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Activity Monitoring Systems: What's New and What's Improved?

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- Affordable advanced computer technology that includes mini printed circuit boards that contain microelectronic circuits that function as an on-board micro-computer that track and transmit data has driven an explosion of available activity monitor systems (AMS).
- All AMS include three basic components, the sensor on each cow, the hardware receiver to collect data from the sensors, and computer software.
- AMS allow for individual cow management with unique data collection and interpretation practically in real time.
- Specific proprietary complex algorithms allow comparison of both individual and group baselines to identify individuals that deviate from normal or expected levels of activity to determine which animals are outside the desired population confidence interval and require management attention and or action.
- The basic training of new users and continuous support of farm personnel are important to maximize the benefits of any AMS.

INTRODUCTION

Farris (1954) was the first to report using pedometers to measure activity associated with estrus in dairy cows. Data from six cows that had AM and PM pedometer data showed an average increase in activity during estrus of 218%. More than 20 years elapsed before research revived interest in pedometry as a practical tool for detection of estrus of dairy cattle (Kiddy, 1977). It was noted that the daily activity for each cow must be monitored and activity associated with estrus compared with that obtained during the other stages of the estrous cycle for pedometry to be most effective in identifying estrus. A second significant finding was that individual cows differed significantly in the amount of activity expressed under the same conditions. The average increase in activity at the time of estrus was 393%. For 93% of the estrous periods the activity was 3 standard deviations above the mean activity during diestrus. These two studies were the basis for the development of activity systems. Over the next 38 years, numerous scientific studies reported on various properties of activity monitoring systems (**AMS**) from environmental factors that affected accuracy relative to the ideal timing of insemination.

Transfer of data occurs during milking, via a walk-through portal or with a reader at each stall, or periodically during the day using radio frequency technology. The latest systems are using the Internet via the Web or Cloud services to alleviate the necessity for on-farm software and allow for remote access from almost anywhere.

Increased physical activity is associated with estrus, and various automated systems have been developed to detect standing to be mounted or increased activity either as steps or neck movements (Nebel et al., 2000; Firk et al., 2002). Numerous research reports reveal ample evidence that activity systems (pedometers or accelerometers) are able to accurately identify the majority of cow/heifers that are in estrus (van Erdenburg, 2008; Hockey et al., 2010; Kamphuis et al., 2012; Lovendahl and Changunda, 2010; Neves et al., 2012; Valenza et al., 2012; Chanvallon et al., 2014; Stevenson et al., 2014). As a result of technical progress in detecting estrus and health related activity with the use of computers, AMS have become a reality on many dairy farms. Efficient and accurate detection

varied depending on the threshold value to determine when to declare high activity. Across numerous herds that we have evaluated insemination rates using AMS the detection rates obtained were commonly in the mid-70 to approximately 80% range.

Measurements associated with rumination and its relationship to health is a comparatively new function with the Heatime/ai[24] SCR system being the first AMS to offer rumination in mid-2012. The SCR system tracks rumination with a tuned microphone that detects sounds of the bolus passing the esophagus and has been reported as a reliable source for detection of rumination (correlations = 0.94) when compared with visual observations of rumination minutes (Schirmann et al., 2009). Bikker et al. (2014) evaluated the CowManager AMS on accuracy and precision by ear movements for ruminating, eating, resting, or active classification by the three-dimensional accelerometer. The overall kappa (κ) for the comparison of CowManager and visual observation was 0.78, with κ values of 0.85, 0.77, 0.86, and 0.47 for rumination, eating, resting, and active, respectively. Pearson correlation and concordance correlation coefficients between CowManager and visual observations for rumination, eating, resting and active minutes per hour were 0.93, 0.88, 0.98, and 0.73 and 0.93, 0.75, 0.97, and 0.35, respectively. Thus, these peer-reviewed publications provide strong evidence that these two systems can be used to monitor ruminating and resting behavior of free stall-housed dairy cattle.

Affordable advanced computer technology that includes mini-printed circuit boards containing microelectronic circuits that function as an on-board micro-computer that tracks and transmits data, either using radio frequency or infrared technology, to either an on-farm personal computer or a web or cloud-based software package has driven an explosion of available AMS commercially available. Current AMS allow for individual cow management with unique data collection and interpretation practically in real time. The AMS initially were developed for detection of estrus but today's systems monitor rumination, resting time, temperature, lying time and bouts, and many other events associated with animal well-being. Activity monitoring has many different approaches, from pedometers that measure walking activity and lying bouts, to accelerometers that measure head movements, and ear sensors that monitor movement associated with estrus, rumination and ear surface temperature. Proprietary complex algorithms allow comparison of both individual baselines, and for a few systems, a group baseline to identify individuals that deviate from normal or expected levels of activity. Algorithms then determine which animals are outside the desired population confidence interval and which may require management attention and or action. Each AMS archives different types of activity. One of the key differentiators between AMS is the level of accuracy and false positives of detection algorithms.

All AMS include three basic components: (1) the sensor on each cow; (2) the hardware receiver to collect the data from the sensors; and (3) computer software that outputs alerts and levels of activity. Sensors are presently in the form of either an ankle-mounted pedometer, collar-mounted monitor, an ear sensor, or a rump-mounted transmitter. All sensors transfer data either wirelessly using radio frequency or infrared technology to some configuration of a reader that transmits the data, usually in binary code, to a coordinator that translates and decodes the signal. The software is either located in an on-farm computer or a server that receives the information via web or cloud-based technology where the proprietary algorithms sort the information and determine which individual cows need attention. Web apps, email alerts, test messages, and smart phone program downloads are available with most AMS. Table 1 summarizes the AMS available or soon-to-be available in North America.

What's New with Activity Monitoring Systems?

- Monitoring of rumination and eating, either minutes per day or duration and number of eating bouts is now available with many systems (Table 1).
  - In the fresh-cow pen activity and rumination monitoring can identify sick cows before visual or acute symptoms are seen.
  - To evaluate ration changes or how cows (groups) respond to different feed ingredients, mold or toxin presence, or fiber sources.
- Health alerts or an index displaying the level or decrease in rumination and increase in non-active time (Figure 1).
  - Identify cows that need individual attention before it can be visually observed.
  - Avoids over-treating animals and allows tracking of which treatments are successful and which cows may need additional follow-up.
- Lying time and number of bouts as a measure of cow well-being is available on numerous systems.
  - Cows can be identified and examined for possible health complications without having to walk pens.
- Temperature monitoring as a secondary measure of health.
  - Especially in the close-up and fresh pens where individual health checks can be reduced and individual temping can be eliminated. (Figure 2).
- Cow locator in real time using either sensor triangulation via multiple signal receivers or a signal sent from the sensor to alert a hand held device where sensor is located (Figure3).
  - Labor savings especially for large pens when only a few individuals have alerts for breeding or health observations.
- Cloud or web based data computing and storage.
  - The dairy is usually not a friendly environment for computers.
  - Cloud or web AMS requires constant reliable internet connection. Faster internet speed quickens data transfer reducing frustration waiting for data transfer.
  - Allow for global up-dating of algorithms and on-screen graphics.
- Two systems have sensors mounted on ear tags that allow flexibility for installation and transferring to another cow or heifer.
  - CowManager and SMARTBOW

What's Improved with Activity Monitoring Systems?

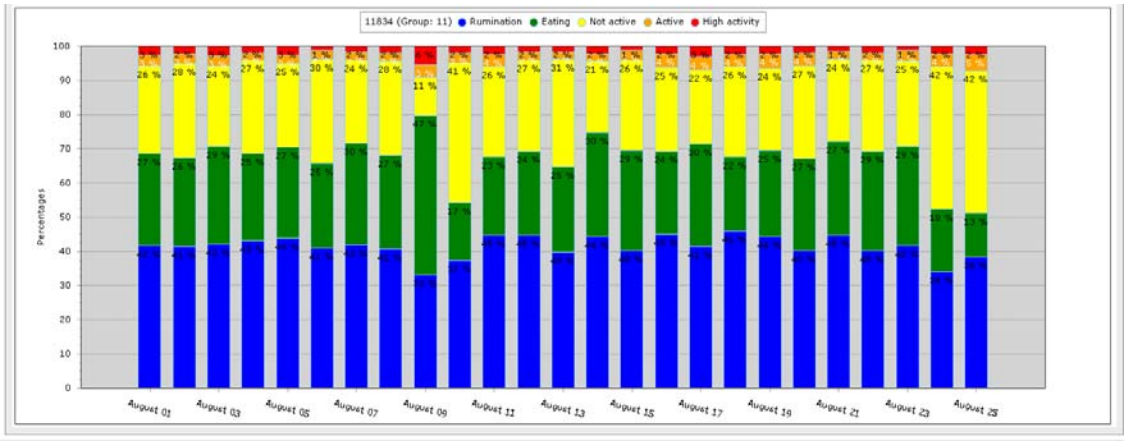
- Warranty is now usually five years and either full or pro-rated.
- Longer lasting batteries and lower failure rates
- Technical support after installation
- The second, third, and for some AMS, the fourth generation sensor-system is now available with improved more durable wearables and enhanced proprietary algorithms. Information allows for individual cow management and immediate decision implementation related to breeding, cow health and ration evaluation.
- With increased competition comes lower prices and flexibility of what functions can be purchased.
- Smartphone app(s) are now available for practically all AMS with enhance graphics and lookup functions

Table 1. Currently or soon-to-be-available activity monitoring systems (AMS) in the United States (September 2015)

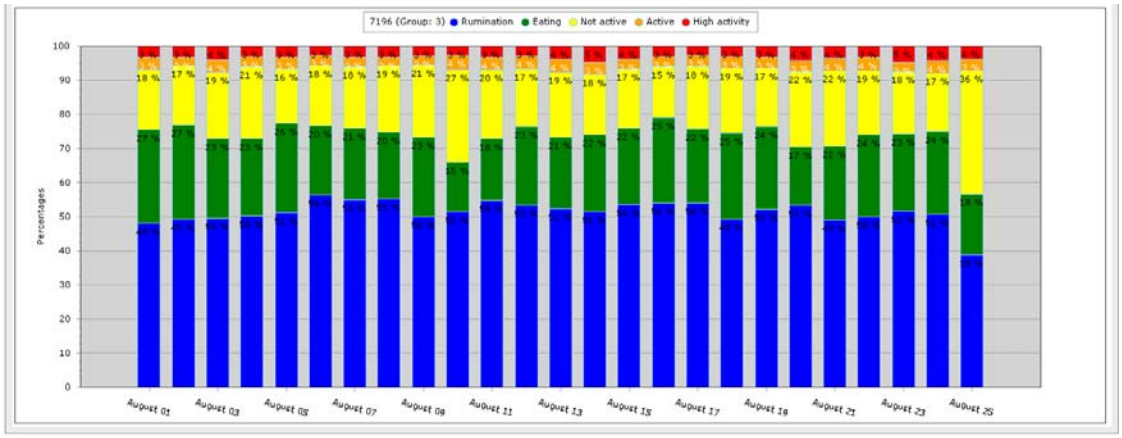
AMS	Company	Location	Activity	Rumination	Cloud-Web	Other
AccuBreed	Estrotect	Rump	✓			Standing events
AfiAct II	Afimilk	Ankle	✓		✓	Lying bouts Resting time Resting/bout Calving alert
CowAlert	IceRobotics	Ankle	✓		✓	Lying bouts
CowManager	Agis Select Sires	Ear	✓	✓	✓	Eating, Resting, Temperature, Locator
CowScout I or S	Nedap GEA	Anke or neck	✓			Lying and eating bouts CowView-locator
DeLaval	DeLaval	Ankle				
Heat Phone		Neck	✓		✓	
Feed Phone	Medria	Neck		✓		Ingestion
Vel Phone		Vagina				Calving
RealTime+	Nedap Boumatic	Ankle or neck	✓			Lying and eating bouts
Heatime/ai^{24}	SCR Genex Select Sires Semex	Neck	✓	✓	✓	HealthyCow24
MooMonitor+	Dairymaster	Neck	✓	✓	✓	
Silent Herdsman	Embedded Technology Solutions	Neck	✓	✓	✓	Eating
SMARTBOW	MKW Elec-tronics Precision Animal Solu-tions	Ear	✓	✓	✓	Locator
Track a Cow	Animart	Ankle	✓			Eating duration and total bouts, Lying bouts

Figure 1. Examples of the change in daily rumination and non-active resting minutes as a percentage of total daily activity for the three health alerts available in the AMS CowManager (Agis Automatisering, Harmelen, NL).

Panel 1. Health alert "Suspicious": increase in non-active time from 25 to 42%.



Panel 2. Health alert "Sick": decrease in rumination from 51 to 39% and increasing in non-active time from 17 to 36%.



Panel 3. Health alert "Very Sick": decrease in rumination from 51 to 20% and increase in non-active time from 35 to 66%.

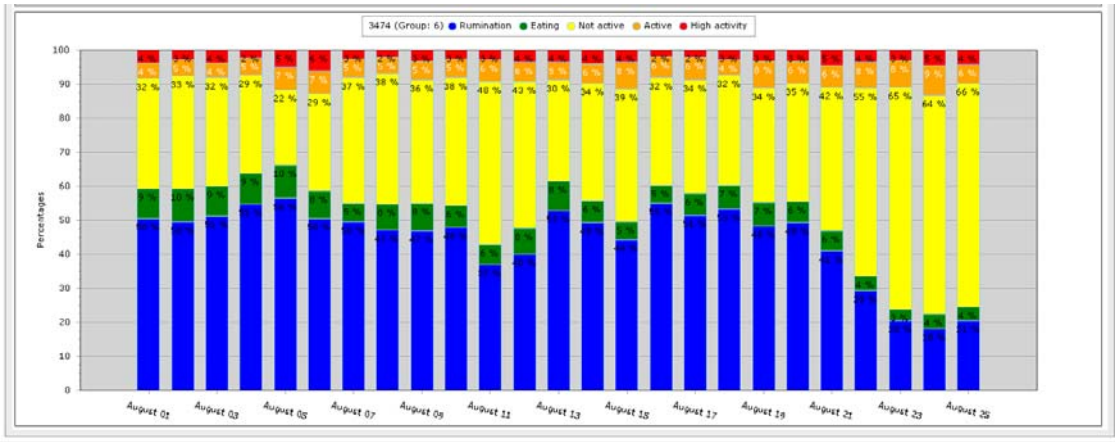


Figure 2. Example of the change in ear surface temperature that triggers an alert in CowManager (Agis Automatisering, Harmelen, NL). Green line is the mean temperature for all cows with a sensor compared with the blue line which is the individual cow that has the alert. Ear temperature is inversely related to core body temperature.

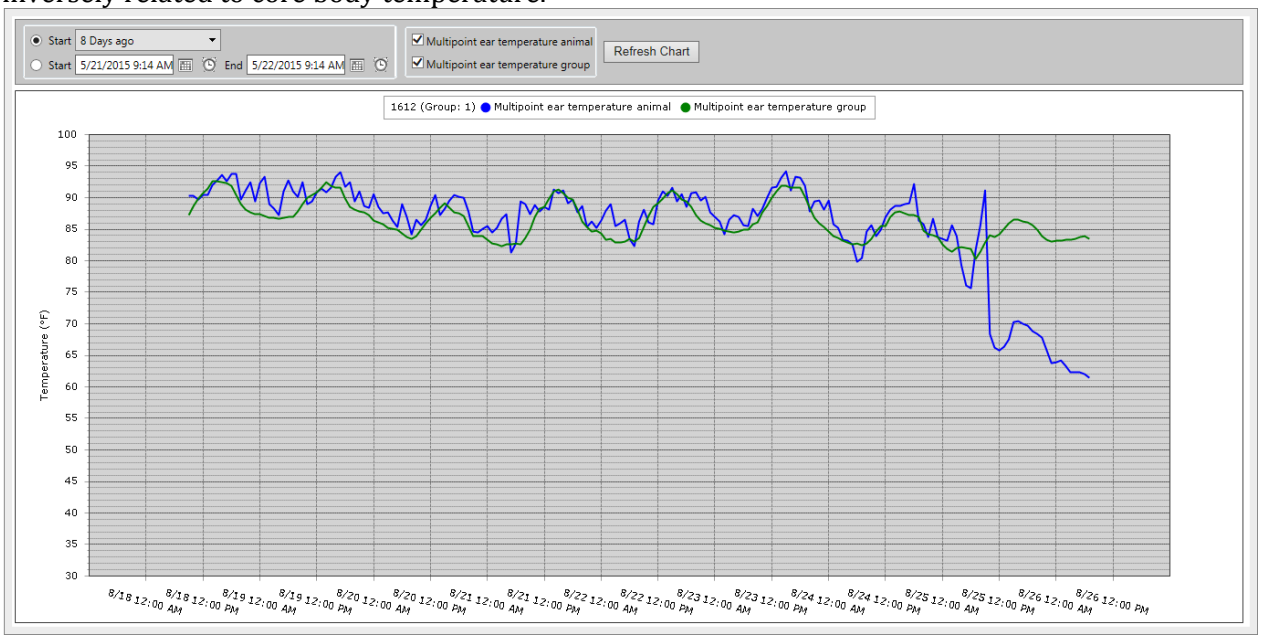
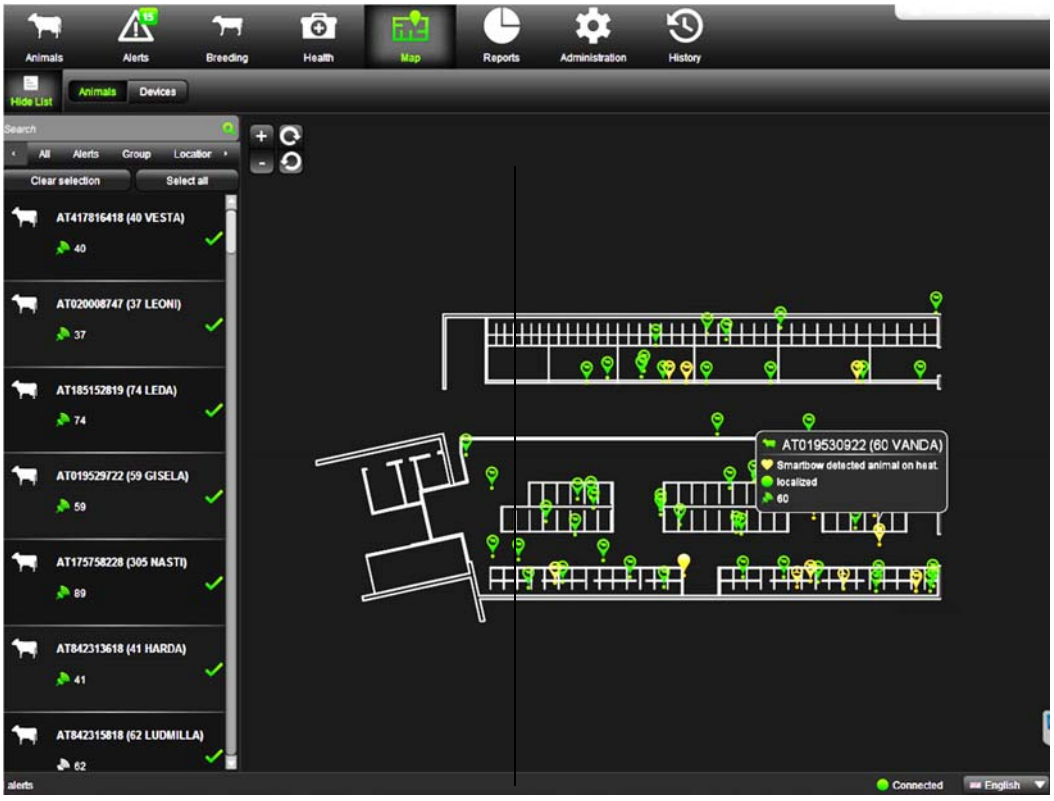


Figure 3. Example of real-time localization of cows with sensors (cows with normal activity levels are represented by green circles and cows with heat alerts are represented as yellow circles) with the SMARTBOW system.



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