Aiming capabilities of gum chewing semi-social urban people

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1 Introduction

Nowadays a lot of people are used to chew gum while they are walking through town. After a certain period of being chewed on, chewing gum looses its taste and people tend to get rid of it. Not seldom, it ends up on the streets, where it forms a huge problem for city-cleaners all around the world[**?**, **?**, **?**, **?**]. Some chewers though, have the decency to try to aim it in a pit. This can be noticed by the high density of chewing gums around pits, evidently the result of 'misses'.

In this work we describe the distribution of chewing gums around several urban pits. Using this we analyze the aiming capabilities of urban people, which proves to be rather limited.

2 Methods

The chewing gum density around urban pits was measured around 2 pits in Utrecht. They were selected to be on a relatively open space, with pedestrians coming from several directions. These pits had a clearly observable increased concentration of gum around them.

We divided the space around each pit into circular areas of 18, 30, 60, 90 and 150 cm radius, and counted the number of sticked gums in these 4 regions (the region from 0 to 18 contains the pit, can cannot be counted). From that the gum-density as a function of the distance of the pit can be calculated.

The numbers were counted independently by two persons (the authors) and averaged. This to get a feeling of the accuracy of the decision about when a gum should be counted or not, or to be noticed at all. The results usually differed a few per cent.

Because the number of hits could not be counted directly - these gums did disappear in the sewer system - the central area of the distribution was left out of the measurement. We will be able to extrapolate this number from the rest of the distribution.

The distribution is supposed to be gaussian, dependent on two variables N and σ which we will find by an optimization based on the measurements. From N and $sigma$ then follows the number of gums in the sewer. This can be expressed by the formula:

$$\rho(r) = \rho'(r) + \rho_0 = \frac{N}{2\pi\sigma^2} e^{-\frac{r^2}{2\sigma^2}} + \rho_0 \tag{1}$$

where $\rho(r)$ is the density of gums per square meter at distance r from the pit. N is the total number of gums which were aimed at the pit. ρ_0 is the 'background' density of gums, caused by the anti-social individuals, who do not try to dispose their gum in a pit.

ρ_0 was separately measured on a similar location near to the pit, sufficiently far away to assume that no 'misses' land there.

The number of gums between r_j and r_{j+1} would according to formula (**??**) be:

$$N_j = \rho(R_j) \cdot \pi(r_{j+1}^2 - r_j^2) = \int_{r_j}^{r_{j+1}} \rho(r) 2\pi r dr$$

$$= \int_{r_j}^{r_{j+1}} \left(\frac{N}{2\pi\sigma^2} e^{-\frac{r^2}{2\sigma^2}} + \rho_0 \right) 2\pi r dr$$

$$= N \left(e^{-\frac{r_j^2}{2\sigma^2}} - e^{-\frac{r_{j+1}^2}{2\sigma^2}} \right) + \rho_0 \cdot \pi (r_{j+1}^2 - r_j^2) \quad (2)$$

Where we define R_j to be the distance to the pit where the gum density $\rho(r)$ takes its average value of the area defined by the two distances r_j and r_{j+1}. The number of gums in this area we call N_j, which we want to fit to the counted number n_j. This means that we are minimizing as function of σ and N this expression:

$$\Sigma_j \left(N_j - n_j \right)^2 \quad (3)$$

This optimalisation will be done by a Marquardt-Levenberg algorithm[?] (using the implementation of GNUPlot[?]) to fit $N_j(R_j)$ to $n_j(R_j)$. The interesting thing is that R_j is also a function of σ (but independent of N). This can be derived from formula **??**.

For the fitting process this does not matter much, it only means that not only the shape and height of the gaussian fit-function are changed but, while doing so, also the x-values of the fitted data are varied (but in a *coupled* manner).

So we need an expression for R_j (following from **??**):

$$R_j(\sigma) = \sigma \cdot \sqrt{2 \cdot \ln \left(\frac{r_{j+1}^2 - r_j^2}{2 \cdot \sigma^2 \cdot \left(e^{-\frac{r_j^2}{2\sigma^2}} - e^{-\frac{r_{j+1}^2}{2\sigma^2}} \right)} \right)} \quad (4)$$

3 Results

The first measurement was done at the open space near the corner of the Amsterdamsestraatweg and that other street in the centre of Utrecht. This is a square (30cm x 30cm) pit with 10 slits in it. The results are presented graphicly in figure **??** and figure **??**.

The results fo the gaussian fits are

pit	N (total number of gums)	σ (width of the distribution) (m)
pit 1	159.7 ± 1.6	0.340 ± 0.002
pit 2	177 ± 18	0.303 ± 0.021

We can now calculate how many aimed gums hit the central region (of 18 cm radius) (from eq. **??**) :

$$\int_0^{0.18m} 2\pi r \rho'(r) dr = \int_0^{0.18m} 2\pi r \frac{N}{2\pi\sigma^2} e^{-\frac{r^2}{2\sigma^2}} dr = N \left(1 - e^{-\frac{0.18^2}{2\sigma^2}} \right) \quad (5)$$

Applying this formula for pit 1 gives a number of 20.8 (13 %) gums. And for pit 2 it gives a number of 29.0 (16 %) gums. In reality even more gums would have been a 'miss' because the pit entrance is actually smaller, because it is not circular (but square) and for about 50% blocked by bars.

From the figures **??** and **??** it can be seen that 1.5 meters from the pit there are virtually no misses any more, $\rho'(r > 1.5) \approx 0$. Therefore the total counted number in the 1.5 meter area (which did not include this central region) plus the calculated number of central hits minus the 'background' density should also give approximately the total number of aimed gums N at the pit.

For pit 1 the measured number of gums between $0.18m$ and $1.5m$ distance is: 217.5. The number of accidental drops in this region $\pi(r_2^2 - r_1^2)\rho_0 = \pi \cdot (1.5^2 - 0.18^2) \cdot 11.5 = 80.1$. So the total number of misses outside the central area is $217.5 - 80.1 = 137.4$, plus the number of hits in the central area $= 137.4 + 20.0 = 157.4$ should be equal to 161.4, which sounds reasonable.

For pit 2 these numbers are 194.1 and 177 ± 18.

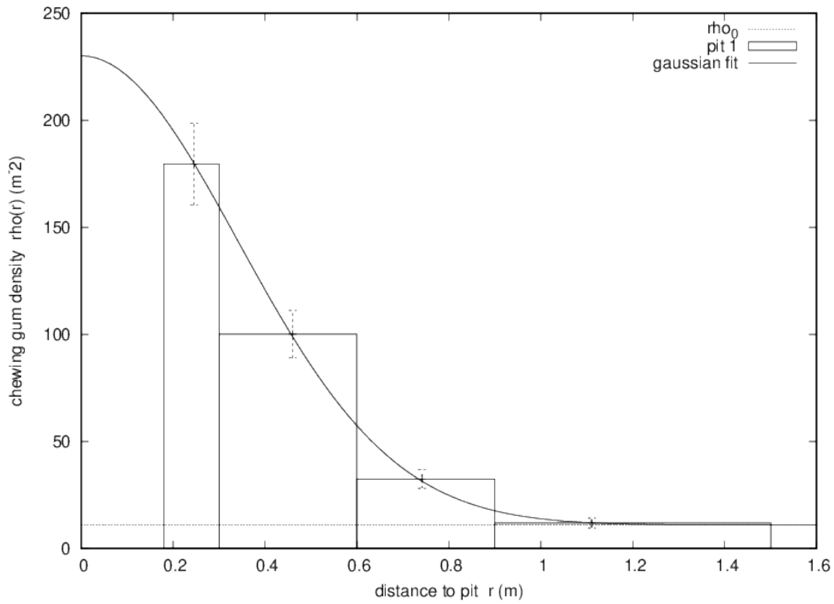

Figure 1: Density distribution of the gums around the pit near the , together with a gaussian fit.

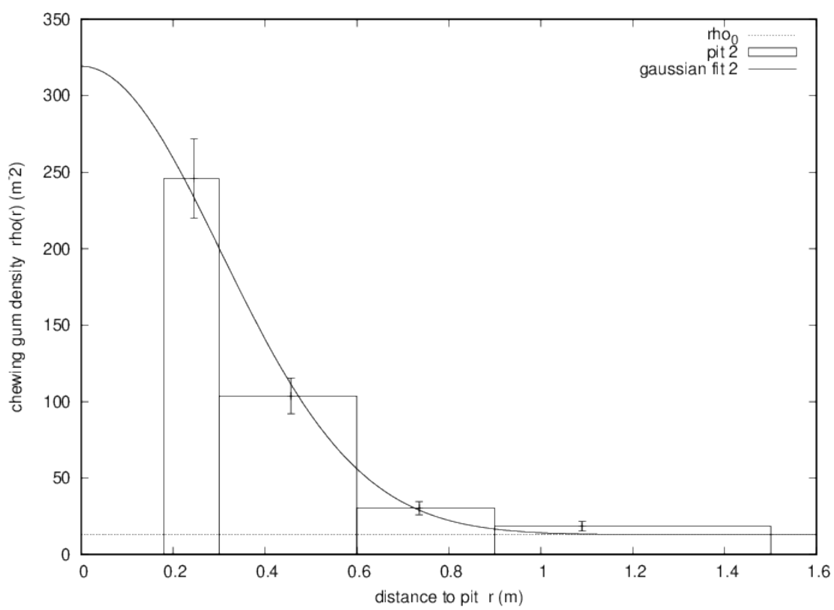

Figure 2: Density distribution of the gums around the pit near the , together with a gaussian fit.

If we are interested only in the relative number of hits then we do not need the number N, and we can also take the results of the two measurements together (assuming that the success ratio of the gum aimers is a constant). The weighted average for $\sigma_{\text{pit 1}}$ and $\sigma_{\text{pit 2}}$ is $\overline{\sigma} = 0.30$.

4 Conclusions

The most interesting number if of course the value of σ, which is the width of the gaussian radial density distribution. This is a measure for the preciseness of aim of the subjects, which are the urban semi-social people, who spit their gums at pits. We found 2 values for σ for two different targets. These values are very comparable, but probably not the same, since they differ more then twice the estimated standard deviation. This could be caused by the slightly varying demographic circumstances in the neighborhood of the two pits.

When averaged anyway we find that considerably less than 15% of the targeted gums actually hits its goal: disappearance in the sewer system, which is a regrettably low figure. This leads us to conclude that these semi-social aiming individuals can as well not even try, or promote themselves to decent civilians. They can also choose the solution based on swallowing.

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