Automating Monitoring of Cat Feeding Behaviour

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***Abstract*—Cat food manufacturers spend a significant proportion of their research budget on food formulation and palatability. In this paper we propose an efficient and economic method of monitoring cat feeding behaviour during palatability trials. Instrumenting food bowls with load cells measures how much is eaten in each meal, and video records the interaction with the food during meals. Adaptive background subtraction is used to trigger recording, eliminating long periods of animal inactivity and uninteresting video. A single computer is able to monitor and record 4 cages simultaneously at 25 frames per second.**

Keywords—load cell, video, behaviour analysis

I. Introduction

Cats are popular pets, with 48% of New Zealand households owning an average of two cats [1]. The primary source of nutrition for most of these cats is commercially prepared foods. Consequently, consumers expect high standards of quality, nutrition and value for their pets. The pet food industry is highly competitive, so pet food manufacturers are continually working to increase their knowledge of pet nutrition, ensuring the food they produce is both palatable and healthy [1]. A significant proportion of their research budget is spent on palatability testing [2].

Cats have a reputation for being fussy eaters. They are relatively insensitive to the saltiness or sweetness of food [3, 4], but are sensitive to the physical form and palatability of their food [5]. Palatability depends on a number of factors, including aroma, taste, temperature, texture and consistency of the food, and when presented with a choice of commercially prepared foods, palatability is the determining factor in food selection [6]. Therefore, food properties such as nutrition, taste and texture all need to be incorporated into the recipe development process.

However, unlike humans, cats cannot directly be asked how their food tastes, so for this reason, palatability trials are required to elicit food preferences. This is complicated by the fact that there is a high variability of eating patterns between cats [5], and that they like to eat many small meals throughout the day, rather than eating a complete meal in a single sitting, when it is presented [7]. This makes observational studies more difficult and time consuming.

Palatability trials must therefore test a number of cats, and be run over an extended time. The Centre for Feline Nutrition at Massey University is responsible for assessing the quality of different cat food products, and regularly runs palatability trials to determine which food formulation is preferred by the majority of a test panel of cats. Their standard testing procedure is to place 8 cats in eight cages for 2 hours a day for 5 days; with each cage having two bowls of different food formulations (see Fig. 1). The initial and the final weights of the food in each bowl are measured to determine the amount of each diet consumed [8].

Manual analysis and observation is both time consuming and expensive. Therefore, to obtain more detailed information on when the cats ate, how much food was eaten in each meal, and how the cats interacted with their food during the food selection process, it was necessary to instrument the cages. Each food bowl was placed on a load cell, which enabled the food in each bowl to be weighed in real time. Each cage was also fitted with video monitoring which detected when the cat was in the vicinity of the food bowls, and recorded only the video of the interaction with the food. This feature avoids the need for watching through hours of animal inactivity and uninteresting video, where little is happening.

The remainder of this paper is structured as follows. Section II briefly reviews prior work on automated monitoring of animal behaviour. Section III describes the setup of the sensors, with results from preliminary studies described in section IV.

Fig. 1. The set of cages for a food palatability trial.

II. Related Work

While the use of digital scales for automated weighing and analysis of feeding behaviour is not new, very little is reported in the literature with regard to automating the monitoring or analysis.

As early as 1991, Hulsey and Martin [9] proposed a load cell based system for monitoring the feeding behaviour of rats. Automated analysis was limited to measuring the cumulative food eaten, and determining how the interval between meals depended on the time of day. They also adapted their setup for looking at cat feeding behaviour, although the results presented were from a single meal, rather than from a comparative study.

Peachey and Harper [10] used a load cell to automatically determine meal size, meal frequency, meal duration, and rate of eating. They recorded weights every 3 seconds, and defined the start of a meal as three consecutively decreasing readings, and the end of a meal as 10 consecutive readings without any weight change.

Video analysis has often been used for analysing behaviour of animals. For cats, it has been used for analysing feeding behaviour [11], measuring the time it takes a hungry cat to be attracted by a live rat, through to interactions between feeding cats [12] within a group. In most cases, the video is simply recorded, and later analysed manually.

In animal studies, time lapse video is often used to reduce the volume of data. However, with cat feeding, it is important to have good temporal resolution during the meals, and it is unnecessary to record the other activities. More sophisticated systems use motion sensing to trigger recordings [13], allowing only activity of interest to be recorded.

This paper describes the integration of the two sensing technologies for palatability studies: weighing the food consumed through instrumentation of the food bowls, and triggered video recording of the cat's interaction with the food during mealtimes.

III. System Setup

A. Load Cells

Each cage requires two separate bowls for the palatability studies. The weight of each bowl, including food was up to 500 grams, with an additional weight of 350 grams for the load cell platform. Therefore, an aluminium single point cantilever load cell (Precision Transducers PTASP6-B-1.2) with a maximum capacity of 1200 grams was used for each bowl.

Two load cells were mounted on a 2 mm aluminium base, reinforced by a 5mm steel strip for structural rigidity. The steel prevented the aluminium base from flexing which distorted the measurements. An aluminium platform was bolted onto the mounting pad of the load cell. This holds the bowl in place, and also protects the load cell (and associated electronics) from curious cats (see Fig. 2). Overload protection stops were mounted on the base. A centre stop was placed immediately below the load cell, and corner stops were mounted below each corner of the platform. The stops were set by filling the bowl with water until the load cell gave the maximum reading, and then adjusting the stops so that they were just contacting at this load.

With a 5 volt reference, the load cell has a full scale differential output of approximately 4.4 mV. A dual instrumentation amplifier (Texas Instruments INA2126) was used to amplify each load cell output to give a 2.4 V output signal. A 150Ω gain control resistance gives the required 550 factor for the voltage gain.

After amplification, the signals are passed to a microcontroller (Silicon Laboratories C8051F020) where they are digitised by an integrated 12 bit A/D converter, and scaled by a calibration constant to give the weight. The 12 bit converter gives a weight resolution of 0.3 grams. A single microcontroller is used for each pair of load cells to make the instrumentation for each cage independent. The microcontroller makes weight readings about every 5 seconds; this is limited by the settling time of the load cell. The weights are then sent to a host computer using an RS232 link.

The electronics are powered from a single 12 volt DC power adaptor, with a 5 volt regulator for the load cell reference, and a 3.3 volt regulator for the microcontroller.

To validate the setup, a 100 gram weight was placed in 5 different positions within the food bowl. The measured outputs were the same (within 0.001 mV) indicating that the single point load cell accurately measures the weight regardless of the position of the food within the bowl. A series of known weights was added to the bowls, and the measured weights were accurate to within 0.8 gram, which is adequate for this application.

B. Video Recording

To record the activity during meals, a USB camera (Logitech HD Webcam 720p) was attached on an arm to the door of each cage. This kept its position relative to the food bowls constant, simplifying setup. The cameras captured video using 720p (1280×720) resolution. The image was captured at a vertical angle, so that when the cat was not interacting with the food, it was not visible within the image. The resulting image was cropped to 1280×480 pixels to include only the feeding area, as shown in Fig. 2.

Image capture, motion detection, and recording were implemented using Labview running under Windows on a host computer. A single computer (Intel Core i5 CPU at 2.67 GHz) was able to successfully capture, process and compress images from four cameras simultaneously. Two such computers were therefore required to monitor all eight cages used in a palatability trial.

Fig. 2. Image of the feeding area, showing the instrumented feeding bowls.

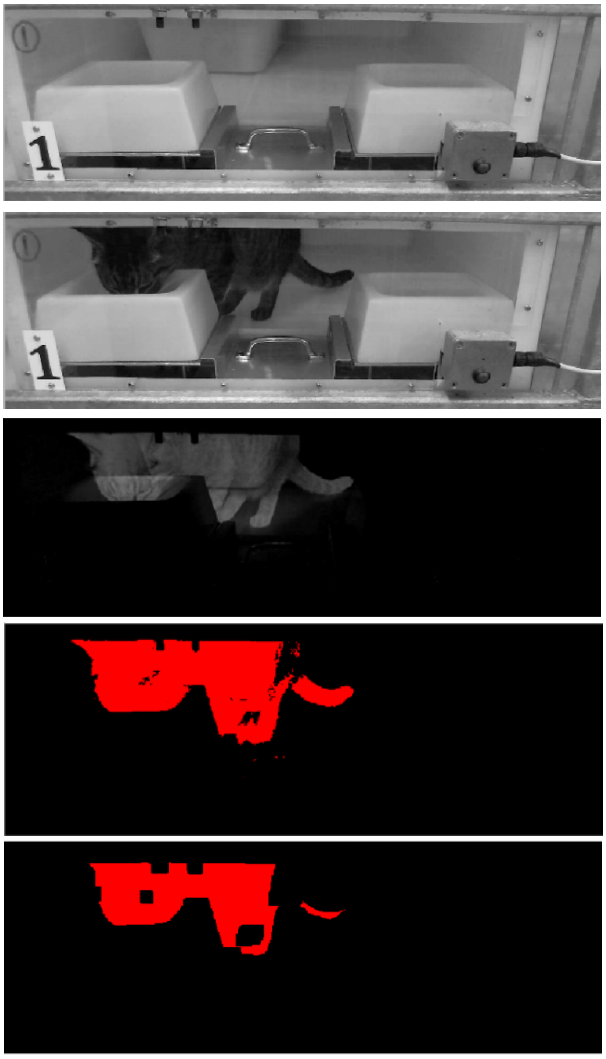

Fig. 3. Image processing sequence. From top: background image; image with cat feeding; absolute difference; after thresholding; after filtering.

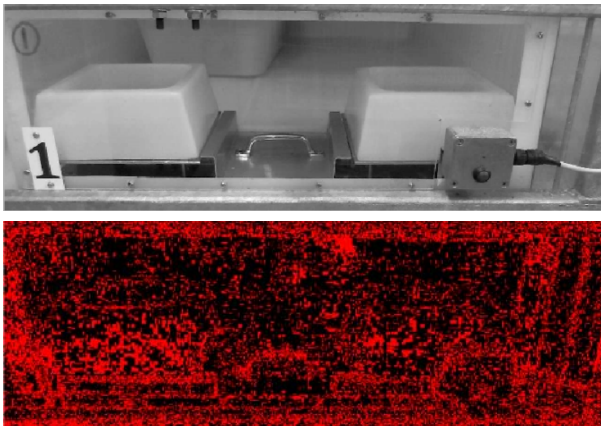

Fig. 4. Automating thresholding of an empty frame.

During setup, the cage identifier was detected and recognised using normalised cross-correlation (the templates of each cage number had been captured in advance). This gave a one-to-one association between each camera and its associated cage.

The presence of a cat within the feeding area was detected using background subtraction (the processing sequence is illustrated in Fig. 3). An image with no cat in the field of view was captured and used as a reference. The absolute difference between a captured image and the reference image was dynamically thresholded using Otsu's algorithm [14]. This accounted for the different colourings of the different cats used within the trials. If no cat was present, the threshold was very low, and the resulting binary image consisted of noise (see Fig. 4). Therefore, a detected threshold of less than 20 (out of 255) indicates that no cat was present. After thresholding, the binary image is cleaned using morphological closing with a 5×5 pixel square structuring element. This removed noise, and any edges detected as a result of small offsets caused by mechanical movement or vibration. A second erosion filter with an 11×11 square structuring element prevented detection of a tail which occasionally came into the field of view when the cat was sitting on the shelf above the feeding area. A resulting detected area greater with than 2000 pixels was considered to be a cat.

To account for changes in the background due to lighting changes, whenever a cat was not detected, the background was updated using a recursive temporal filter.

$$BG_i = \alpha BG_{i-1} + (1-\alpha)F_{i-1} \tag{1}$$

where BG is the background image, F is the new captured image, and α is the adaptation factor (set at 0.995, corresponding to a time constant of 200 frames, or about 8 seconds).

Detected frames were recorded using JPEG still image compression. While this requires more storage than video recording, it requires less computation time, enabling the single computer to record video from four cameras simultaneously at 25 frames per second. It also has the advantage that navigation through the video sequence is easier for later analysis.

Frequently the cat would leave the food area for a few seconds before returning and resuming their meal. This was solved by continuing recording for 10 seconds after the last detected frame. This also minimised problems with the occasional false rejection resulting in missed frames.

Occasionally the cat would move past the feeding area in the background without eating any food. These and other false acceptances were eliminated by deleting sequences shorter than 4 seconds in duration (14 seconds after the 10 second buffer was included).

To validate the system, it was run for five days, four hours per day, simultaneously monitoring four cages. During this period, the system was able to successfully process the video with an average frame rate of 26.7 frames per second. Manual analysis of the resulting data indicated that the feeding event detection had a false rejection rate of 1% and a false detection rate of 5%. False rejections were detected by recording one frame every second, and manually determining where there is movement which was not detected by the algorithm. In practise, these were actually detected, but the video was deleted because the duration was less than the 4 second threshold. The

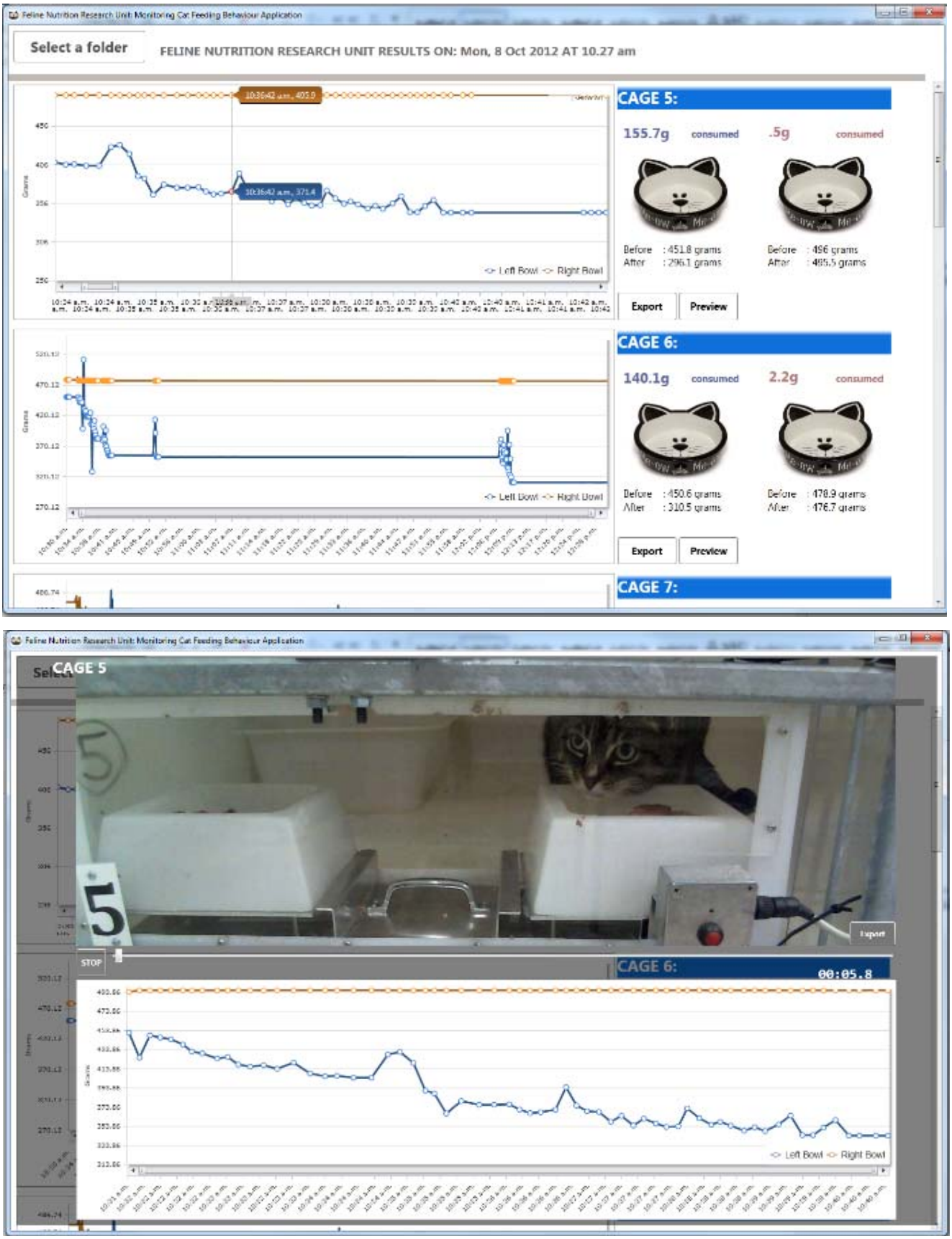

Fig. 5. Screen shots of the presentation application. Top: main window showing a summary of the results, and the real time weight record. Bottom: media player, with video stream and navigation, and associated weight enabling rapid navigation to points of interest.

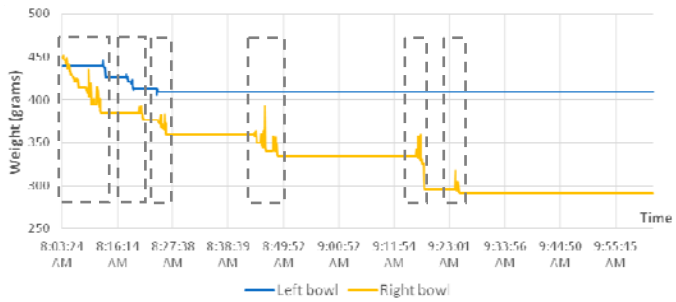

Fig. 6. Example record from a food palatability study.

majority of the false acceptances were the result of the cat moving from the bench to the back of the cage more than once during a 10 second period. These can be filtered by lack of activity on the load cells.

C. Data Presentation

A separate Windows application was written to provide a user interface to the recorded data. The main window (shown in Fig. 5) provides an overview of the results from each cage. The summary displays the amount of food consumed from each bowl, along with a complete time record of the weight recorded for each bowl. The user can click on any marked point within the time record to display the video of the cat at that time.

Within the video record, the user can pause, stop, replay, or use the linked weight record to navigate through the video stream. This latter feature enables the user to directly view the cat's behaviour associated with a weight sample on the chart.

IV. Experimental Work

The monitoring system has been used for a number of studies within the Centre for Feline Nutrition.

A. Food Palatability and Selection

The aim of the experiment was to assess how the system will help the analyser assess food palatability, and in particular, investigate the visual components related to the cats' preference of the tested foods.

The system was installed at the Centre for Feline Nutrition and it was used to monitor four cats simultaneously for two 2 hour periods per day, over a five day period. Then the results were analysed by the authors on a daily basis.

During these five days the analyser was able to watch the cats while they consumed their meals and to observe their behaviours. The recorded weights gave a clear indication of the food preferences of each individual cat. Real time weighing enabled the Centre to access information that not able to be attained solely from the final weights of the bowls.

An example of such an instance is shown in Fig. 6. It clearly shows the number of meals (three meals from the left bowl and six meals from the right bowl in), and the period between meals (much shorter for the first six meals, before 8:25 am, than between the last three meals). In the early stages of the test, when the cat was hungry, it did not discriminate between the two diets alternating between both. However, after 19 minutes of the test period it ate exclusively from the right bowl, returning for further meals 19, 53 and 61 minutes later. The amount of food consumed in each meal can be clearly seen.

Finally, there were several occasions during the testing when the cats rejected certain foods because of their smell. This was revealed in the video record by the cat being in the feeding area, and triggering the motion detection, but not actually eating from a particular bowl. This information was unattainable from the weight records alone.

B. Dry Food Study

In addition to food palatability, the real time monitoring system can also be used for other nutrition studies. Cats fed solely on dry food are susceptible to kidney disease as a result of inadequate hydration. The system was set up to provide dry food in one bowl, with differing water contents (55%, 45%, 35%, 25%, 15% and 5%), and water in the second bowl. This enabled researchers in the Centre for Feline Nutrition to assess how well the cats could gauge water content, and whether they adequately compensated for lower dietary water content by drinking the water. (This is a scenario faced by many domestic cats within a home environment).

The study using a group of 8 cats fed the different diets for 5 days in a random block design, found that total voluntary water intake generally increased as dietary moisture decreased (see Fig. 7). However, as the percentage of water in the diet was reduced below 35% the cats did not appear to fully compensate by drinking more water, and there was a inflection point between the 35% and 25% dietary moisture levels.

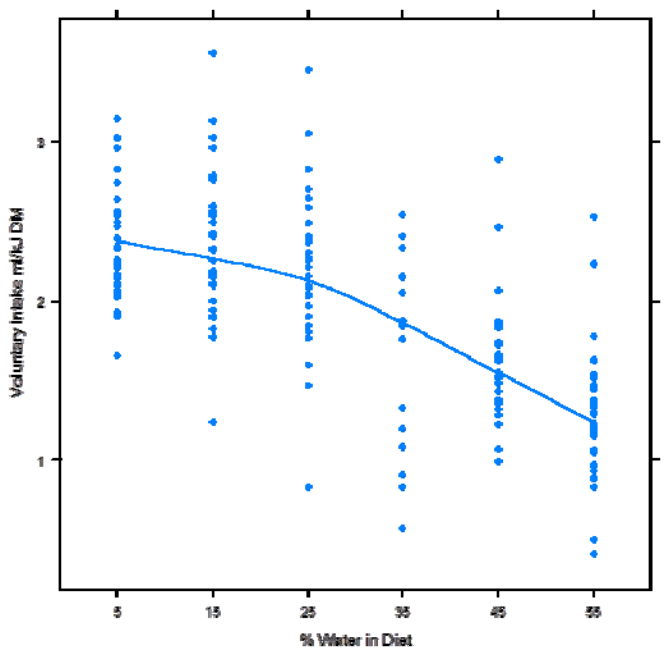

Fig. 7. Water drunk (ml/kJ DM of diet consumed) by 8 cats fed *ad libitum* on diets of varying moisture content.

V. CONCLUSIONS

The real time video-based monitoring of cat feeding behaviour has the following advantages over manual observation and analysis:

- The system can readily monitor multiple cages, and record detailed interaction of the cats with their food.
- Allows the analyser to determine how and where the cats have their meals.
- The weight records both the quantity of food consumed, and timing of each meal.
- The video record shows interactions with the food, including whether the cat plays with the food, or removes food from the bowl without eating it.
- Enables the analyser on determining the role of olfaction in meal choice.

Real time monitoring of cat feeding behaviour has enabled the Centre for Feline Nutrition to access new information that was unattainable before. The system will assist the Centre in understanding some of the reasons behind the cat's rejections and acceptance of certain food products, thus providing more feedback to the pet food manufacturer in relation to their products.

REFERENCES

[1] New Zealand Pet Food Manufacturers Association, Available from: http://www.petfoodnz.co.nz/ [cited 27 April, 2012]

[2] G. Zaghini and G. Biagi, "Nutritional peculiarities and diet palatability in the cat," *Veterinary Research Communications,* vol. 29, no. 2 Supplement, pp. 39-44, 2005.

[3] J. W. S. Bradshaw, "The evolutionary basis for the feeding behavior of domestic dogs (*canis familiaris*) and cats (*felis catus*)," *The Journal of Nutrition,* vol. 136, no. 7, pp. 1927S-1931S, 2006.

[4] X. Li, W. Li, H. Wang, D. L. Bayley, J. Cao, D. R. Reed, A. A. Bachmanov, L. Huang, V. Legrand-Defretin, G. K. Beauchamp, and J. G. Brand, "Cats lack a sweet taste receptor," *Journal of Nutrition* vol. 136, no. 7, pp. 1932S-1934S, 2006.

[5] M. L. MacDonald, Q. R. Rogers, and J. G. Morris, "Nutrition of the domestic cat, a mammalian carnivore," *Annual Review of Nutrition,* vol. 4, pp. 521-562, 1984.

[6] J. W. S. Bradshaw, D. Goodwin, V. Legrand-Defretin, and H. M. R. Nott, "Food selection by the domestic cat, an obligate carnivore," *Comparative Biochemistry and Physiology Part A: Physiology,* vol. 114, no. 3, pp. 205–209, 1996.

[7] R. A. Mugford and C. Thorne, "Comparative studies of meal patterns in pet and laboratory housed dogs and cats," in *Nutrition of the Dog and Cat*, R. S. Anderson, Ed. Oxford, UK: Pergamon Press, 1980, pp. 3-14.

[8] M. F. Tartellin, "Gaining and maintaining market share in a competitive environment: Some views on long and short term pet food testing," *Proceedings of the Nutrition Society of New Zealand,* vol. 22, pp. 192-201, 1997.

[9] M. G. Hulsey and R. J. Martin, "A system for automated recording and analysis of feeding behavior," *Physiology & Behavior,* vol. 50, no. 2, pp. 403-408, 1991.

[10] S. E. Peachey and E. J. Harper, "Aging does not influence feeding behavior in cats," *The Journal of Nutrition,* vol. 132, no. 6, pp. 1735-1739, 2002.

[11] R. E. Adamec, "The interaction of hunger and preying in the domestic cat (*felis catus*): An adaptive hierarchy?," *Behavioral Biology,* vol. 18, no. 2, pp. 263-272, 1976.

[12] R. J. Knowles, T. M. Curtis, and S. L. Crowell-Davis, "Correlation of dominance as determined by agonistic interactions with feeding order in cats," *American Journal of Veterinary Research,* vol. 65, no. 11, pp. 1548-1556, 2004.

[13] B. J. T. Jones, "Low-cost outdoor video motion and non-motion detection," in *29th Annual International Carnahan Conference on Security Technology*, Sanderstead, England, 1995, pp. 376-381.

[14] N. Otsu, "A threshold selection method from gray-level histograms," *IEEE Transactions on Systems, Man and Cybernetics,* vol. 9, no. 1, pp. 62-66, 1979.