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POTENCIAL DO MÉTODO UNIDADE DE MEDIDA INERCIAL NA DETECÇÃO DE BOCADOS

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Jusiane Rossetto
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POTENCIAL DO MÉTODO UNIDADE DE MEDIDA INERCIAL NA DETECÇÃO DE BOCADOS[1]

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RESUMO
Para ampliar os conhecimentos relacionados a avaliação do comportamento ingestivo em pastejo, foram realizados dois estudos. O primeiro estudo com o objetivo de desenvolver um algoritmo de código aberto que permite detectar bocados no domínio do tempo utilizando unidade de medida inercial (IMU) de um celular. Foram testados os sinais da taxa de rotação ao longo dos eixos y e x (Ry e Rx, respectivamente) e aceleração do usuário ao longo dos eixos y e x (Uy e Ux, respectivamente). Os principais parâmetros que foram considerados foram o valor mínimo de cada pico (h) e o intervalo mínimo entre dois picos (d) fixado em 0,4 segundo. A partir do conjunto de dados de calibração, a porcentagem de bocados corretamente detectadas quando comparado ao observado foi maior para a taxa de rotação ao longo do eixo y com h = 0,2 e h = 0,3 rad. s^{-1} (82 e 85%) em relação aos outros sinais (Rx, Uy e Ux). Após a validação do algoritmo, não houveram diferenças entre os valores de h para a percentagem de bocados corretamente detectados e a taxa de falsos positivos. Houveram diferenças para a taxa de falso negativo, onde h = 0,2 obteve a menor taxa (2.88%). A taxa rotação do eixo y obteve os melhores resultados para detecção dos bocados com uma acurácia entre 76.48 e 91.1%. No segundo estudo, o objetivo foi avaliar se diferentes estruturas do pasto podem influenciar na qualidade de detecção dos bocados pelos métodos IMU e IGER (Registrador de comportamento IGER). O experimento foi conduzido na Estação Experimental da Universidade Federal do Rio Grande do Sul, Brasil, em maio de 2018. Os tratamentos consistiram de diferentes alturas do pasto pré-pastejo: 20, 40 e 60 cm de altura em pastagem de *Urochloa brizantha* cv Marandu. As diferentes alturas de entrada influenciaram de forma linear e negativa a qualidade de detecção dos bocados. Não houve relação entre a altura do pico (taxa de rotação ao longo do eixo y) e a massa dos bocados, no entanto, a altura do pico diminuiu com o aumento da altura do dossel. Quando comparados os métodos de detecção de bocados o método IMU foi superior ao IGER nos tratamentos de 20 e 60 cm, não havendo diferenças no tratamento de 40 cm. O tratamento com 60 cm de altura do dossel foi menos acurado na detecção dos bocados nos dois métodos de detecção aplicados. Portanto, a estrutura da pastagem influencia a qualidade de detecção dos bocados. O método IMU mostrou-se eficaz na detecção de bocados em experimentos de pastejo.

Palavras chave: bocado, bovinos, pecuária de precisão, sensor, unidade de medida inercial

[1]Tese de Doutorado em Zootecnia - Produção Animal, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil. (98 p.) Março, 2019.

POTENTIAL OF THE INERTIAL MEASUREMENT UNIT IN THE DETECTION OF BITES[2]

Author: Jusiane Rossetto
Advisor: Paulo César de Faccio Carvalho

ABSTRACT

To improve our knowledge on the evaluation of ingestive behavior two studies was performed. The first one with the objective to develop an open-source algorithm that allows to detect bites in the time domain using the inertial measurement unit (IMU) of a smartphone. The signals of the rotation rate along the y and x axis (Ry and Rx, respectively) and user acceleration along the y and x axis (Uy and Ux, respectively) were tested. The main parameters that were considered are the minimum value of each peak (h) and the minimum interval between two peaks (d) fixed in 0.4 second. From the calibration data set, the percentage of bites correctly detected when compared to observed was higher for the rate of rotation along the y-axis with h = 0.2 and h = 0.3 rad. s^{-1} (82 and 85%) in relation to the other signals (Rx, Uy and Ux). After the validation of the algorithm, there were no differences between the values of h for the percentage of correctly detected bits and the false positive rate. There were differences for the false negative rate, where h = 0.2 obtained the lowest rate (2.88%). The y-axis rotation rate obtained the best results for detecting bits with an accuracy between 76.48 and 91.1%. In the second study the objective was to evaluate if different pasture structures can influence the quality of detection of the bites by IMU and IGER (IGER Behavior Register) methods. The experiment was conducted at the Experimental Station of the Federal University of Rio Grande do Sul, Brazil, in May 2018. Treatments consisted of different pre grazing intended sward heights (20, 40 and 60 cm) of *Urochloa brizantha* cv Marandu pasture. The different sward height influenced in a linear and negative way the detection quality of the bites. There was no relationship between peak height (rate of rotation along the y axis) and mass of the bites, however, the height of the peak decreased with increasing of sward height. When comparing the methods of detection of bites, the IMU method was superior to the IGER in the treatments of 20 and 60 cm, without differences in the treatment of 40 cm. The treatment with 60 cm of height of the sward was lower accurate in the detection of the bites in the two methods of detection applied. Therefore, the structure of the pasture influences the detection quality of the bites. The IMU method was effective in detecting bites in grazing experiments.

Keywords: bite, cattle, livestock precision, sensor, inertial measurement unit

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BF: Fator *Branching*

cm: centímetros

d: distance; distância

FN: False negative; falso negativo

FNR: false negative rate

FP: False positive; falso positivo

FPR: False positive rate

GRA: Grass intake

h: height; altura

Hz: Hertz

IGER: registador de comportamento *IGER*

IMU: inertial measurement unit; unidade de medida inercial

MB: Massa do bocado

MF: Fator *Miss*

QF: Percentagem de bocados corretamente detectados

rad.s^{-1}: radian per second; radiano por segundo

RUM: Rumination

Rx: rotation rate signal along the x axis;

Ry: rotation rate signal along the y axis; taxa de rotação do eixo y

TN: True negative; verdadeiro negativo

TP: True positive; verdadeiro positivo

Ux: user acceleration signal along the x axis

Uy: user acceleration signal along the y axis

CAPÍTULO I

1. INTRODUÇÃO

Pastejo, ruminação e ócio são as principais atividades diárias dos ruminantes (Gregorini, 2012) e desempenham papel fundamental na regulação da ingestão de forragem. O monitoramento dessas atividades é importante para a tomada de decisões no manejo de sistemas pastoris (Giovanetti et al., 2017). Na escala diária, o monitoramento dos movimentos mandibulares permite a mensuração confiável dos distintos ciclos de pastejo e ruminação. O monitoramento preciso do comportamento ingestivo dos animais é necessário para assegurar que os requisitos mais básicos de saúde e bem-estar animal sejam atendidos e consistentes com práticas que possam assegurar o uso sustentável e eficiente dos recursos forrageiros (Chelotti et al., 2016).

Desta maneira, é possível entender como a estrutura e a composição da vegetação influenciam a taxa na qual os animais ingerem material vegetal e, portanto, nutrientes (Bonnet et al., 2015). Contudo a mensuração direta e acurada dos movimentos mandibulares ainda não é realidade. Para ser de uso corrente, o monitoramento deve ser realizado de forma totalmente automática e não invasiva, de modo a não perturbar o comportamento normal do animal. Além disso, o sistema deve ser capaz de funcionar continuamente e realizar medições precisas de dias á semanas (Vanrell et al., 2018).

Assim, ao longo do tempo várias técnicas foram desenvolvidas para monitorar os movimentos mandibulares dos ruminantes (Andriamandroso et al, 2016). Podendo ser realizada através de sensores de pressão (Rutter et al., 2000; Ungar & Rutter, 2006), monitoramento acústico (Laca & Wallis DeVries, 2000, Chelotti et al., 2016, Vanrell et al., 2018), e mais recentemente com acelerômetros (Tani et al., 2013; Oudshoornet al., 2013), mas os resultados disponíveis indicam que essa classificação requer desenvolvimento adicional para ser confiável e automático (Chelotti et al., 2018).

Os acelerômetros registram somente a aceleração linear baseada na vibração do dispositivo. No entanto, unidades de medida inercial (IMU) compreendem dois ou três sensores que medem e registram a força específica do corpo, a taxa angular e o campo magnético ao redor do corpo, sendo composto por acelerômetro, giroscópio e um magnetômetro (Ahmad et al., 2013). Os IMUs podem medir muitos parâmetros físicos dentro de dois ou três eixos (Debauche et al., 2018) e medir tanto a aceleração estática devido à gravidade, o componente de baixa frequência da aceleração (Almeida et al., 2013), e a aceleração dinâmica devido a movimentos impressos pelo animal (Brown et al., 2013).

Guo et al., (2018) utilizou unidade de medida inercial para classificar o comportamento em pastejando e não pastejando com acurácia de 97% em uma janela de 10 segundos. Já Andriamandroso et al., (2017) desenvolveu um algoritmo booleano de código aberto baseado em IMU registrado em celular para classificar as atividades de pastejo e ruminação de vacas, com acurácia de 91% e 93%, respectivamente. Este algoritmo foi desenvolvido combinando limites máximos e mínimos de diferentes sinais, que discriminaram os comportamentos numa janela de segundo, assumindo que os animais realizam diferentes grupos de movimentos de cabeça e intensidade dos movimentos mandibulares (Andriamandroso et al., 2017). No entanto, ambos os trabalhos foram realizados em escalas diárias e de refeição, não gerando informações da maneira como os animais realizavam a colheita dos alimentos, ou seja, avaliações a nível do bocado.

Diante do exposto, propõe-se desenvolver um algoritmo de código aberto para detectar com acurácia os bocados desferidos no pasto através da interpretação do registro dos movimentos da cabeça através do método unidade de medida inercial (IMU).

2. REVISÃO BIBLIOGRÁFICA

O pastejo é um processo fundamental que afeta a dinâmica e o funcionamento dos ecossistemas pastoris. O comportamento ingestivo é consequência da relação entre o animal, seus recursos alimentares e o meio ambiente (Shipley, 2007). Está relacionado a busca e coleta do alimento e o processo digestivo dos tecidos vegetais (Carvalho 2013), através dos movimentos e atividades realizadas em diferentes escalas temporais e espaciais (Larson-Praplan et al., 2015). O comportamento ingestivo pode fornecer detalhes sobre as condições do pasto que maximizam a ingestão de nutrientes e o desempenho animal, conforme descrito na Figura 1.

Ao longo da vida de um animal, a ingestão de nutrientes é regulada para atender as demandas de manutenção e produção (Shipley et al., 1994). Em escalas diárias, a taxa de ingestão é limitada pela digestão e excreção, pela quantidade de tempo que um animal pode investir na alimentação, e pela taxa de consumo de curto prazo alcançada enquanto o animal se alimenta. Ainda numa escala mais fina, a taxa de consumo é limitada pelas propriedades espaciais e morfológicas das plantas e pela capacidade de coleta e mastigação dos animais (Shipley et al., 1994).

O processo de pastejo é, ao mesmo tempo, causa e consequência da estrutura de um ambiente pastoril (Carvalho, 2013). Mudanças na estrutura do pasto têm como causa o pastejo. De forma concomitante, a estrutura do pasto resultante afeta o processo de pastejo, disso decorrendo um ciclo contínuo de relação causa-efeito (Carvalho et al., 2016). No entanto, diferentes animais têm necessidades alimentares diferentes, relacionadas a fase crescimento, nível de produção, reprodução, condições climáticas, estado fisiológico, entre outros (González et al., 2018) e usam estratégias diferentes para adquirir seus alimentos. Laca (2008) descreveu que a heterogeneidade está presente em diferentes níveis dentro de cada escala. Em nível de detalhe espacial, a heterogeneidade da vegetação está presente dentro da comunidade (mosaicos com diferentes espécies, densidade, altura das plantas) e a nível de indivíduo (relação folha: colmo, estágio de crescimento, arquitetura dos componentes morfológicos) (Laca, 2008).

Face ao exposto, tanto as plantas quanto os animais são componentes dinâmicos e complexos no processo de pastejo. Deste modo, o monitoramento do comportamento ingestivo em nível individual é fundamental, pois ele permite compreender a complexidade da interação planta-animal (Carvalho et al., 2009)

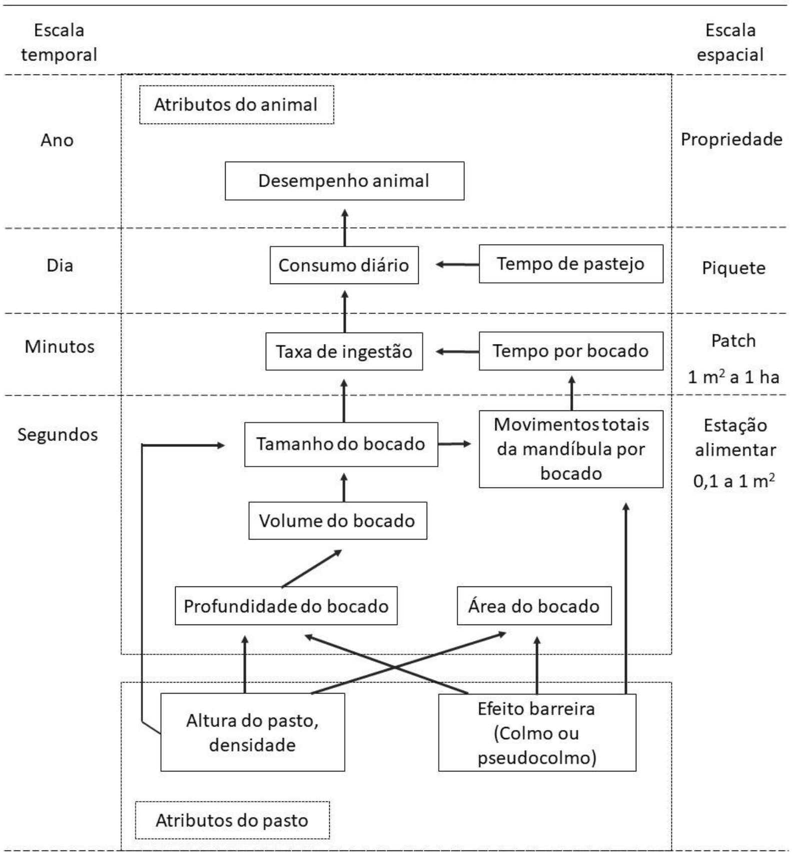

Figura 1: Atributos do pasto e sua relação com parâmetros de ingestão e desempenho animal (adaptado de Gordon e Benvenutti, 2006).

Uma questão central nos estudos em pastejo é entender como a estrutura e a composição da vegetação influenciam a taxa na qual os animais ingerem forragem e, portanto, nutrientes (Bonnet et al., 2015). Em resposta a diferentes estruturas de pasto, os animais alteram sua dinâmica de aquisição de forragem, os padrões de movimentação e a utilização de estações alimentares (Carvalho, 2013). Em ofertas de forragens limitantes, o número de estações alimentares pastejadas é similar ao número de estações alimentares existentes. No entanto, em ofertas de forragem mais altas, a proporção de estações alimentares efetivamente pastejadas diminui, indicando que animais expressam maior seleção nas estações alimentares que serão utilizadas (Mezzalira et al., 2013). Em geral, herbívoros em pastejo selecionam plantas e componentes morfológicos para otimizar a ingestão de nutrientes, além de minimizar o custo energético e a ingestão de fitoquímicos prejudiciais (Carvalho 2013).

O consumo individual de pasto pode ser determinado através do produto entre a massa do bocado, a taxa em que os bocados são formados e o tempo dedicado a atividade de pastejo (Spalinger e Hobbs, 1992). Muitas dessas decisões são baseadas à nível de estação alimentar e são feitas na escala de tempo de segundos ou minutos (Bailey e Provenza, 2008). O bocado é a unidade fundamental do consumo (Ungar, 1996), sendo considerado o átomo de pastejo (Laca e Ortega, 1996).

O bocado pode ser definido pelo momento que o animal remove a vegetação (Gibb, 1998). A quantidade de material removida do pasto a partir do bocado é uma função do volume de pasto coletado, limitado pela área do bocado e pela profundidade em que o animal insere sua boca no pasto (profundidade do bocado) (Cangiano, 1999). Os animais frequentemente pastejam a um ritmo de um bocado a cada 1-2 segundos (Carvalho et al., 2008), sendo que bovinos dispendem em média 0,68 segundos para completar um movimento mandibular (abrir e fechar a boca) (Laca et al., 1994). Nesse sentido, os herbívoros avaliam a relação custo: benefício entre a quantidade e a qualidade do alimento, para a realização do bocado dentro e entre os patches (Shipley, 2007). Em outras palavras, o custo de aquisição da forragem é sempre contraposto ao benefício em obtê-la (Prache, 1997). O sucesso com que os animais selecionam os alimentos terá impacto sobre o seu desempenho produtivo e reprodutivo (Provenza et al, 2015).

2.1 Monitoramento do comportamento ingestivo

O controle e monitoramento dos rebanhos em nível individual possibilita o controle sanitário e produtivo. Por exemplo, o uso de acelerômetros para identificar com antecedência e/ou na fase inicial de doenças como, acidose (Nogami et al., 2017), claudicação (Barwick et al., 2018a; Weigele et al., 2018), bem como o estro dos animais (Reith & Hoy, 2017), ciclos de amamentação em bezerros (Kour et al., 2018) e variáveis do comportamento ingestivo, como pastejo e ruminação (Andriamandroso et al., 2017; Barwick et al., 2018b; Guo et al., 2018). Desta forma, integrando o conhecimento de comportamento animal e a tecnologia podemos aumentar a eficiência dos sistemas produtivos.

Controlar o comportamento individual de forrageamento animal em pastagem significa monitorar os comportamentos de pastejo, ruminação e ócio, que juntos representam 90% a 95% do tempo diário. O restante do tempo, de 5 a 10%, são ocupados exibindo comportamentos sociais e outros (Walker et al., 2008). O monitoramento preciso do comportamento ingestivo dos animais é necessário para assegurar que os requisitos mais básicos de saúde e bem-estar animal sejam atendidos e consistentes com práticas que possam assegurar o uso sustentável e eficiente dos recursos forrageiros (Chelotti et al., 2016).

O monitoramento individual dos animais em pastejo é baseado no registro de três principais parâmetros: a localização do animal para identificar a estação de pastejo; a postura do animal que representa o elemento estático como a posição da cabeça ou das costas, e o movimento do animal, o elemento dinâmico que compõe um comportamento como mover as pernas ou a mandíbula (Andriamandroso et al., 2016). Os movimentos mandibulares podem servir como mensuração confiável dos distintos ciclos de pastejo e ruminação (Chelotti et al., 2016).

Os eventos mastigatórios podem ser classificados como bocado, quando a forragem é apreendida e cortada; mastigação, quando a forragem é fragmentada; e um movimento composto chamado mastigação-bocado, quando a forragem é cortada e fragmentada no mesmo movimento mandibular (Laca et al., 1992; Ungar e Rutter, 2006; Chelotti et al., 2018). Durante o pastejo, os eventos de bocado, mastigação e mastigação-bocado apresentam interrupções e são heterogeneamente distribuídos no tempo (Vanrell et al., 2018).

Há diferenças na formação do bocado entre as espécies de herbívoros no uso dos lábios (e.g. ovinos) e da língua (e.g. bovinos) para apreender forragem. A apreensão em bovinos é realizada com o auxílio de movimentos circulares da língua para agarrar a forragem na cavidade oral, antes de ser cortado, acompanhado de um movimento da cabeça (Galli et al., 1996). O movimento da cabeça em bovinos tipicamente envolve alguns movimentos circulares, enquanto em ovinos o movimento da cabeça é essencialmente para trás e para frente no eixo longitudinal do corpo (Chambers et al., 1981). E os bovinos podem direcionar o movimento da cabeça de acordo com a condição física da forragem apreendida (Hongo et al., 2003). Os ruminantes geralmente evitam materiais vegetais rígidos, de alta resistência estrutural, devido aos altos custos de manuseio e baixo valor nutritivo (Benvenutti et al., 2009).

Os movimentos mandibulares de animais em pastejo podem ser medidos por observação direta ou com gravações em vídeo. No entanto, essas metodologias são extremamente laboriosas e inviáveis para grandes rebanhos. Assim, desde a década de 50, pesquisadores vêm tentando desenvolver equipamentos e dispositivos para identificar, classificar e interpretar os movimentos mandibulares (Duckwort & Shirlaw, 1955). Para ser de uso prático, o monitoramento deve ser realizado de forma totalmente automática e não invasiva, de modo a não perturbar o comportamento normal do animal. Além disso, o sistema deve ser capaz de funcionar continuamente e realizar medições precisas durante dias ou semanas (Vanrell et al., 2018).

De acordo com Andriamandroso et al. (2016), os dispositivos automáticos utilizados para a detecção de movimentos mandibulares podem ser classificados em cinco grupos: interruptores de mandíbula, sensores de pressão, monitoramento acústico, acelerômetros e eletromiografia, sendo que os sensores de pressão e o monitoramento acústico são os mais utilizados para monitorar os movimentos mandibulares, e o uso de acelerômetros está aumentando rapidamente nos últimos anos. No decorrer do manuscrito, será realizada breve descrição dos sensores de monitoramento acústico, registrador de comportamento IGER e de acelerômetros.

A biotelemetria acústica foi usada pela primeira vez para registrar o comportamento de porcos-espinho em cativeiro (Alkon e Cohoen, 1986). Além de identificar a vocalização dos animais também foi possível detectar os componentes da alimentação (mastigação e bocado) em diferentes tipos de alimentos, e de forma remota. Desde então, o método de monitoramento acústico, utilizando microfones, tem sido aplicado para analisar os movimentos mandibulares ingestivos de ruminantes em pastejo, e permite contagens precisas do bocado, mastigações e eventos complexos de mastigação-bocado (Laca et al., 1992; Laca e Wallis De Vries, 2000; Galli et al., 2006; Ungar & Rutter, 2006; Galli et al., 2017; Vanrell et al., 2018. No entanto, este método apresenta alguns entraves, pois são propensos à interferência de fontes externas de som (Navon et al., 2013), com necessidade de automatização do método de monitoramento acústico (Chelotti et al., 2018).

Penning (1983) desenvolveu um transdutor de pressão que registra os movimentos mandibulares através de um sensor que fica localizado abaixo da maxila do animal. A resistência elétrica muda enquanto as maxilas abrem e fecham, e essas mudanças são registradas como um sinal analógico. Este equipamento permitia a identificação do tempo de pastejo, ruminação e ócio. Posteriormente, Penning et al. (1984) desenvolveram um algoritmo com informações do formato da onda para classificar os movimentos mandibulares em mastigação e apreensão. Posteriormente, Rutter et al., (1997) propuseram melhorias para o registrador de comportamento *IGER* (IGER), como registro digital do sinal elétrico e propôs o software GRAZE® (Rutter et al., 2000) para análise automática dos dados, que utiliza os critérios distância mínima entre dois picos e altura mínima do pico para identificar os movimentos mandibulares. E utiliza os critérios de formato do pico e a presença de um sub-pico ao pico principal para classificar os movimentos mandibulares como bocado e mastigação (Rutter et al., 2000). O procedimento apresentou concordância média de 91% comparado com observações visuais dos eventos de mastigação e bocado. No entanto, Ungar & Rutter (2006) identificaram que o IGER superestimou a taxa de bocados em todas as sessões de pastejo, com média de 24,6%, variando de 8,8% a 58,1%. Além de erroneamente classificar mastigação como bocado durante o pastejo, também identificou bocados durante os *bouts* de ruminação.

Inúmeros trabalhos vêm sendo realizados utilizando acelerômetros, com um ou mais eixos, para identificar o comportamento ingestivo (Alvarenga et al., 2013; Vanrell et al., 2018; Tani et al., 2013; Oudshoorn et al., 2013; Nielsen, 2013). Em trabalho pioneiro, Chambers et al. (1981) avaliaram a qualidade de transdutores (Figura 2) adaptados a ovinos e bovinos para descrever os movimentos mandibulares e da cabeça associados ao pastejo e ruminação, em pastagem de *Lolium perenne*. Os autores observaram que o formato das ondas da saída do acelerômetro durante o pastejo foram semelhantes entre ovelhas e vacas, com taxa de variação de aceleração e valor dos picos maiores em ovinos (7.5 a 8.8 m/s^2) comparado a bovinos (4.5 a 5.2 m/s^2), e a proporção de movimentos mandibulares representados pelo movimento de cabeça sempre foi maior, tanto para ovinos como para bovinos. No entanto, a taxa de bocados (movimentos de cabeça) foi significativamente menor em dossel mais alto do que em dossel mais baixos, demonstrando potencial de utilizar esse tipo de dispositivo para registrar a taxa com que os bocados são realizados.

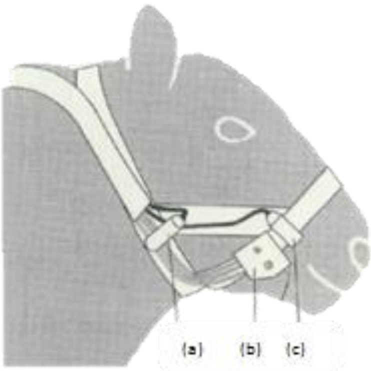

Figura 2: Posicionamento de um (a) interruptor de mercúrio, (b) interruptor mandibular e (c) do acelerômetro no lado direito do buçal de um ovino (Chambers et al., 1981).

Dispositivos contendo unidades de medida inercial que compreendem dois ou três sensores registram a velocidade, orientação e força gravitacional usando acelerômetros e giroscópios (tipo I) (Ahmad et al., 2013). Em dispositivos mais recentes (Tipo II), um magnetômetro é adicionado para medir o desvio magnético (rotação do ângulo de *yaw*) melhorando as medidas do giroscópio. Os IMUs podem medir muitos parâmetros físicos dentro de três eixos, como aceleração linear, ângulo de rotação (*pitch, roll* e *yaw*) e velocidade angular (Ahmad et al., 2013). As IMUs são consideradas vantajosas quando comparado com os sensores eletromecânicos individuais, pois os pontos fortes de cada componente individual podem ajudar e compensar as limitações de outro (Schall Jr. et al., 2016).

Os celulares, particularmente o iPhone, podem ser instrumentos relevantes para pesquisadores porque estão prontamente disponíveis no planeta, contêm muitos sensores e não necessitam de desenvolvimento de hardware (Debauche et al., 2018). Bem como, esses dispositivos são equipados com sensores de movimento e localização capazes de gravar sinais em alta frequência (Tabela 1), apresentando grande potencial para identificar o comportamento ingestivo com precisão (Andriamandroso et al., 2017).

Tabela 1: Lista de sinais capturados pela IMU do iPhone 4S/5S usando o aplicativo SensorData® (Adaptado Debauche et al., 2018).

Sensor	**Sinal**	**Unidade**
Acelerômetro	Aceleração em x, y e z	Gravidade
Giroscópio	Ângulo de Euler (pitch, roll, yaw)	Radiano
	Atitude quatérnions em x, y e z	Radiano
	Matriz de rotação [3x3]	-
	Componente gravitacional da aceleração em x, y e z	Gravidade
	Componente do usuário da aceleração em x, y e z	Gravidade
	Taxa de rotação em x, y e z	Radiano por segundo
Magnetômetro	Dados magnéticos	μT
	Rumo magnético e verdadeiro	-
Localização	Latitude e longitude	-
	Altitude e acurácia	Metros
	Curso	Metros
	Velocidade	Metros por segundo
	Sensor de proximidade	[0,1]

Andriamandroso et al. (2017) desenvolveram um algoritmo de código aberto que identifica com precisão os eventos de pastejo e ruminação de bovinos, ao interpretar unidades de medida inercial capturadas e armazenadas pelo aplicativo SensorData® instalado em iPhone 4S. O princípio discriminatório entre as atividades de pastejo e ruminação é baseado na posição da cabeça do animal (para baixo ou para cima) e a intensidade dos movimentos mandibulares.

Desta maneira, a hipótese é que a unidade de medida inercial registradas durante a atividade de pastejo permitirá detectar com acurácia os bocados desferidos por ruminantes em pastejo, bem como, permitirá detectar a influência da estrutura do dossel na qualidade de detecção dos bocados pelos métodos IMU e o registrador de comportamento IGER.

3. HIPÓTESE

1) Ao isolar as sequências onde o animal está realizando somente a atividade de pastejo é possível detectar com acurácia os bocados desferidos no pasto através do registro de unidade de medida inercial (IMU).
2) A estrutura do dossel influencia a qualidade de detecção dos bocados pelo método IMU, sendo que o IMU tem a mesma capacidade de detectar bocados que o IGER.

4. OBJETIVOS

1) Desenvolver um algoritmo de código aberto dedicado a interpretar sinais de unidade de medida inercial para identificar os bocados desferidos durante a atividade de pastejo;
2) Avaliar o efeito de diferentes estruturas do pasto sob a qualidade de detecção dos bocados desferidos por bovinos pelos métodos IMU e IGER.

CAPÍTULO II

Article prepared according to the norms of the Computers and Electronics in Agriculture (Appendices)

An open-source algorithm allows detecting bites by grazing cattle equipped with inertial measurement units of commercial-grade smartphones

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Abstract

Bite scale constitutes the elementary level of the interaction between grazing animals and the forage. The aim was developed an open-source algorithm allows detecting bites by grazing cattle using the inertial measurement unit (IMU) of a smartphone with signals recording data at 100 Hz. The signals of the rotation rate along the y and x axis (Ry and Rx, respectively) and user acceleration along the y and x axis (Uy and Ux, respectively) were tested. The main parameters that were considered are the minimum value of each peak (h) and the minimum interval between two peaks (d) fixed in 0.4 second. From the calibration data set, the percentage of bites correctly detected when compared to observed was higher for the rate of rotation along the y-axis with h = 0.2 and h = 0.3 rad. s^{-1} (82 and 85%) in relation to the other signals (Rx, Uy and Ux). After the validation of the algorithm, there were no differences between the values of h for the percentage of correctly detected bits and the false positive rate. There were differences for the false negative rate, where h = 0.2 obtained the lowest rate (2.88%). The y-axis rotation rate obtained the best results for detecting bites

Keywords: cattle, grass intake, pasture, sensor, bites

1. Introduction

Grasslands are unique components of agroecosystems. They cover 26% of total land and 69% of agricultural areas in the world supporting grazing livestock as the least expensive way to feed ruminants such as cattle, for both milk and meat productions (O'Mara, 2012). Traditional pasture management uses static tools. It is based on the balance between pasture production and its usage by the animal by manipulating variables such as stocking rate, type of animals or type of grazing method (Carvalho et al., 2018, Holechek et al., 2011). However, since both plants and animals are complex dynamic components of the grazing process. Farmers who rely on pastures require new tools specifically targeted at the accurate measurement of pasture biomass, its nutritional value and valorization by ruminants and how they change in time (French et al., 2015).

Concerning the monitoring of grazing behavior at its individual level, there are advances in sensor technology allowing remote monitoring of many physical variables for research or practical farm level applications (Berckmans, 2014). Different type of sensors are proposed to automatically detect behaviors such as grazing, ruminating, resting, and walking from recordings of posture, movements and location of animals (Andriamandroso et al., 2016). As grazing combines spatially and temporally variable movements and activities, more attention should be paid to the smallest scale of this process, the bite, as it determines intake regulation of the animal from the short term intake on a feeding station to the exploitation of an entire paddock over a whole grazing season (Ungar et al., 2006; Carvalho, 2013; Andriamandroso et al., 2016).

The combination of bite rate, bite mass, and time spent grazing allows the calculation of intake (Spalinger and Hobbs, 1992) which is actually the least accurately measured variable in the whole grazing process (Hills et al., 2016). Although, it is the most important one. To identify bites and chews, jaw movements can be detected over time-windows ranging from seconds to minutes using pressure, associated with changes in electrical resistance (Rutter et al., 1997; Rutter, 2000), acoustic (Chelotti et al., 2018), electromyography (Rus et al., 2013) or accelerometer sensors (Oudshoorn et al., 2013).

In this way, the hypothesis is that the inertial measurement unit recorded during the grazing activity will to accurately detect the bites of grazing ruminants. For this purpose, building on the open-source algorithm classifying grazing and ruminating behaviors of cattle based on signals acquired from an inertial measurement unit (IMU) (Andriamandroso et al., 2017), we developed a complementary analysis protocol to detect automatically bites performed when cow grazing mixed temperate pastures.

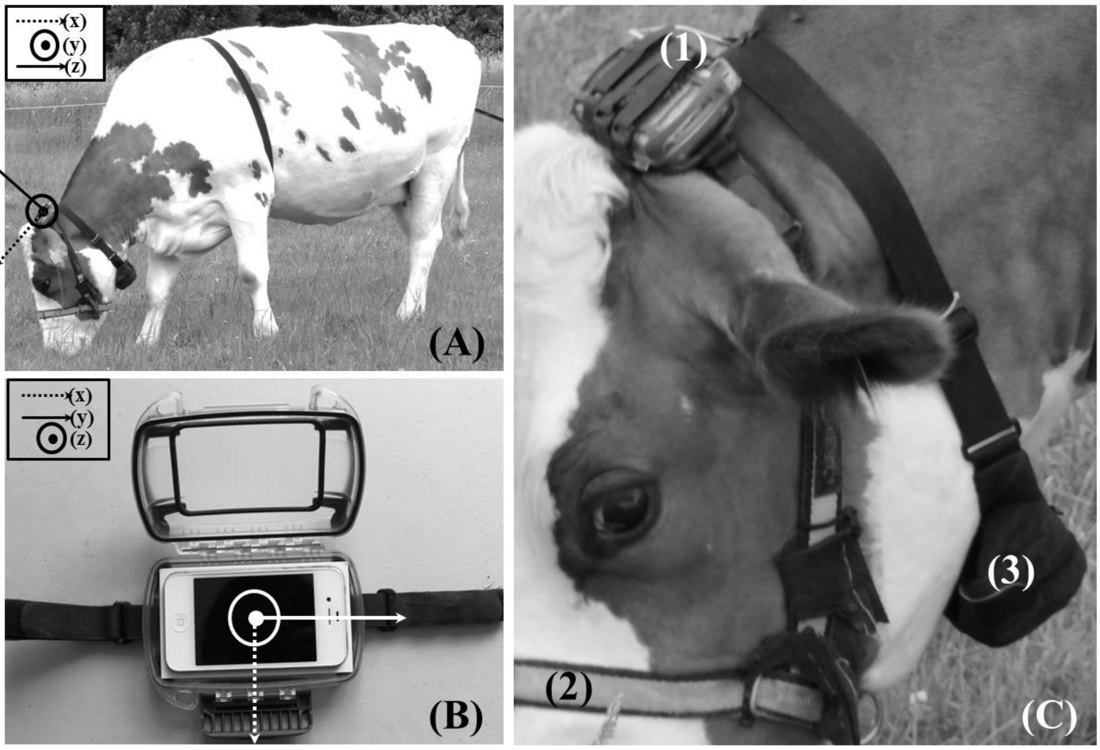
2. **Material and methods**

All experimental procedures performed on the animals were approved by the Committee for Animal Care of the University of Liège (Belgium, experiment n°14-1627).

2.1 Data acquisition and grazing experiments

A grazing experiment was performed in May 2017 on the dairy farm of the Centre des Technologies Agronomiques (Strée, Belgium). Eight dairy cows with weight 580 ±40, production of 18l of milk and with 314 days in lactation (in average), were set to graze a pasture dominated by perennial ryegrass (*Lolium perenne*), rough meadow grass (*Poa trivialis*), dandelion (*Taraxacum* spp.) and white clover (*Trifolium repens*), with average height 7.9 ± 2.63 cm. The animals entered in the paddock at 9 AM and stayed for 24 hours.

As described by Andriamandroso et al. (2017), during experiments each cow was fitted with a halter containing an iPhone 4S (Apple, Cupertino, CA, USA) inside a waterproof box (Otterbox Pursuit series 20, 152.4 × 50.8 × 101.6 mm, 142 g, Otter Products, LLC, USA) (Figure 1B). Each mobile phone was equipped with SensorData (Wavefront Labs) downloaded from Apple Store (Apple, Cupertino, CA, USA) which captures and stores data from the IMU of the iPhone at 100 Hz. The IMU of the iPhone 4S uses STMicro STM33DH 3-axis as an accelerometer, STMicro AGDI 3-axis as a gyroscope (STMicroelectronics, Geneva, Switzerland) and AKM 8963 3-axis electronic compass as a magnetometer (Asahi Kasei Microdevices Corporation, Tokyo, Japan). To extend the data recording duration from 8 to 24 hours, the original 3.7V 1420mAh Li-Polymer battery was connected to an additional external battery (Anker Astro E5 16000mAh portable charger, 150 × 62 × 22 mm, 308 g, Anker Technology Co. Limited, CA, USA) and attached as a collar around the neck of the animal (Figure 1C).



(1) Box containing the iPhone, (2) Halter, (3) Bag containing a supplementary battery

Figure 1: Inertial measurement unit (IMU) device description, (A) IMU 3-D axis representation on a grazing cow, x-axis is aligned with the tail to head symmetry axe of the animal, y-axis describes lateral movements (right-left), and z-axis gives up and down movements; (B) iPhone 4S and its IMU placed in a waterproof box; (C) all equipment components including the iPhone box (1), the halter (2) and the supplementary battery (3).

Video recording sessions of cattle behaviors were performed. Eight videos were taken to allow the development of the algorithm for bite detection by zooming on the head of the cows during the recording sessions.

2.2. Data analysis

2.2.1. Detection of grazing behaviors

Cattle grazing behaviors were determined using an open-source algorithm dedicated to interpreting IMU signals from iPhone into behaviors: grass intake (GRA), ruminating (RUM) and others (OTHERS) (Andriamandroso et al., 2017).

2.2.2. Detection of bites

During the grazing experiments, eight fifteen minutes videos were observed in total using CowLog 3.0.2 (Pastell, 2016) at two times slower than the normal speed. Each bite performed by the cow was recorded and it constituted the basis of the detection (matrix of observation, MO). A bite was considered as the action performed by the cow when she uproots the grass from the ground (Gibb, 1998). The time spent searching, masticating and swallowing the grass was not taken in account as bite although these activities are part of the grazing behavior.

The complete dataset was then divided into two, one for calibrating the detection algorithm exclusively and the other for its validation. The choice of the IMU signal corresponding to each observed bite was made with two fifteen-minute videos dedicated for building and calibration of the algorithm. A bite was observed to be represented by a peak in the time-domain series of rotation rate signal along the y- and x-axis and user acceleration signal along the y and x-axis of the IMU (Figure 1). in order to clean the raw signal and keep only the peaks related to grazing jaw movements, the Fast Fourier Transform was applied to identify the frequency range with the greatest amplitude**.** This frequency range was isolated by a second order Butterworth bandpass filter. That way, Ry was filtered between 0.5 Hz and 2 Hz, Rx was filtered between 0.5 Hz and 1.5 Hz, Uy was filtered between 1 Hz and 4 Hz, and Ux was filtered between 1 Hz and 2 Hz.

An automated detection of each of the hypothetical bites, thus of each peak, was afterwards performed in Matlab R2015a (Mathworks, NL) creating the matrix of detected bites using the “findpeaks” function. The parameter peak height or amplitude, noted as *h*, was firstly assessed with the calibration dataset and minimum time distance between two consecutive peaks *d* fixed to 0.4 seconds. Bite rates are usually close to 1 bite s^{-1} but to avoid missing bites, we prioritized the detection of more presumed peaks and chose the minimal possible value of distance with two peaks as half of the normal average distance of 0.8 second (Rutter et al., 2002).

Following the determination of *h*, the main purpose of the method was the reduction of the distance between observed and detected peaks. To match a detected peak with an observed one, differences between matrix of observed bites and matrix of detected bites were assessed using k-nearest neighbors method to find the minimum delay between two peaks from matrix of observed bites and matrix of detected bites. As one observed bite must correspond to one detected bite, all peaks with too long delay compared to observation (>0.5 second) were eliminated and classified into false positive (representing incorrectly detected bites while there is no bite observed on the video at that moment) or false negative (representing incorrectly undetected bites while they are observed on the video).

The quality of the detection was assessed with the validation dataset composed of six independent grazing sequences by comparing observed with detected bites in order to obtain the highest percentage of correctly detected bites (%Correctly = 100-(FPR+FNR)). False positive rate (FPR=100*(FP/(FP+TN) and false negative rate (FNR=100*(FN/ (FN + TP) completed the quality assessment of the algorithm.

2.3. Statistical analyses

Analyses of variance (ANOVA) for variables of FNR, FPR and %Correctly was performed with JMP software (v.14.0., SAS Institute Inc., Cary, NC, USA) and when presented significance effect, test *t* Student was used at level of 5%.

3. Results

3.1. Bites detection

3.1.1. Determination of parameters for bites detection

The observed increasing signal, represented by a peak (Figure 2), is considered as a response to the abrupt head movement in addition to the jaw movement associated to the severing of the grass, which is theoretically a bite. Although it is distinguishable at low speed and when reconstruction of the signal after the filter was applied, the exact time of a bite might have some delay. To detect the peak, the main parameter that should be considered were the minimum value of each peak (*h*) and the minimum fixed distance (*d*) of 0.4 seconds.

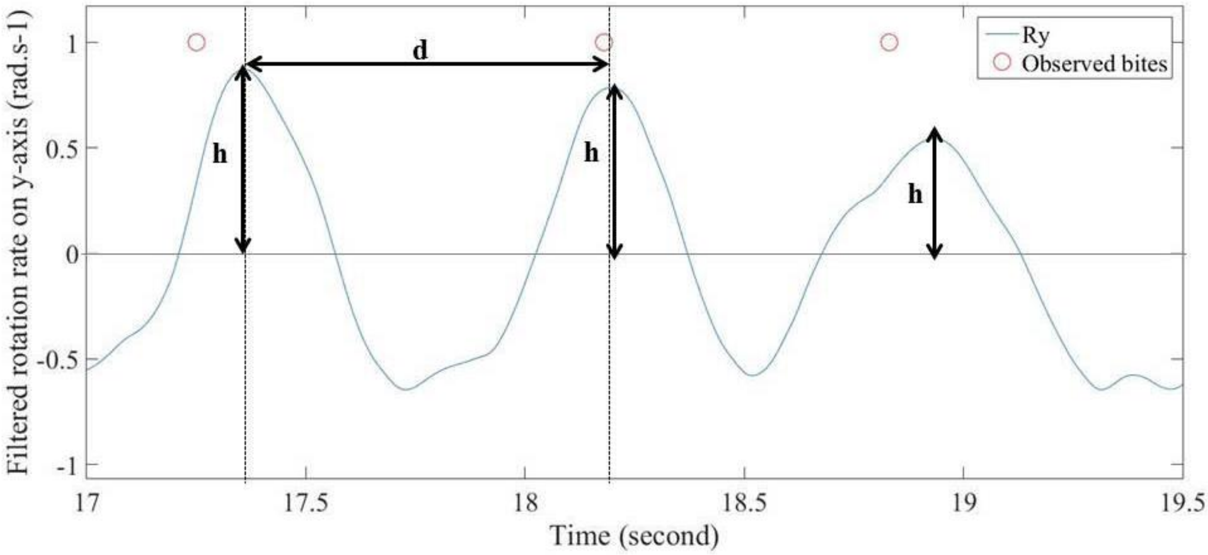


Figure 2: Example of the correspondence between location in time of observed bites and the presumed peaks observed in the rotation rate along the y-axis (Ry) of the IMU placed on the neck of a cow.

From the observed peaks, different values of *h* were tested in order to have the best detection of the bite. The amplitudes of *h* tested were different for each signal. Values used were chosen from the lowest possible value when visualizing the signals from the calibration data set, and the highest value was selected so that the maximum rate of correctly detected bite was achieved.

Table 1 details the percentage of correctly detected bites when compared to the reality on calibration dataset. From these results, the rotation rate along y-axis on the h=0.2 e h=0.3 rad.s^{-1} was used for bite detection on validation dataset.

Table 1: Comparison of different signals and different minimum peak heights in terms of percentage of correctly detected bites when compared to observations (N=300 bites; Cow: 6631 e 5444).

signal	*h*	%Correctly
Rotation rate y-axis (rad.s^{-1})	0.1	78.58
	0.2	85.39
	0.3	82.88
	0.4	79.22
Rotation rate x-axis (rad.s^{-1})	0.1	74.55
	0.2	73.99
	0.3	71.73
	0.4	72.91
User acceleration y-axis (g)	0.02	69.28
	0.04	67.00
	0.06	67.59
	0.08	70.66
	0.1	68.77
User acceleration x-axis (g)	0.01	71.28
	0.02	73.21
	0.03	76.75
	0.04	76.01
	0.05	78.46

3.2. Peak detection quality

Using the most promising signal previously determined (i.e. the rotation rate along the y-axis), false positive rate, false negative rate and the percentage of bites detected correctly applied was evaluated in the independent validation database reported in Table 2.

Table 2: Assessment of the quality of bite detection by finding peaks on Ry signal compared to observation using three parameters with the validation dataset (N=6).

cow	h (rad.s^{-1})	observed bite	detected bite	FNR[1]	FPR[2]	%Correctly[3]
5423	0.2	291	365	3.02	23.01	73.97
	0.3		320	6.98	16.56	76.48
5457	0.2	598	646	4.63	8.20	87.17
	0.3		623	15.57	7.06	77.36
5478	0.2	515	614	0.78	16.78	82.45

	0.3		569	5.6	14.6	79.8
6636	0.2	684	737	2.78	9.77	87.45
	0.3		650	11.99	7.38	80.63
1514	0.2	443	466	2.03	6.87	91.10
	0.3		395	14.22	3.8	81.98
5432	0.2	392	435	4.08	13.52	82.36
	0.3		352	16.07	6.53	77.39

1) FNR: false negative rate representing incorrectly detected bites while there is no bite observed on the video at this moment. 2)FPR: false positive rate representing incorrectly undetected bites while they are observed on the video. 3) %Correctly: percentage of correctly detected bites.

Table 3: Analyses of variance of minimal height peaks (average of all animals evaluated) using three parameters with the validation dataset.

Height ($rad.s^{-1}$)	FNR[1]	FPR[2]	%Correctly[3]
0.2	2.88	13.02	84.08
0.3	11.74	9.32	78.94
P value	0.0009	0.2784	0.0755

1) FNR: false negative rate representing incorrectly detected bites while there is no bite observed on the video at this moment. 2)FPR: false positive rate representing incorrectly undetected bites while they are observed on the video. 3) %Correctly: percentage of correctly detected bites.

There was no difference between heights of the peaks of 0.2 and 0.3 for the variables %Correctly and FPR. For the variable FNR was different between the height with 0.2 presented a mean value of 2.88 and 0.3 a mean value of 11.73%. This result shows that only 2.88% of observed bite were not detected by IMU. The procedure detailing the bites detection is presented on Figure 2 and descript in appendices 1.

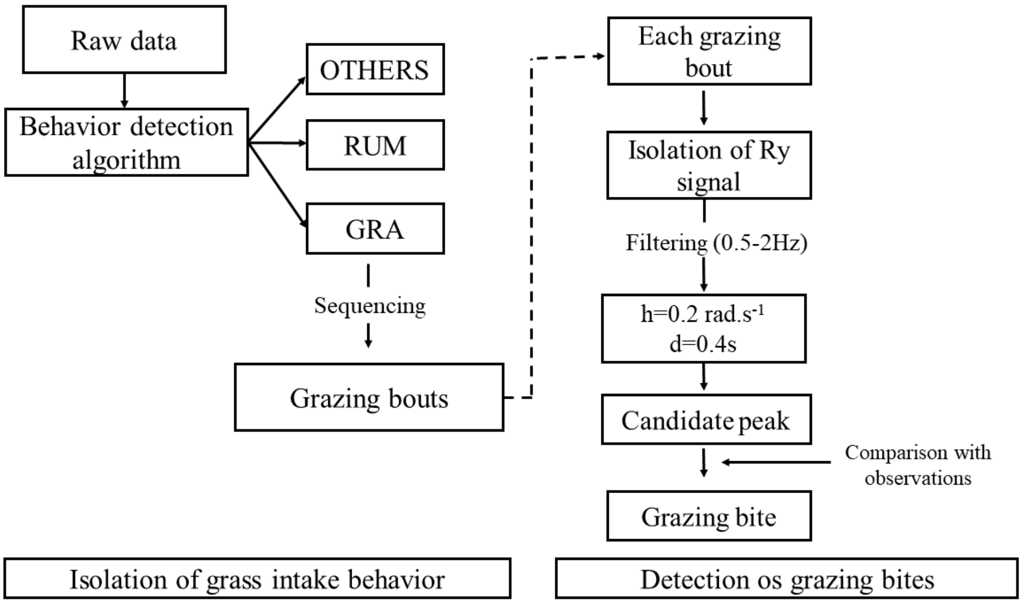


Figure 3: Grazing bites detection process starting from isolation of grass intake behavior sequences and validation by comparison with observations.

4. Discussion

The method of detecting bites is performed in two steps. A detection of forage intake behavior performed before detecting individual bites, identifying each time sequence this behavior was performed. Most of the head movements during the search for new feeding stations are not included because of the use of the simultaneous criteria of the gravitational acceleration signals along the x-axis and rate of rotation along the y axis, so limiting the movements performed to the apprehension of forage (head down) (Andriamadroso et al., 2017). In the second step for the bite detection algorithm, the 'findpeaks' function of MatLab was applied with the 0.4 seconds fixed distance criteria between two peaks (*d*) and the minimum height of the peak (*h*). However, when the *h* and *d* criteria were simultaneously applied, the "findpeaks" function did not identify peaks with values higher than 1 rad.s^{-1}. Thus, for several grazing sequences it was necessary to perform the peaks in two stages. First selecting all peaks with less than 0.99 rad.s^{-1}. Secondly, selecting all the peaks greater than 1 rad.s^{-1}. However, this problem did not compromise the quality of detection of peaks in the time domain. The maximum amplitude of the Ux and Uy signals did not show values above 0.99 g because these signals have a lower amplitude. Hence, all peaks could be correctly detected by the “findpeaks” function.

Herbage prehension in cow is performed with circular movements of the tongue to grasp the forage into the oral cavity, before being severed, accompanied by a head movement (Galli et al., 1996). The lips, the teeth as well as the tongue, are all used to grab and move the forage into the mouth (Phillips, 2002). It results in typical circular movements of the head (Chambers et al., 1981) and some are longitudinal to the animal body. Rotation rate along the y-axis presented higher correctly detected bites compared to other tested signals (Table 1) because Ry registers the angular velocity of the head movements, which is the better representation of the movements related to the bites performed.

Therefore, the way of the bite formation influences the quality of detection. Since a wide circular movement of the head occurs, all observed bites are detected, but when an observed bite is characterized by a short, sharp jerk of the animal's head, it may not be recorded or be represented by a peak of small amplitude, not detectable by the algorithm within values of *h* 0.2 (corresponding to FN). This bite is characterized by a small apprehension of the leaf blade and its frequency is heterogeneous in time. In addition, the smaller peaks (<0.199 rad.s^{-1}) are head movements before the bite is realized, perhaps related to herbage manipulation. In this sense, there is a trades-off between the identification of all observed bites beyond the movements of the head associated to the herbage manipulation (corresponding to FP).

The percentage of correctly detected bites ranged between 76.5 to 91.1%, largely due to presence of the FP, because during a grazing sequence some head movements are related to the search of new locations, inside and between feeding stations, to perform the bite. These detected peaks show similarity to the bite peak, both in shape and height (*h*).

Jaw movements performed by the GRAZE software (Rutter et al., 1997; Rutter, 2000) allows to classify a bite when the main peak followed by a small subpeak. For chewing, the peaks are more symmetrical in shape, with equal rise-times and fall-time (Rutter, 2000), nevertheless, there is an overestimate average rate of 24.6% due to incorrect classification of the chews as a bite (Ungar and Rutter, 2006).

The simultaneous use of the open algorithm for detection of ingestive behavior (GRA, RUM), and the detection bite algorithm, allows for a complete description of the ingestive behavior. It is accurate to provide information from daily scales (meals) to the finer scale, the bite. It can be used to improve understanding of the interactions between plants and herbivores.

5. Conclusion

The signal rotation rate y-axis is the better representation of the movements related to the bites performed.

The algorithm developed was able to identify bites performed by grazing cattle, with accuracy between 76.5 to 91.1%.

6. References

Andriamandroso, A.L.H., Bindelle, J., Mercatoris, B., and Lebeau, F. 2016. A review on the use of sensors to monitor cattle jaw movements and behavior when grazing. Biotechnol. Agron. Soc. 20, 273-286.

Andriamandroso, A.L.H., Lebeau, F., Beckers, Y., Froidmont, E., Dufrasne, I., Heinesch, B., Dumortier, P., Blanchy, G., Blaise, Y., Bindelle, J., 2017. Development of an open-source algorithm based on inertial measurement units (IMU) of a smartphone to detect cattle grass intake and ruminating behaviors. Comput. Electron. Agr. 139, 126-13.7

Berckmans. D., 2014. Precision livestock farming technologies for welfare management in intensive livestock systems. Rev. sci. tech. Off. Int. Epiz. 33, 1, 189-196.

Carvalho, P.C.F., 2013. Harry Stobbs Memorial Lecture: Can grazing behavior support innovations in grassland management? Trop. Grassl. 1, 137-155.

Carvalho, P.C.F., Barro, S.B., Barth Neto, A., Nunes, P.A.A., Moraes, A., Anghinoni, I., Bredemeier, C., Bayer, C., Martins, A.P., Kunrath, T.R., Santos, D.T., Carmona, F.C., Barros, T., Souza Filho, W., Almeida, G.M., Caetano, L.A.O., Cecagno, D., Arnuti, F., Denardin, L.G.O., Bonetti, J.A., Toni, C.A.G. and Moraes, J.B., 2018. Integrating the pastoral component in agricultural systems. R. Bras. Zootec. 47-59.

Chambers, A.R.M., Hodgson, J. and Milne, J.A.,1981. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. Grass Forage Sci. 36, 97-105.

Chelotti, J.O., Sebastian R., Vanrell, S.R., Galli, J. R., Giovanini l.L. and Rufiner L.H., 2018. A pattern recognition approach for detecting and classifying jaw movements in grazing cattle. Comput. Electron. Agr. 145, 83-91.

French. P., O'Brien. B. and Shalloo. L., 2014. Precision technology for pasture management. In Proceedings of the 5th Australasian Dairy Science Symposium 2014. 326-331.

Galli, J.R., Cangiano, C.A. and Fernández, H.H., 1996. Comportamiento ingestivo y consumo de bovinos en pastoreo. Rev. Arg Prod. Anim., 16, 9-42.

Gibb. M.J., 1998. Animal grazing/intake terminology and definitions. In: Proceedings of pasture ecology and animal intake workshop for concerted action AIR3-CT93-0947. 24-25 September 1998. Dublin. Ireland. 20-35.

Hills, J.L., Rawnsley, R.P., Harrison, M.T., Bishop-Hurley, G.J., Henry, D.A., Raedts, P., Freeman, M. and Roche, J.R., 2016. Precision feeding and grazing management for temperate pasture-based dairy systems. In: Kamphuis, C. and Steenveld, W., (eds.), Precision Dairy Farming 2016, Proceedings of Precision Dairy Farming 2016 Conference, Leeuwarden, The Netherlands. Wageningen Publishers, The Netherlands. pp. 25-32.

Holechek J.L., Pieper R.D. and Herbel C.H., 2011. Range management. Principles and practices. 6th edition. Prentice Hall. Boston. USA.

O'Mara, F.P., 2012. The role of grasslands in food security and climate change. Ann. Bot. 110, 1263-1270.

Oudshoorn, F.W., Cornou, C., Hellwing, A.L.F., Hansen, H.H., Munksgaard, L., Lund, P. and Kristensen, T., 2013. Estimation of grass intake on pasture for dairy cows using tightly and loosely mounted di- and tri-axial accelerometers combined with bite count. Comput. Electron. Agric., 99. 227-235.

Phillips, C. 2002. Cattle Behaviour and Welfare. 2nd ed. John Wiley & Sons, Blackwell Science, Oxford, UK.

Pastell, M., 2016. CowLog – Cross-Platform Application for Coding Behaviours from Video. J. Open Source Softw. 4, 1, 15.

Rossi, R., 2013. Facts and figure on organic agriculture in the European Union. Report of Agriculture and Rural Development. Unit Economic Analysis of EU Agriculture. European Union. 2013.

Rus, M.A., Wobschall, A., Storm, S. and Kaufmann, O., 2013. DairyCheck – a sensor system for monitoring and analysis of the chewing activity of dairy cows. LandTechnik, 8, 6, 395-398.

Rutter, S.M., Orr, R.J., Penning, P.D., Yarrow, N.H., Champion, R.A., 2002. Ingestive behaviour of heifers grazing monocultures of ryegrass or white clover. Appl. Anim. Behav. Sci.,76,1-9.

Rutter, S.M., 2000. Graze: a program to analyze recordings of the jaw movements of ruminants. Behav. Res. Meth. Instrum. Comput., 32, 1, 86-92.

Rutter, S.M., Champion R.A. & Penning P.D., 1997. An automatic system to record foraging behaviour in free-ranging ruminants. Appl. Anim. Behav. Sci., 54, 185-195.

Spalinger, D.E., Hobbs, N.T., 1992. Mechanisms of foraging in mammalian herbivores: new models of functional response. Am. Nat. 140, 325–348.

Ungar, E.D., Ravid, N., Zada, T., Bem-Moshe, E., Yonatan, R., Baram, H. and Genizi, A., 2006. The implications of compound chew–bite jaw movements for bite rate in grazing cattle. Appl. Anim. Behav. Sci. 98, 183–195.

Ungar, E.D., Rutter, S.M., 2006. Classifying cattle jaw movements: comparing IGER Behaviour Recorder and acoustic techniques. Appl. Anim. Behav. Sci. 98, 11–27.

CAPÍTULO III

Artigo preparado de acordo com as normas da revista Computers and Electronics in Agriculture (Apêndices 2)

Avaliação do método de unidade de medida inercial (IMU) para detecção de bocados de ruminantes em pastejo

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Resumo

O objetivo do estudo foi avaliar se diferentes estruturas de pasto podem influenciar na qualidade de detecção dos bocados pelos métodos IMU (unidade de medida inercial) e IGER (Registrador de comportamento IGER). O experimento foi conduzido na Estação Experimental da Universidade Federal do Rio Grande do Sul, Brasil, em maio de 2018. Os tratamentos consistiram em diferentes alturas do pasto: 20, 40 e 60 cm, em pastagem de *Urochloa brizantha* cv Marandu. As diferentes alturas influenciaram de forma linear e negativa a qualidade de detecção dos bocados. Não houve relação entre a altura do pico (taxa de rotação ao longo do eixo y) e a massa dos bocados. No entanto, a altura do pico diminuiu com o aumento da altura do pasto. Quando comparados os métodos de detecção de bocados, o método IMU foi superior ao IGER nos tratamentos de 20 e 60 cm, não havendo diferença no tratamento de 40 cm. A detecção de bocados no pasto mais alto, de 60 cm, foi a menos acurada em ambos os métodos de detecção aplicados. Os resultados demonstram que a estrutura do pasto influencia a qualidade de detecção dos bocados, e que o método IMU é superior ao IGER na amplitude de estrutura de pastos estudadas.

Palavras chave: bovinos, massa do bocado, taxa de bocados, sensor

Abstract

The objective was to evaluate if different pasture structures can influence the quality of detection of the bites by IMU and IGER (IGER Behavior Register) methods. The experiment was conducted at the Experimental Station of the Federal University of Rio Grande do Sul, Brazil, in May 2018. Treatments consisted of different pre grazing intended sward heights (20, 40 and 60 cm) of *Urochloa brizantha* cv Marandu pasture. The different sward height influenced in a linear and negative way the detection quality of the bites. There was no relationship between peak height (rate of rotation along the y axis) and mass of the bites, however, the height of the peak decreased with increasing of sward height. When comparing the methods of detection of bites, the IMU method was superior to the IGER in the treatments of 20 and 60 cm, without differences in the treatment of 40 cm. The treatment with 60 cm of height of the sward was lower accurate in the detection of the bites in the two methods of detection applied. Therefore, the structure of the pasture influences the detection quality of the bites. The IMU method was effective in detecting bites in grazing experiments. The IMU method is greater than the amplitude of IGER studied pastures structure.

Keywords: bite mass, bite rate, cattle, sensor

1. Introdução

Pastejo é um processo complexo pelo qual os herbívoros buscam seus alimentos, e caracteriza-se pelas ações do animal na busca, seleção e colheita da forragem. O bocado é o átomo do processo de pastejo (Laca e Ortega, 1996), e resulta de uma série complexa de decisões tomadas pelo animal (Carvalho et al., 2018). A linha de tempo da atividade mandibular permite que a duração e o padrão diurno do comportamento animal sejam inferidos, e é um meio importante para compreender a mecânica do processo de pastejo (Ungar e Rutter, 2006).

Mudanças na estrutura do pasto têm como causa o pastejo. De forma concomitante, a estrutura do pasto afeta o processo de pastejo, disso decorrendo um ciclo contínuo de relação causa-efeito (Carvalho et al., 2016). Os animais interagem com a estrutura do pasto ajustando as dimensões do bocado (Prache et al., 1997). A taxa com que os bocados são formados, e sua massa, são determinantes da taxa de ingestão de curto prazo pelos herbívoros (Laca, 2001) e parâmetros para identificar a estrutura ótima que maximiza a colheita do pasto pelos animais. Portanto, o monitoramento do comportamento em pastejo deve possibilitar o rastreamento indireto da condição do pasto e a utilização dessas informações na tomada de decisões (Ungar et al., 2018).

Dentre as diferentes metodologias de avaliação do processo de pastejo, a observação visual (Altman, 1974, Agreil e Meuret, 2004, Bonnet et al., 2015) é tida como laboriosa e impossibilita o acompanhamento de vários animais. Como alternativa, sensores individuais ou combinados podem identificar o comportamento ingestivo dos animais. Sensores de pressão, como o registrador de comportamento IGER (Rutter, 2000; Ungar e Rutter, 2006), identificam eventos de bocados e outros movimentos mandibulares. Já o monitoramento acústico (Laca e WallisDeVries, 2000; Chelotti et al., 2018) apresenta sensibilidade na identificação de eventos de bocado, mastigação e mastigação-bocado. Nos últimos anos, o uso de acelerômetros tem crescido devido aos avanços tecnológicos, a redução do tamanho dos equipamentos e dos custos para implementação. Eles têm diferentes aplicações, tais como na saúde animal (Weigele et al., 2018), no manejo reprodutivo (Reith e Hoy, 2017), e mais recentemente na identificação dos comportamento ingestivo (Guo et al., 2018; Peng et al., 2019; Andriamandroso et al, 2017). Por exemplo, Oudshoorn et al. (2013) investigaram o uso do acelerômetro para estimar o tempo de pastejo, que foi posteriormente combinado com dados de frequência de bocados para modelar a ingestão de pasto.

Segundo Ahmad et al. (2013), é possível utilizar uma combinação de sensores, tais como acelerômetro, giroscópio e magnetômetro, que compõem a unidade de medida inercial (IMU). A IMU permite a identificação da velocidade linear e angular dos movimentos de cabeça relacionados com os bocados desferidos. Desta maneira, a hipótese é que a unidade de medida inercial registradas durante a atividade de pastejo permitirá detectar com acurácia os bocados desferidos por ruminantes em pastejo, bem como, permitirá detectar a influência da estrutura do dossel na qualidade de detecção dos bocados pelos métodos IMU e o registrador de comportamento IGER.

Portanto, este trabalho teve como objetivo testar a qualidade de detecção dos bocados de animais pastejando pastos de braquiária. Uma ampla faixa de alturas de pasto procurou provocar situações extremas de tipos de bocado. Por ter desempenho conhecido e estar sendo utilizado há muitos anos, utilizou-se o IGER behaviour recorder para fins de contraste de desempenho de sensores na detecção dos bocados.

2. Material e Métodos

Todos os procedimentos experimentais realizados nos animais foram aprovados pelo Comitê de ética do uso de animais da Universidade Federal do Rio Grande do Sul (Brasil, protocolo de n ° 33970)

O experimento foi desenvolvido na estação experimental da Universidade Federal do Rio Grande do Sul localizada em Eldorado do Sul, Brasil (30°05’27’’S, 51°40’18’’W), em maio de 2018. Os tratamentos consistiram em diferentes alturas do dossel de *Urochloa brizantha* cv Marandu: 20, 40 e 60 cm. Os tratamentos foram alocados aleatoriamente em seis piquetes de aproximadamente 500m² cada, com duas repetições de área. Antes de iniciar o pastejo, foram realizadas duzentas medições de altura da superfície do pasto em cada unidade experimental, utilizando-se um bastão graduado conhecido como *sward stick* (Barthram, 1986). A massa de forragem pré-pastejo foi medida cortando ao nível do solo usando um quadrado de 0,25 m² (0,50 x 0,50 m) e replicado em quatro amostras por piquete. Cada amostra foi separada em dois estratos (superior e inferior) que compuseram a massa total da forragem. Todas as amostras de forragem foram secas em estufa (55 °C por 72 h) e, posteriormente, os componentes foram separados em lâminas de folhas, colmo + bainha. As caraterísticas do pasto são apresentadas na tabela 1.

Tabela 1: Características do pasto de capim braquiária sob diferentes manejos de altura de pasto.

	Altura do dossel (cm)		
	20	40	60
Altura média real	22,66	38,10	64,95
Massa de forragem total (MF) (kg ha^{-1})	2148,17	3934,10	7479,48
MF – Estrato superior (kg ha^{-1})	832,21	1698,34	2859,36
MF – Estrato inferior (kg ha^{-1})	1307,38	2245,58	4641,48
Relação colmo/folha	1,90	1,29	0,84

2.1 Animais e equipamentos

Foram utilizadas três vacas adultas (60 ± 2 meses) da raça Red Brangus, com peso médio de 684,05 ±88,88kg em ensaios de 45 minutos de pastejo. Durante os períodos onde não havia avaliações, os animais foram mantidos em uma área próxima as áreas experimentais, com acesso a água, sombra e pastos de *Urochloa brizantha* cv Marandu. Deste modo, os animais entravam nos piquetes experimentais somente para os ensaios de pastejo, não sendo realizado previamente jejum de sólidos e líquidos.

Antes dos ensaios de pastejo, todos os animais foram equipados com buçal contendo um Registrador de Comportamento IGER (IGER) (Rutter, Champion, & Penning, 1997) com o objetivo de registrar os movimentos mandibulares. Os dados foram registrados em frequência de 20Hz (Rutter, 2000). Adicionalmente, foi fixado um iPhone 4S (Apple, Cupertino, CA, EUA) dentro de uma caixa impermeável e posicionado na parte superior do pescoço. Em cada aparelho celular foi instalado o aplicativo SensorData (Wavefront Labs), que captura e armazena dados de unidades de medida inercial (IMU), em frequência de 100 Hz.

O IMU do IPhone 4S usa STMicro STM33DH 3 eixos como um acelerômetro, STMicro AGDI 3 eixos como um giroscópio (STMicroelectronics, Genebra, Suíça) e AKM 8963 bússola eletrônica de 3 eixos como um magnetômetro (Asahi Kasei Microdevices Corporation, Tóquio, Japão). O eixo *x* representa os movimentos verticais (para cima e para baixo), o eixo *y* representa os movimentos laterais (direita-esquerda) e o eixo *z* representa os movimentos longitudinais (para frente e para trás). O pastejo de dois animais por unidade experimental foi registrado em vídeo, uma câmera por animal. O registro foi feito de com zoom na cabeça do animal de modo que os bocados pudessem ser identificados para compor a matriz de bocados observados com o objetivo de comparar com a matriz de bocados detectados pelos métodos IMU e IGER.

2.2 Análise dos dados

*2.2.*1 Detecção dos bocados

Os bocados realizados pelos animais foram observados nos vídeos e transcritos usando o programa Cowlog 3.0.2 (Pastel, 2016) em velocidade duas vezes mais lenta que a normal, compondo a matriz de bocados observados no domínio do tempo. Doze vídeos com duração aproximada de 10 minutos foram utilizados para validar o algoritmo de detecção de bocados. O bocado foi considerado como a ação realizada pela vaca quando ela remove material vegetal do dossel (Gibb, 1998). O tempo gasto procurando, mastigando e engolindo a forragem não foi considerado como bocado, embora essas atividades sejam parte do comportamento de pastejo.

2.2.1.1 Método IMU de detecção dos bocados

Para realizar a detecção dos bocados pelo método IMU é necessário identificar e isolar os intervalos de tempo em que o animal realiza somente as ações de pastejo. Caracterizado pelo momento que o animal baixa a cabeça e desfere um bocado, até o momento que o animal levanta a cabeça (maiores detalhes podem ser encontrados em Andriamandroso et al., 2017). A segunda etapa compreende a identificação dos bocados durante as sequências de pastejo (descrito no capítulo II desta tese).

Desta maneira, os intervalos de tempo em que o animal realizou somente as ações de pastejo foram identificadas usando o algoritmo de código aberto dedicado a interpretar os sinais IMU do iPhone descrito por Andriamandroso et al., 2017 sendo realizado em Matlab R2015a (Mathworks, NL).

Para se detectar bocados utilizou-se o sinal da taxa de rotação ao longo do eixo *y* (Ry) registrado pelo iPhone, filtrado entre 0,5 e 2 Hz. Uma detecção automatizada de cada bocado hipotético, ou seja, de cada pico registrado nas sequências de pastejo, foi realizada em Matlab R2015a (Mathworks, NL). Criou-se uma matriz de bocados detectados no domínio do tempo, usando a função “findpeaks” com os critérios de distância mínima entre dois picos de 0,4 segundos e altura mínima dos picos de 0,2 radiano s^{-1}, conforme descrito no Capítulo II e no apêndice 1 desta tese.

Com o objetivo de relacionar a altura dos picos (bocados hipotéticos) com as diferentes alturas do dossel, foi gerado uma matriz contendo a amplitude de Ry para cada bocado detectado para cada unidade amostral.

Durante os ensaios de pastejo, foi realizado o registro visual instantâneo dos bocados pelo método do monitoramento contínuo de bocados (Monitoring, Agreil & Meuret 2004; Bonnet et al., 2015) para monitorar a diversidade de bocados realizados pelos animais. Antes do início do experimento, foi realizado um período de familiarização, onde dois observadores foram treinados para identificar e descrever os tipos de bocados sem influenciar o comportamento dos animais. Os bocados foram codificados considerando origem, tipo e disposição do tecido vegetal coletado e as dimensões do bocado.

Após a observação visual, foram realizadas as simulações de cada tipo de bocado executado pelo animal, realizando-se coletas por simulação de pastejo de 20 amostras por cada tipo de bocado (Bonnet et al., 2011). Posteriormente, as amostras foram secas em estufa com circulação de ar forçado a 55°C por 72 horas, para compor o peso seco médio (massa do bocado) por cada categoria de bocado

2.2.1.2 Método IGER de detecção dos bocados

Em cada ensaio com os animais foi identificado os possíveis eventos de pastejo dos arquivos .BIN correspondentes ao momento de início e fim dos ensaios de pastejo e os movimentos mandibulares no programa de análise de dados GRAZE (Rutter, 2000). A classificação dos movimentos mandibulares em bocados e não bocados foi realizada pela seleção dos valores mais apropriados para os critérios de “minimal rise:total ratio for mastication (%)” e “minimal prehension sub peak’ (Rutter et al., 1997; Rutter, 2000). As análises no programa GRAZE foram realizadas sem referência a matriz de bocados observados.

Posteriormente, foi exportado um vetor com o tempo da ocorrência dos movimentos mandibulares e sua classificação (preensão e mastigação). Apenas um dos ensaios de pastejo realizado no tratamento 40 cm, um equipamento apresentou problemas e não realizou nenhum registro dos movimentos mandibulares, havendo uma unidade amostral perdida.

2.2.1.3 Sincronização

O momento exato em que os equipamentos foram ligados e configurados foram registrados em vídeo, em escala de segundos, possibilitando construir uma linha do tempo para cada animal a partir do tempo “zero” de cada equipamento. Além disso, foi adicionado na linha do tempo o momento exato em que cada vaca desferiu os primeiros dez bocados e realizou o primeiro intervalo intra refeição (início e fim). Posteriormente, quando necessário, foi realizado ajustes em centésimos de segundos na sincronização entre a matriz de bocados observados e detectados pelos diferentes métodos.

2.2 Análises dos dados

Para verificar a correspondência entre um bocado detectado e um bocado observado, para ambos os métodos de detecção, diferenças entre a matriz de bocados observados e a matriz de bocados detectados foram avaliadas usando o método de k-vizinhos mais próximos. Como um bocado observado teve que corresponder a um bocado detectado (verdadeiro positivo, TP), todos os picos com atraso maior que 0,5 segundo em comparação com a observação foram eliminados e classificados como falsos positivos (FP) representando bocados detectados incorretamente, enquanto não há bocado observado no vídeo, ou falso negativo (FN) representando bocados incorretamente não detectados enquanto são observados no vídeo. A percentagem de bocados corretamente detectados (QF), o Fator *Branching* (BF) representa a relação entre os bocados detectados incorretamente (FP) e os bocados corretamente detectados(TP), e o Fator *Miss* (MF) que representa a relação entre os bocados não detectados (FN) e os bocados corretamente detectados (TP) foram considerados. As equações são descritas a seguir:

$$QF = \frac{TP}{TP+FN+FP} * 100 \quad (1)$$

$$BF = \frac{FP}{TP} \quad (2)$$

$$MF = \frac{FN}{TP} \quad (3)$$

2.3 Análise estatística

Foi realizada análise da variância e testada regressão para as variáveis BF, MF e percentagem de bocados corretamente detectados (QF) e intensidade do sinal taxa de rotação ao longo do eixo y (Ry) entre as diferentes alturas do dossel. Foi testada regressão entre os valores de altura do pico (sinal Ry) e a massa do respectivo bocado por tratamento.

Foi realizada análise da variância dentro de cada tratamento entre os métodos de detecção de bocados sobre a percentagem de bocados corretamente detectados (QF), MF, QF e a taxa de bocados detectados/observados. As médias foram comparadas pelo teste *t* de Student 5% de significância no programa estatístico JMP (versão 14.0., SAS Institute Inc., Cary, NC, USA).

3. Resultados

3.1. Método IMU para detecção dos bocados

A altura do dossel apresentou relação significativa e positiva com a taxa de ocorrência de falso positivo (BF), indicando que à medida que aumenta a altura, maior a proporção de outros movimentos da cabeça que são erroneamente classificados como bocado. Consequentemente, houve relação negativa entre a percentagem de bocados corretamente detectados com o aumento da altura do dossel (Figura 1). No entanto, a amplitude dos movimentos da cabeça diminui com a altura do dossel, representados pela amplitude dos picos na taxa de rotação do eixo y (Figura 2).

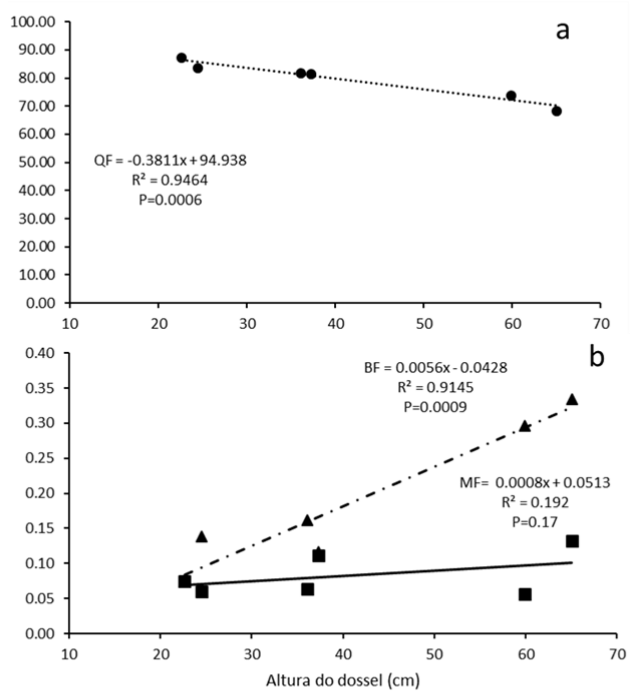

Figura 1: Relação entre a percentagem de bocados corretamente detectada (QF) (1.a), Fator Miss (MF) e Fator Branching (BF) (1.b) pelo método IMU (unidade de medida inercial) nas diferentes alturas do dossel.

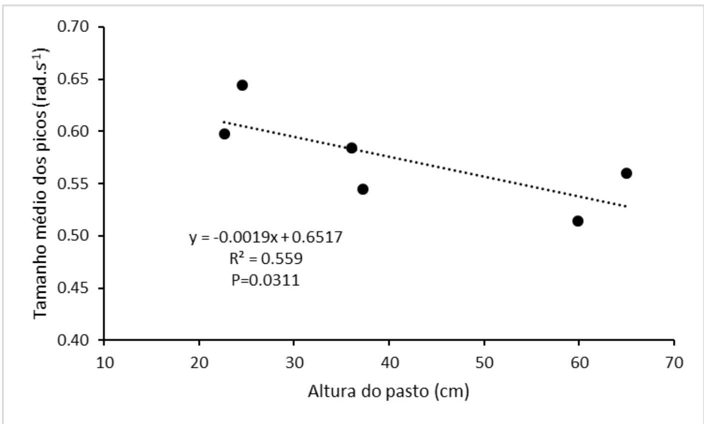

Figura 2: Relação entre a altura média dos picos (radiano s^{-1}) nas diferentes alturas do dossel.

Não houve relação entre diferentes amplitudes dos picos (bocados) e a massa dos bocados para nenhuma das alturas do dossel testadas (Figura 3).

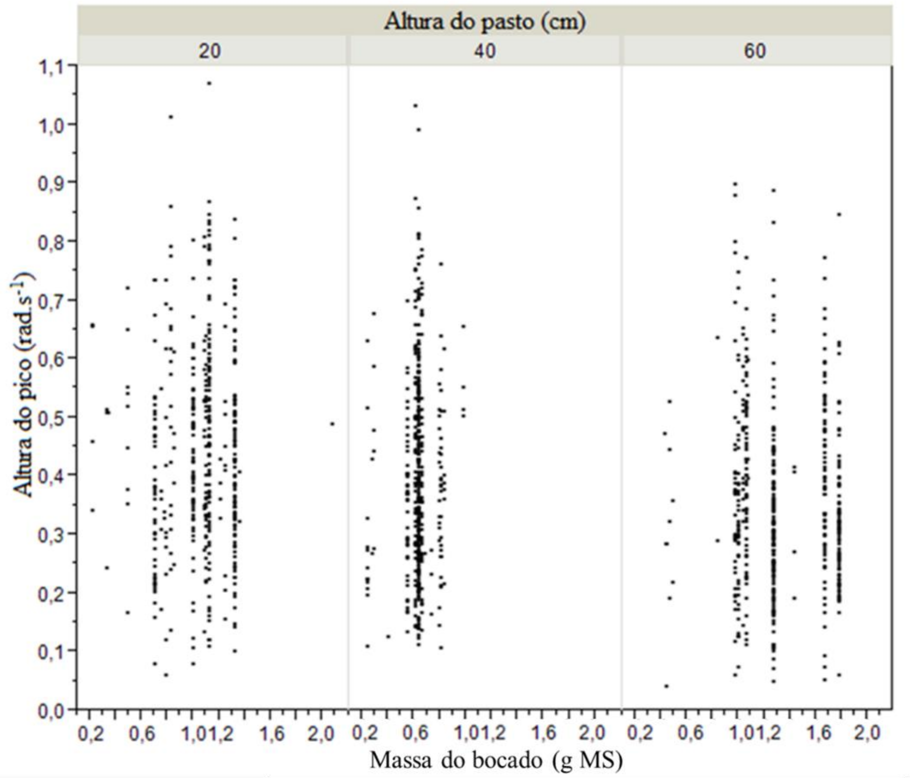

Figura 3: Relação entre a altura dos picos (radiano s^{-1}) e a massa do bocado (gramas de matéria seca) por alturas do dossel (N=1500 bocados). T20: altura do pico (AP) =0,4346942+ 0,0074392* massa do bocado (MB) R=0; T40: AP =0,3332794+ 0,1030671* MB R=0,004; T60: AP=0,3332794+0,1030671*MB R=0

3.2 Comparação entre os métodos IMU e IGER na detecção dos bocados

Não houve diferença significativa entre os métodos de detecção dos bocados dentro de cada tratamento para os valores de MF (Tabela 2). No entanto, houve diferença para o BF e para a percentagem de bocados corretamente detectados (QF), mostrando que independente da altura do dossel, o método IMU apresenta maior porcentagem de bocados corretamente detectados. Ambos os métodos superestimam a taxa em que os bocados são desferidos. No entanto o método IMU apresenta menor proporção que o método IGER no tratamento 40cm.

Tabela 2: Comparação entre os métodos de detecção dos bocados, unidade de medida inercial (IMU) e IGER behaviour recorder (IGER) na correta detecção dos bocados dentro das diferentes alturas do dossel.

Altura do dossel	Método	MF[1]	BF[2]	QF[3]	Bocados detectados/ observados
20 cm	IMU	0.07	0.11	85.33	1.04
	IGER	0.09	0.24	75.27	1.14
		P=0.304	P=0.023	P=0.027	P=0.080
40 cm	IMU	0.09	0.14	81.67	1.05
	IGER	0.07	0.28	73.89	1.20
		P=0.635	P=0.018	P=0.072	P=0.011
60 cm	IMU	0.11	0.32	70.11	1.18
	IGER	0.28	0.63	52.52	1.28
		P=0.055	P=0.004	P=0.003	P=0.287

1) MF: Fator *Miss*; 2) BF: Fator *Branching*; 3) QF: percentagem de bocados corretamente detectados.

4. Discussão

O pastejo é uma atividade complexa que engloba um conjunto de vários movimentos da cabeça, pescoço e corpo (Becciolini e Ponzetta, 2018). Os movimentos de cabeça realizados durante o pastejo são tipicamente circulares para bovinos (Chamber et al., 1981). No entanto, em pastos altos esses movimentos não são tão evidentes, pois os animais selecionam a direção dos movimentos de cabeça de acordo com a estrutura da forragem colhida (Hongo e Akimoto, 2003), e o ângulo da posição da cabeça em relação aos membros dianteiros aumenta com a altura do dossel. Portanto, os animais realizam três tipos de movimentos de cabeça: cabeça para frente (tipo I) ou para trás (tipo II), e em poucos bocados são necessários dois movimentos de cabeça (sequencial para frente e para trás) (tipo III) (Hongo e Akimoto, 2003), porque a força exercida somada a distância máxima do deslocamento da cabeça para uma direção não foi suficiente para o rompimento de todas as fibras vegetais. Ao visualizar os vídeos em baixa velocidade, os bocados do tipo III foram registrados com mais frequência no tratamento 60 cm. Hongo e Akimoto, (2003) identificaram que a força aplicada para a realização dos bocados muda em função da direção do movimento da cabeça, sendo que bovinos realizam duas vezes mais força (Newton) para desferir um bocado para frente do que para trás. Essas interações refletiram em uma relação linear e negativa entre a intensidade da taxa de rotação do eixo y com o aumento da altura do dossel (Figura 2).

Alguns bocados não são detectados pelo método IMU, pois apresentam altura do pico menor que 0,2 radiano s^{-1}. Esses bocados são realizados principalmente por um movimento de cabeça mais sutil e longitudinal ao corpo. A taxa com que esses bocados são formados não tem relação com a altura do dossel, compondo em média 9% (MF) dos bocados desferidos. No entanto, ao modificar os valores do critério ‘altura mínima do pico’ para 0,1 radiano s^{-1}, por exemplo, todos os bocados poderiam ser identificados. Entretanto, a diminuição deste critério de seleção acarretaria na detecção de picos (FP) que representam movimentos da cabeça relacionados com a mastigação e/ou a seleção de novos locais para desferir o bocado, o que aumentaria os valores de fator *Branching*, reduzindo a percentagem de bocados corretamente detectados.

Os valores do fator *Branching* representam a taxa de movimentos de cabeça que não são relacionados com um bocado desferido e que são registrados pelo sensor. Estes valores apresentaram relação linear e negativa em consequência ao aumento da altura do dossel.

Os herbívoros respondem a mudanças estruturais do pasto por meio de estratégias de pastejo (Laca e Demment,1992), intensificando os processos de busca e apreensão da forragem em pastos manejados com baixa altura e menor massa de forragem (Baggio et al., 2009). Em pastos mais altos (e.g. 60 cm), os animais realizam mais do que apenas um movimento de língua e mandíbula por bocado como estratégia para aumentar a área do bocado, pois as lâminas foliares são mais esparsas, além de maior densidade de colmos no estrato superior, limitando a formação do bocado (Benvenutti et al., 2009).

Outro fator que dificulta a manipulação do bocado pelo animal é o fato das lâminas foliares serem mais longas (Soder et al., 2009) e com maior teor de parede celular, que demanda mais tempo para mastigação da forragem antes da deglutição. Desta maneira, pastos de braquiária manejados com altura do dossel entre 20 cm e 40 cm de altura do pasto, apresentam acurácia de 85,3 e 81,7%, respectivamente, ou seja, a maioria dos movimentos de cabeça registrados pelo sensor IMU são relacionados com um bocado realizado. Já em alturas de dossel próximas de 60 cm, ou acima, o método IMU apresenta valores de QF em torno de 70% e superestima em média o número de bocados desferidos em 18%.

A massa do bocado é a variável do comportamento ingestivo mais importante, pois explica a maior porcentagem da variação no consumo diário de forragem (Laca, 2001). No entanto, a intensidade dos movimentos de cabeça não são preditores da massa do bocado (Figura 3). Todavia, a velocidade com que as vacas movimentam a cabeça pode estar relacionada com a arquitetura, e densidade dos componentes do pasto, e com a resistência das fibras vegetais (Hongo e Akimoto, 2003), além do ângulo da posição da cabeça em relação aos membros dianteiros.

O método IMU foi superior ao método IGER na correta detecção dos bocados nos tratamentos 20 e 60 cm de altura do dossel. Na classificação dos bocados pelo IGER, foi observado que eventos de mastigação foram erroneamente classificados como bocado (FP), resultando em menor acurácia. Isso ocorre porque picos secundários associados aos bocados em bovinos provavelmente estão sendo confundidos como picos primários dos movimentos mandibulares (Rutter, 2000), principalmente no tratamento 60 cm de altura, pois apresentou QF de 52,5%. Em alturas mais altas, o animal realiza bocados maiores e necessitam maior tempo de manipulação e movimentos mastigatórios. Ungar e Rutter, (2006) observaram que o método IGER superestima em média 28% o número de bocados, podendo variar de 8 a 54%, dependendo do animal.

Conclusão

A estrutura do pasto influencia a qualidade de detecção dos bocados tanto para o método IMU quanto para o método IGER. A acurácia na detecção utilizando o método IMU foi de 85,3 e 81,7%, para os tratamentos 20 e 40 cm, respectivamente e 70,1% para o tratamento 60 cm.

O método IMU mostrou-se eficaz na detecção de bocados em experimentos de pastejo.

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6. Referências bibliográficas

Agreil, C., Meuret, M., 2004. An improved method for quantifying intake rate and ingestivo behaviour of ruminants in diverse and variable habitats using direct observation. Small Rumin. Res. 54, 99-113.

Ahmad, N., Ghazilla, R.A.R., Khairi, V.K., 2013. Reviews on Various Inertial Measurement Unit (IMU) Sensor Applications. J. Signal Process. Syst. 1, 2. DOI:10.12720/ijsps.1.2.256-262

Altman, F., 1974. Observational Study of Behavior: Sampling Methods. Behaviour. 49, 227-267.

Andriamandroso, A. L. H., Lebeau, F., Beckers, Y., Froidmont, E., Dufrasne, I., Heinesch, B., Dumortier, P., Blanchy, G., Blaise, Y., Bindelle, J., 2017. Development of an open-source algorithm based on inertial measurement units

(IMU) of a smartphone to detect cattle grass intake and ruminating behaviors. Comput. Electron. Agr. 139, 126-137.

Baggio, C., Carvalho, P. C. F., Silva, J. L. S., Anghinoni, I., Lopes, M. L. T. and Thurow, J. M. 2009. Padrões de deslocamento e captura de forragem por novilhos em pastagem de azevém anual e aveia-preta manejada sob diferentes alturas em sistema de integração lavoura-pecuária. R. Bras. Zootec. 38, 215-222.

Barthram, G.T., 1986. Experimental techniques: the HFRO sward stick. Penicuik: Hill Farming Research Organization, 29-30.

Becciolini, V., Ponzetta, M.P., 2018. Inferring behaviour of grazing livestock: opportunities from GPS telemetry and activity sensors applied to animal husbandry. In: 18th International Scientific Conference Engineering for Rural Development. Proceeding… Jelgava, LATVIA 2018. DOI: 10.22616/ERDev2018.17.N202

Benvenutti, M.A., Gordon, I.J., Poppi, D.P., Crowther, R., Spinks, W., Moreno, F.C., 2009. The horizontal barrier effect of stems on the foraging behaviour of cattle grazing five tropical grasses. Livest. Sci. 126, 229-238.

Bonnet, O.J.F., Meuret, M., Tischler, M.R., Cezimbra, I.M., Azambuja, J.C.R., Carvalho, P.C.F., 2015. Continuous bite monitoring: a method to assess the foraging dynamics of herbivores in natural grazing conditions. Animal Prod. Sci., 55, 339-349.

Bonnet, O.J.F., Hagenah, N., Hebbelmann, L., Meuret, M., Shrader, A.M., 2011. Is Hand Plucking an Accurate Method of Estimating Bite Mass and Instantaneous Intake of Grazing Herbivores? Rangeland Ecol. Manag. 64, 366-374.

Carvalho, P.C.F., Bremm, C., Mezzalira, J.C., Fonseca, L., Trindade, J.K., Bonnet, O.J.F., Tischler, M., Genro, T.C.M., Nabinger, C., Laca, E.A., 2015. Can animal performance be predicted from short-term grazing processes? Animal Produc. Sci. 55, 319–327.

Carvalho, P.C.F., Barro, R.S., Barth Neto, A., Nunes, P.A.A., Moraes, A., Anghinoni, I., Bredemeier, C., Bayer, C., Martins, A.P., Kunrath, T.R., Santos, D.T., Carmona, F.C., Barros, T., Souza Filho, W., Almeida, G.M., Caetano, L.A.M., Cecagno, D., Arnuti, F., Denardin, L.G.O., Bonetti, J.A., Toni, C.A.G., Borin, J.B.M., 2018. Integrating the pastoral component in agricultural systems. R. Bras. Zootec. 47.

Carvalho, P.C.F., Bremm, C., Bonnet, O.J.F., Savian, J.V., Schons, R.M.T., Szymczak, L.S., Baggio, T., Moojen, F.G., Silva, D.F., Marin, A., Gandara, L., Bolzan, A.S.M., Da Silva Neto, G. F., Moraes, A., Monteiro, A.L.G., Santos, D.T., Laca, E.A. Como a estrutura do pasto influencia o animal em pastejo? Exemplificando as interações planta-animal sob as bases e fundamentos do Pastoreio Rotatínuo. VIII SIMFOR: Simpósio sobre Manejo estratégico de pastagens. 8ed.Viçosa MG, 2016, 309-330.

Chambers A.R.M., Hodgson, J., Milne, J.A., 1981. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. Grass Forage Sci. 36, 97-105.

Chelotti, J.O., Vanrell, S.R., Galli, J.R., Giovanini, L.L., Rufiner, H.L., 2018. A pattern recognition approach for detecting and classifying jaw movements in grazing cattle. Comput. Electron. Agr. 145, 83-91.

Gibb. M.J., 1998. Animal grazing/intake terminology and definitions. In: Proceedings of pasture ecology and animal intake workshop for concerted action AIR3-CT93-0947. Dublin. Ireland. 20-35, 1998.

Guo, L., Welch, M., Dobos, R., Kwan, P., Wnag, W., 2018. Comparison of grazing behaviour of sheep on pasture with different sward surface heights using an inertial measurement unit sensor. Comput. Electron. Agr. 150, 394-401.

Hongo, A., Akimoto, M., 2003.The role of incisors in selective grazing by cattle and horses. J. Agr. Sci. 140, 469-477.

Laca, E.A., Shipley, L.A., Reid, E.D., 2001. Structural anti-quality characteristics of range and pasture plants. J. Range Manag. 54, 413-419.

Laca, E.A., Demment, M.W. Modelling intake of a grazing ruminant in a heterogeneous environment. In: INTERNATIONAL SYMPOSIUM ON VEGETATTION HERBIVORE RELATHIONSHIPS, 1992, New York. Proceedings... New York: Academic Press, 1992. p.57-76.

Laca, E.A., WallisDeVries, M.F., 2000. Acoustic measurement of intake and grazing behaviour of cattle. Grass Forage Sci. 55, 97-104.

Oudshoorn F.W., Cornou. C., Hellwing. A.L.F., Hansen. H.H., Munksgaard. L., Lund. P., Kristensen. T., 2013. Estimation of grass intake on pasture for dairy cows using tightly and loosely mounted di- and tri-axial accelerometers combined with bite count. Comput. Electron. Agr. 99, 227-235

Pastell. M., 2016. CowLog – Cross-Platform Application for Coding Behaviours from Video. J. Open Res. Software. 4, 15.

Peng, Y., Kondo, N., Fujiura, T., Suzuki, T., Yoshioka, H., Itoyama, E., 2019. Classification of multiple cattle behavior patterns using a recurrent neural network with long short-term memory and inertial measurement units. Comput. Electron. Agr. 157, 247-253.

Prache S., 1997. Intake rate, intake lactating ewes on per bite and time per bite of vegetative and reproductive swards. Appl. Anim. Behav. Sci. 52, 53-61.

Reith, S., Hoy, S., 2017. Review: Behavioral signs of estrus and the potential of fully automated systems for detection of estrus in dairy cattle. Animal. 1-10.

Rutter S.M., 2000. Graze: a program to analyze recordings of the jaw movements of ruminants. Behav. Res. Meth. Instrum. Comput. 32, 86-92.

Rutter S.M., Champion R.A., Penning, P.D., 1997. An automatic system to record foraging behaviour in free-ranging ruminants. Appl. Anim. Behav. Sci. 54, 185-195.

Soder, K.J., Gregorini, P., Scaglia, G., Rook, A.J., 2009. Dietary Selection by Domestic Grazing Ruminants in Temperate Pastures: Current State of Knowledge, Methodologies, and Future Direction. Rangeland Ecol. Manag. 62, 389-398.

Ungar, E.D., Rutter, S.M., 2006. Classifying cattle jaw movements: Comparing IGER behaviour recorder and acoustic techniques. Appl. Anim. Behav. Sci. 98, 11-27.

Ungar, E.D., Nevo, Y., Baram, H., Arieli, A., 2018. Evaluation of the IceTag leg sensor and its derivative models to predict behaviour, using beef cattle on rangeland. J. Neurosci. Methods. 300, 127-137.

Weigele, H.C., Gygax, L., Steiner, A., Wechsler, B., Burla, J.B., 2018. Moderate lameness leads to marked behavioral changes in dairy cows. J. Dairy Sci. 101, 2370-2382.

CAPÍTULO IV

CONSIDERAÇÕES FINAIS

Com um algoritmo simples, utilizando dados de unidade de medida inercial, é possível identificar o momento em que os bocados são desferidos, permitindo o conhecimento do número e a taxa com que os bocados são formados ao longo do tempo, deste modo, compreendendo a interface planta-animal na menor escala do comportamento ingestivo de bovinos em pastejo.

A unidade de medida inercial também registra dados sobre a localização geográfica dos animais e o seu deslocamento no tempo. Permitindo explorar o comportamento ingestivo individual e compreender as estratégias dos animais em diferentes condições no tempo e no espaço.

Outros celulares equipados com unidade de medida inercial ou mesmo dispositivos feitos sob medida também podem ser usados com o mesmo algoritmo, supondo que eles forneçam as mesmas características em termos de sensibilidade e frequência de registro. Bem como, o futuro do manejo do pastoreio dependerá muito do crescimento de tecnologias, incluindo o uso de sensores, transferência e armazenamento de informações mais rápidas, já que as informações são altamente valiosas para a compreensão do mecanismo de comportamento.

REFERÊNCIAS

AHMAD, N. *et al.* Reviews on various inertial measurement unit (IMU) sensor applications. **Journal of Signal Processing Systems**, Berlim, v. 1, p. 256–262, 2013.

ALMEIDA, P.R. *et al.* Testing a 3-axis accelerometer acoustic transmitter (AccelTag) on the Lusitanian toadfish. **Journal of Experimental Marine Biology and Ecology**, Amsterdam, v. 449, p. 230–238, 2013.

ALKON, P. U.; COHOEN, A. Acoustical Biotelemetry for Wildlife Research: a preliminary test and prospects. **Wildlife Society Bulletin**, Lawrence, v. 14, n. 92, p. 193-196, 1986.

ALVARENGA, F. A. P. *et al.* Using a three-axis accelerometer to identify and classify sheep behaviour at pasture. **Applied Animal Behaviour Science**, Amsterdam, v. 181, p. 91–99, 2016.

ANDRIAMANDROSO, A. L. H. *et al.* A review on the use of sensors to monitor cattle jaw movements and behavior when grazing. **Biotechnology, Agronomy, Society and Environment**, Gembloux, v. 20, n. 2, p. 273–286, 2016.

ANDRIAMANDROSO, A. L. H. *et al.* Development of an open-source algorithm based on inertial measurement units (IMU) of a smartphone to detect cattle grass intake and ruminating behaviors. **Computers and Electronics in Agriculture**, Amsterdam, v. 139, p. 126-137, 2017.

BAILEY, D. W.; PROVENZA, F. D. Mechanisms determining large-herbivore distribution. *In*: PRINS, H. H. T.; LANGEVELDE, F. (ed.). **Resource ecology:** spatial and temporal dynamics of foraging. The Netherlands: Springer, 2008, p. 7-28.

BARWICK, J. *et al.* Categorizing sheep activity using a tri-axial accelerometer. **Computers and Electronics in Agriculture**, Amsterdam, v. 145, p. 289–297, 2018a.

BARWICK, J. *et al.* Predicting lameness in sheep activity using tri-axial acceleration signals. **Animals**, Berlim, v. 8, n. 12, 2018b.

BENVENUTTI, M. A. *et al.* The horizontal barrier effect of stems on the foraging behaviour of cattle grazing five tropical grasses. **Livestock Science**, Cambridge, v. 126, p. 229–238, 2009.

BONNET, O. J. F. *et al.* Continuous bite monitoring: a method to assess the foraging dynamics of herbivores in natural grazing conditions. **Animal Production Science**, Melbourne, v. 55, p. 339–349, 2015.

BROWN, D.D. *et al.* Observing the unwatchable through acceleration logging of animal behavior. **Animal Biotelemetry**, Londres, p. 1-20, 2013.

CANGIANO, C. A. (ed.). **Conpast 3.0**: programa de computación para la estimación del consumo de bovinos en pastoreo. Balcarce, Buenos Aires: INTA, 1999. 228 p. 1 guia de uso.

CARVALHO, P. C. F. *et al.* Do bocado ao pastoreio de precisão: compreendendo a interface planta animal para explorar a multi-funcionalidade das pastagens. **Revista Brasileira de Zootecnia,** Viçosa, v. 38, p. 109-122, 2009.

CARVALHO, P. C. F. *et al.* Como a estrutura do pasto influencia o animal em pastejo? exemplificando as interações planta-animal sob as bases e fundamentos do Pastoreio Rotatínuo. *In:* SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DE PASTAGENS, 8., 2016, Viçosa MG. **Anais** [...]. Viçosa, 2016. p. 309-330.

CARVALHO, P. C. F. *et al.* Características estruturais do pasto e o consumo de forragem: o quê pastar, quanto pastar e como se mover para encontrar o pasto. *In:* SIMPÓSIO SOBRE MANEJO ESTRATÉGICO DE PASTAGENS, 4., 2008, Viçosa MG. **Anais** [...]. Viçosa, 2018. p. 101-130.

CARVALHO, P. C. F. Harry stobbs memorial lecture: can grazing behavior support innovations in grassland management? **Tropical Grasslands**: forrajes tropicales, Valle del Cauca, v. 1, p.137−155, 2013.

CHAMBERS, A. R. M.; HODGSON, J.; MILNE, J. A. The development and use of equipment for the automatic recording of ingestive behaviour in sheep and cattle. **Grass and Forage Science**, Oxford, v. 36, p. 97-105, 1981.

CHELOTTI, J. O. *et al.* A pattern recognition approach for detecting and classifying jaw movements in grazing cattle. **Computers and Electronics in Agriculture**, Amsterdam, v. 145, p. 83-91, 2018.

CHELOTTI, J. O. *et al*. A real-time algorithm for acoustic monitoring of ingestive behavior of grazing cattle. **Computers and Electronics in Agriculture**, Amsterdam, v. 127, p. 64–75, 2016.

DEBAUCHE, O. *et al.* Cloud services integration for farm animals' behavior studies based on smartphones as activity sensors. **Journal of Ambient Intelligence and Humanized Computing**, Berlim, p. 1-12, 2018.

DUCKWORT, J. E.; SHIRLAW, D. W. The development of an apparatus to record the jaw movements of cattle. **The British Journal of Animal Behaviour**, Cambridge, v. 3, p. 56-60, 1955.

ERTL, P. *et al.* The net contribution of dairy production to human food supply: the case of Austrian dairy farms. **Agricultural Systems**, Amsterdam, v. 137, p. 119–125, 2015.

GALLI, J. R. *et al.* Acoustic monitoring of chewing and intake of fresh and dry forages in steers. **Animal Feed Science and Technology**, Amsterdam, v. 128, p. 14–30, 2006.

GALLI, J. R.; CANGIANO, C. A.; FERNÁNDEZ, H. H. Comportamiento ingestivo y consumo de bovinos en pastoreo. **Revista Argentina de Produção Animal**, Santa Fé, v. 16, n. 2, p. 119-42, 1996.

GIBB, M. J.; HUCKLE, C. A.; NUTHALL, R. Effect of time of day on grazing behaviour by lactating dairy cows. **Grass and Forage Science**, Oxford, v. 53, p. 41–46, 1998.

GIOVANETTI, V. *et al.* Automatic classification system for grazing, ruminating and resting behaviour of dairy sheep using a tri-axial accelerometer. **Livestock Science**, Amsterdam, v. 196, p. 42–48, 2017.

GONZÁLEZ, L. A.; KYRIAZAKIS, I.; TEDESCHI, L. O. Review: precision nutrition of ruminants: approaches, challenges and potential gains. **Animal**, Cambridge, v. 12, p. 246-261, 2018.

GORDON, I. J.; BENVENUTTI, M. Food in 3D: how ruminant livestock interact with sown sward architecture at the bite scale. *In:* BELS V. (ed.) **Feeding in domestic vertebrates.** Wallingford: CAB International, 2006.

GREGORINI, P. *et al.* Rumination behavior of grazing dairy cows in response to restricted time at pasture. **Livestock Science**, Amsterdam, v. 146, p. 95–98, 2012.

GUO, L. *et al.* Comparison of grazing behaviour of sheep on pasture with different sward surface heights using an inertial measurement unit sensor. **Computers and Electronics in Agriculture,** Amsterdam, v. 150, p. 394–401, 2018.

HONGO, A.; AKIMOTO, M. The role of incisors in selective grazing by cattle and horses. **Journal of Agricultural Science**, Toronto, v. 140, p. 469–477, 2003.

KOUR, H. *et al.* Validation of accelerometer use to measure suckling behaviour in Northern Australian beef calves. **Applied Animal Behaviour Science**, Amsterdam, v. 202, p. 1-6, 2018.

LACA, E. A.; ORTEGA, I. M. Integrating foraging mechanisms across spatial and temporal scales. *In:* INTERNATIONAL RANGELAND CONGRESS, 5.,

1996. Salt Lake. **Proceedings** […]. Denver, Colo.: Society for Range Management, ©1996. p. 129-132

LACA, E. A. *et al.* An integrated methodology for studying short-term grazing behaviour of cattle. **Grass and Forage Science**, Oxford, v. 47, n. 1, p. 81–90, 1992.

LACA, E. A. Foraging in a heterogeneous environment: intake and diet selection*. In:* PRINS, H. H. T.; LANGEVELDE, F. (ed.). **Resource ecology**: spatial and temporal dynamics of foraging. Dordrecht: Springer, c2008. (Wageningen UR Frontis series, v. 23).

LACA, E. A.; WALLISDEVRIES, M. F. Acoustic measurement of intake and grazing behaviour of cattle. **Grass and Forage Science**, Oxford, v. 55, 97-104, 2000.

LARSON-PRAPLAN, S. *et al.* Spatial and temporal domains of scale of grazing cattle. **Animal Production Science**, Melbourne, v. 55, n.3, p. 284-297, 2015.

MEZZALIRA, J. C. *et al.* Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. **Applied Animal Behaviour Science**, Amsterdam, v. 153, p. 1–9, 2014.

NADIN, L. B. *et al.* Comparison of methods to quantify the number of bites in calves grazing winter oats with different sward heights. **Applied Animal Behaviour Science**, Amsterdam, v. 139, p. 50– 57, 2012.

NAVON, S. *et al.* Automatic recognition of jaw movements in free-ranging cattle. goats and sheep. using acoustic monitoring. **Biosystems Engineering**, Amsterdam, v. 114, p. 474-483, 2013.

NOGAMI, H. *et al*. Minimized bolus-type wireless sensor node with a built-in three-axis acceleration meter for monitoring a cow’s rumen conditions. **Sensors**, Basel, v. 17, p. 687, 2017.

O’MARA, F. P. The role of grasslands in food security and climate change. **Annals of Botany**, Oxford, v. 110, p. 1263–1270, 2012.

OUDSHOORN, F.W.; JØRGENSEN, O. Registration of cow bites based on three-axis accelerometer data. *In:* BERCKMANS, D.; VANDERMEULEN, J. (ed.). **Precision livestock farming '13.** [Wageningen: Academic Publishers, 2013.]. p. 771–777. Papers apresentados na the 6th European Conference on Precision Livestock Farming, Leuven, Belgium. Disponível em: http://www.eaplf.eu/wp-content/uploads/ECPLF_2013.pdf. Acesso em: 11 abr. 2019.

PENNING, P. D. A technique to record automatically some aspects of grazing and ruminating behaviour in sheep. **Grass and Forage Science**, Oxford, v. 38, p. 89-96, 1983.

PENNING, P. D.; STEEL, G. L.; JOHNSON, R. H. Further development and use of an automatic recording system in sheep grazing studies. **Grass and Forage Science**, Oxford, v. 39, p. 345-351, 1984.

PEYRAUD, J. L.; PEETERS, A. The role of grassland-based production system in the protein security. *In:* **Grassland Science in Europe**, Zurich, v. 21, p. 29-43, 2016. Trabalho apresentado na 26th General Meeting of the European Grassland Federation, 2016, Trondheim. Tema: The multiple roles of grassland in the European bioeconomy.

PRACHE, S. Intake rate, intake per bite and time per bite of lactating ewes on vegetative and reproductive swards. **Applied Animal Behaviour Science**, Amsterdam, v. 52, p. 53–64, 1997.

PROVENZA, F. D. *et al*. Synthesis: foraging decisions link plants, herbivores and human beings. **Animal Production Science**, Melbourne, v. 55, p. 411–425, 2015.

RANDOLPH, T. F. *et al*. Role of livestock in human nutrition and health for poverty reduction in developing countries. **Journal of Animal Science**, Champaign, v. 85, n. 11, p. 2788–2800, 2007.

REITH, S; HOY, S. Review: Behavioral signs of estrus and the potential of fully automated systems for detection of estrus in dairy cattle. **Animal**, Cambridge, p. 1-10, 2017.

RUTTER, S. M. Graze: a program to analyze recordings of the jaw movements of ruminants. **Behavior research methods, instruments and computers**, Austin, v. 32, n. 1, p. 86-92, 2000.

RUTTER, S. M.; CHAMPION, R. A.; PENNING, P.D. An automatic system to record foraging behaviour in free-ranging ruminants. **Applied Animal Behaviour Science**, Amsterdam, v. 54, p. 185-195, 1997.

SHIPLEY, L. A. *et al*. The scaling of intake rate in mammalian herbivores. **The American Naturalist**, Chicago, v. 143, n. 6, p. 1055-1082, 1994.

SHIPLEY, L. A. The influence of bite size on foraging at larger spatial and temporal scales by mammalian herbivores. **Oikos**, Copenhagen, v. 116, p. 1964-1974, 2007.

SPALINGER, D. E.; HOBBS, N. T. Mechanisms of foraging in mammalian herbivores: new models of functional response. **American Naturalist**, Chicago, v. 140, p. 325-348, 1992.

TANI, Y. *et al*. Automatic recognition and classification of cattle chewing activity by an acoustic monitoring method with a single-axis acceleration sensor.

Computers and Electronics in Agriculture, Amsterdam, v. 92, p. 54-65, 2013.

UNGAR, E. D.; RUTTER, S. M. Classifying cattle jaw movements: comparing IGER behaviour recorder and acoustic techniques. **Applied Animal Behaviour Science**, Amsterdam, v. 98, n. 1, p. 11-27, 2006.

UNGAR, E. D. Ingestive behaviour. *In:* HODGSON, J.; ILLIUS, A. W. **The ecology and management of grazing systems**, Oxon: CABI, p.185-218, 1996.

UNGAR, E. D.; RUTTER, S. M. Classifying cattle jaw movements: comparing IGER Behaviour Recorder and acoustic techniques. **Applied Animal Behaviour Science**, Amsterdam, v. 98, p. 11-27, 2006.

VANRELL, S. R. *et al.* A regularity-based algorithm for identifying grazing and rumination bouts from acoustic signals in grazing cattle. **Computers and Electronics in Agriculture**, Amsterdam, v. 151, p. 392-402, 2018.

WALKER, S. L. *et al.* Lameness, Activity Time-Budgets, and Estrus Expression in Dairy Cattle. **Journal of Dairy Science**, Champaign, v. 91, p. 4552–4559, 2008.

WEIGELE, H. C. *et al.* Moderate lameness leads to marked behavioral changes in dairy cows. **Journal of Dairy Science**, Champaign, v. 101, n. 3, 2018.

ZEHNER, N. *et al.* Validation of a new health monitoring system (RumiWatch) for combined automatic measurement of rumination, feed intake, water intake and locomotion in dairy cows. *In:* INTERNATIONAL CONFERENCE OF AGRICULTURAL ENGINEERING, 2012, Valência, Spain. **Proceedings** […]. Valência, 2012. p. 53-58

APÊNDICE

Apêndice 1. Algoritmo de código aberto dedicado a detectar bocados a partir de unidade de medida inercial

```
function [pks,detected,y2]=detectbites(x,height,distance)
%The function allow to find the peaks in the Ry signal that are associated
%to uprroting bites during grazing
%x = a vector with the Ry signal isolated during the grazing events (this
%is done with sequence_grazing and subsequent isolation of the column that
%you need (usually 28 or the one with the header Rot_Rate_y)
%height = minimal peak height (usually 0.2 rad/s)
%distance = minimum time distance between 2 peaks (usually 0.4 s)
%This function yields two vectors: a time vector (pks) displaying where the peaks
%are observed and a corresponding vector (detected) with the height of the detected
%peaks
detected=[];
pks=[];
y2=[];
y1=[];
listpeaks=[];
%Signal filtering
[d,c]=butter(1,6/(100/2),'low');
[b,a]=butter(1,[0.5/(100/2) 2/(100/2)],'bandpass');


y1=filter(d,c,x);%x=rotation rate on y-axis
y2=filter(b,a,y1);
y2=-y2;
%norm_y2 =[];
%norm_y2 = normalise_var(y2,0,1);



%findpeaks on filtered rotation signal
[pks,detected]=findpeaks(y2,'MinPeakHeight',height,'MinPeakDistance',distance);
listpeaks=[detected(:,1) pks(:,1)];
for n=length(listpeaks):-1:1;
    if listpeaks(n,2)>1;
        listpeaks(n,:)=[];
    end
end
detected=listpeaks(:,1);
pks=listpeaks(:,2);
```

Apêndice 2. Normas para elaboração e submissão de trabalhos científicos à revista Computers and Electronics in Agriculture.

COMPUTERS AND ELECTRONICS IN AGRICULTURE

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VITA

Jusiane Rossetto, filha de Orides Rossetto e Neide de Fátima Rossetto, nascida em 26 de março de 1991, em Rio Negro- PR. Cursou o ensino fundamental na E.E.E.F. João Cipriano da Rocha Loires, e o ensino médio na E.E.E.M. Romano Paduan, ambas em Rio dos Índios, RS. Em 2008, ingressou no curso de Zootecnia, na Universidade Federal de Santa Maria – CESNORS – campus Palmeira das Missões – RS. Durante os anos do curso desenvolveu atividades de pesquisa e extensão junto ao grupo INOVAZOOT, sob a orientação do professor João Pedro Velho. Formou-se em Zootecnia em julho de 2012 e em abril de 2013 ingressou no curso Mestrado em Produção Animal, pelo Programa de Pós-Graduação em Zootecnia – UFRGS, sob orientação dos professores Ênio Rosa Prates, Júlio Otávio Barcellos e da pesquisadora, Teresa Cristina Moraes Genro – Embrapa Pecuária Sul, desenvolveu o trabalho de "Caracterização nutricional das espécies forrageiras de ocorrência no bioma Pampa". Em abril de 2015 iniciou seu Doutorado na Universidade Federal do Rio Grande do Sul sob orientação do Prof. Dr. Paulo César de Faccio Carvalho. Foi submetido a banca de defesa de Doutorado em março de 2019.