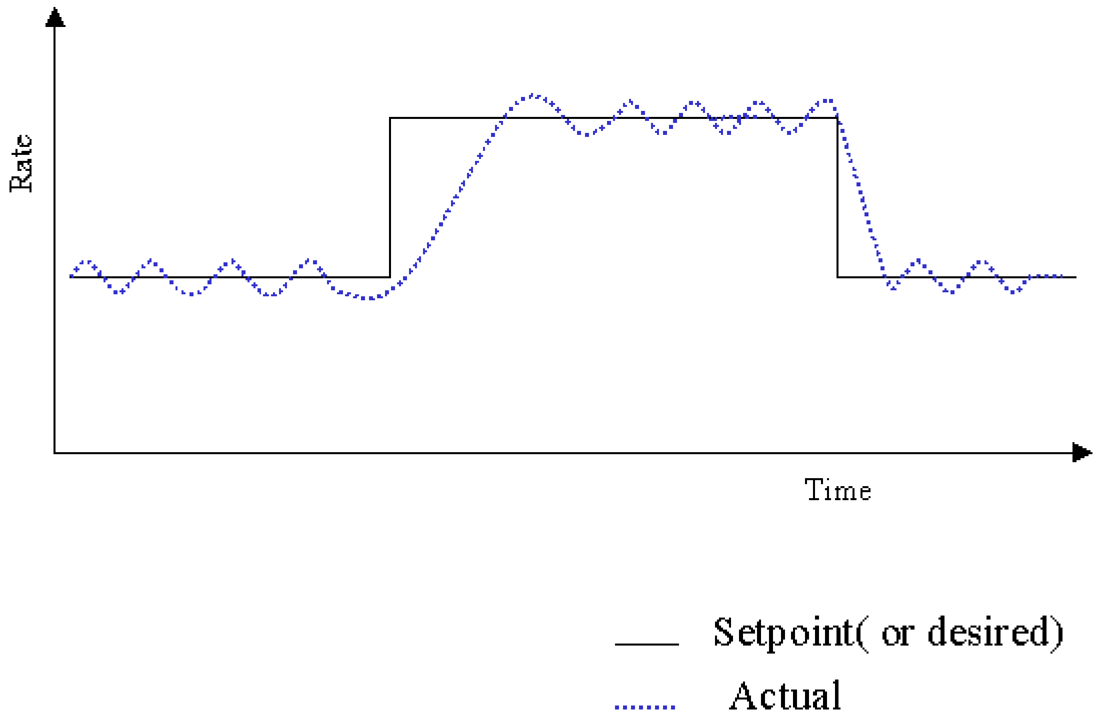
Also, note that anytime the setpoint changes, there is immediately an error! Likewise for speed or width changes !

There are numerous techniques and strategies to optimally correct errors in a control system. These relate to how actuators are adjusted. Some systems compensate the control "action" for the magnitude of the error, historical trend of the error and acceptable error range (deadband). These actions directly relate to dynamic response of the system to setpoint changes. These also relate to *system stability*.

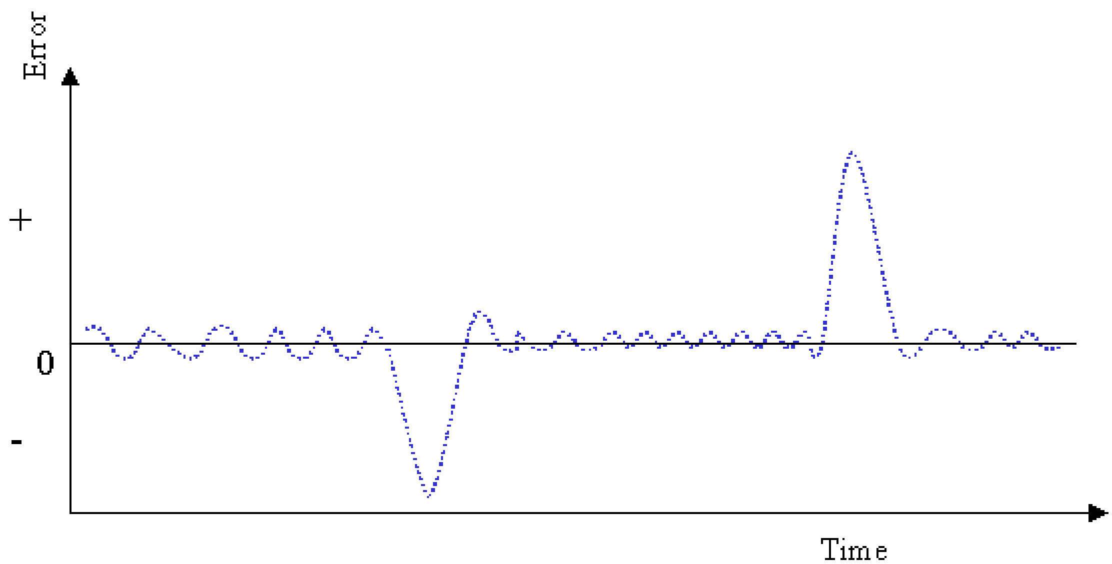
As discussed in the NCR-180 publications (Figs. 12-2 and 12-3), there are two general types of control systems, open-loop and closed-loop. The open-loop system does not use any sensors to determine feedback information. The actual rate is inferred from actuator settings. This is roughly equivalent to driving a car with no speedometer and attempting to control speed by your foot position on the throttle. You have no speed feedback (the speedometer) and you don't know how to compensate for wind, vehicle loading or slope. This approach is cheap but not adequate for process control.

With closed-loop control, the feedback is used to correct actual rate. In the case of liquid application, a flowmeter (discussed later) is generally used for feedback.

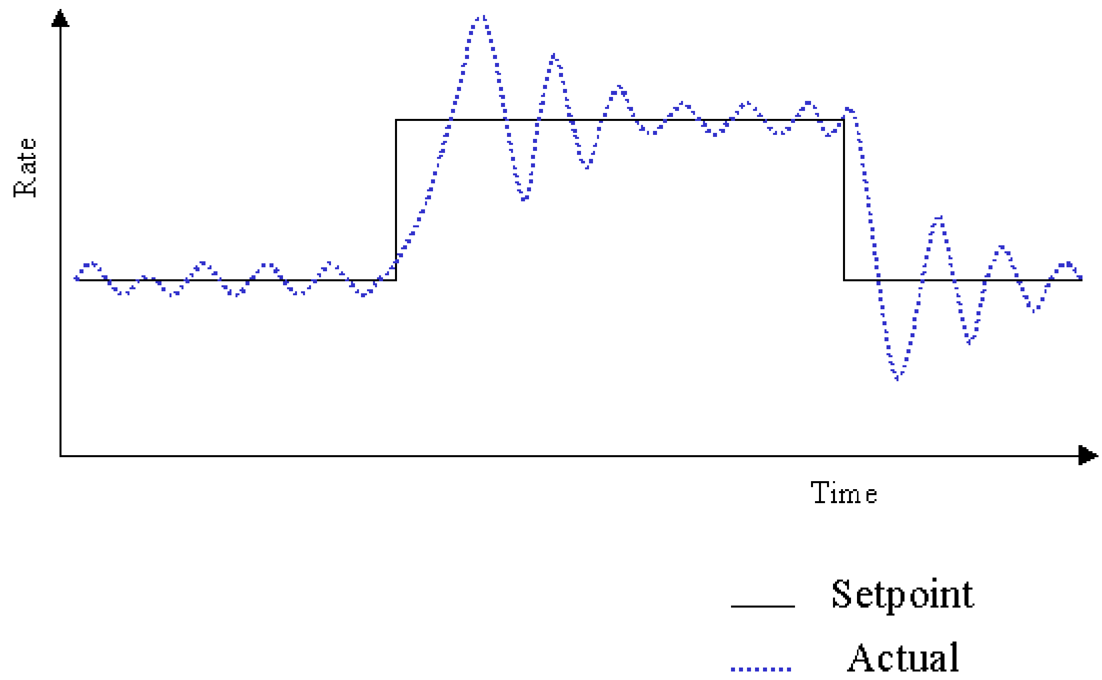
The collection of feedback data, the analysis of that data, the method of making changes in the actuator and the actuator characteristics all determine the system response. For example, consider the following plot of a system response to a setpoint change:



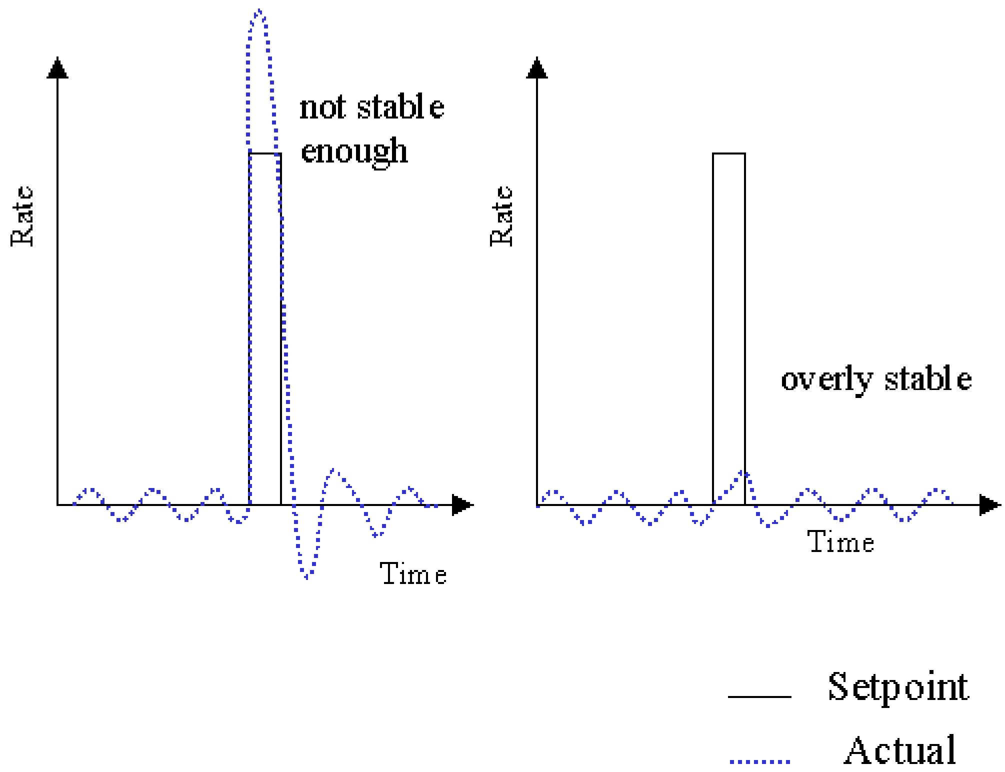
It takes time for the system to adjust the actual flow rate to match the setpoint (zero error). The difference, or error can be calculated as the difference between actual and set point values and displayed similarly:



The dynamics of the control system determine if a system might have the following problem where it is less stable (or "overshoots" the actual rate):



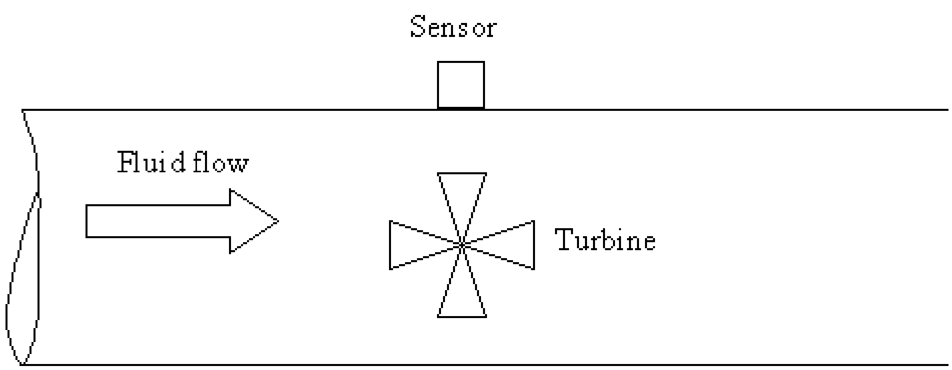
Or, if we have a brief speed variation, (remember this changes the flow rate setpoint), consider how a stable and unstable system might respond. How do you think the second system might respond to routine set point changes ?



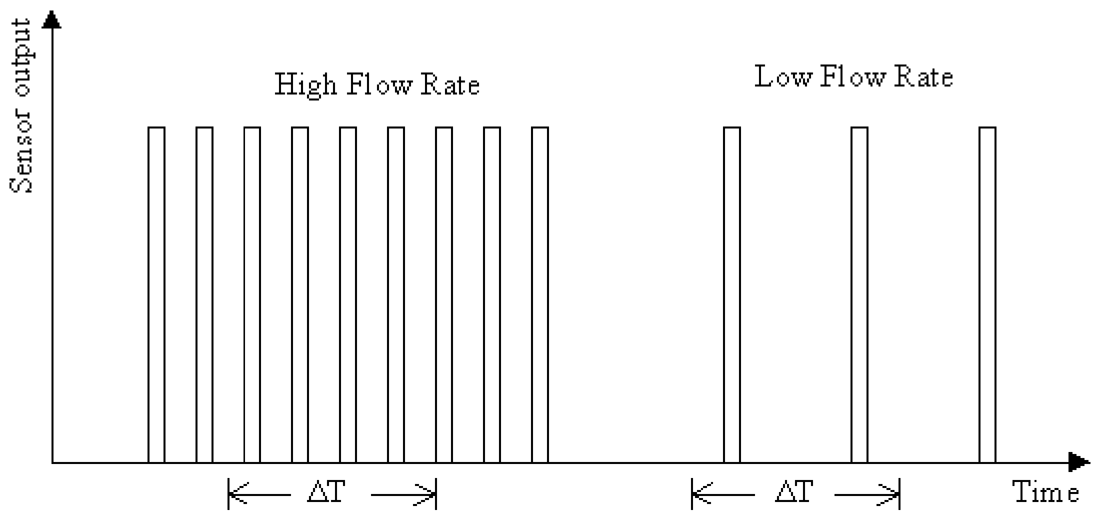
The nuts and bolts and why controllers are not perfect - or even close

Why do controllers take so long to respond and what limits our dynamic response (and consequently, spatial resolution) ?

First consider the flow meter. The most common type is a turbine, digital meter. An internal turbine is driven by fluid in motion. Each blade of the turbine actuates (either magnetically or optically) an electronic circuit which produces a pulse. The flow rate (pulses per unit time) is directly related to the flow rate while the time between pulses is inversely related to flow rate.



So the sensing problem becomes:



Accumulating counts for a fixed time period (delays data) or measuring time between pulses. In the former, resolution decreases with flow rate and in the later decreases with higher flow rate.

Note that this digital technique is also used for determine motor and pump speeds, wheel rotation speeds, belt and shaft speed in general.

Once this data is collected, the computer must decide what to do and then send a signal to an *actuator* which will then respond, some times slowly, to that command. Delays, delays, delays!

Variable Rate Application Spray System:

Dr. Ken Giles from the University of California - Davis has designed , built and evaluated a map based system for variable rate application of liquid chemicals.
The system uses sensors, actuators, microcontrollers and GPS/navigation to control the application rate. Each spray has a solenoid (pulse-width actuator) attached to it. The frequency which the solenoids are turned on/off defines the application rate. A closed-loop sytem uses the information from pressure and flowrate sensors to adjust the actual application to the desired value (set point).

Commercially Available Products:

Information on a variety of VRT components is available on the following sites:

TeeJet® at : http://teejet.com/products/prod.htm

Hardi International at :

http://www.hardi-international.com/Product_and_Solutions/default.htm

Raven Industries, Inc. at: http://ravenind.com/Flow_Control/fc_products/ams198.htm

Midwest Technologies, Inc Mid-Tech at: http://www.mid-tech.com/

Micro-Trak® Systems, Inc. at : http://www.micro-trak.com/

Dickey-John Corporation at:

http://www.dickey-john.com/Ag_Products/Ag_Products.htm

Capstan Ag Systems, Inc. at: http://www.capstanag.com/