

Dans la série  
**Les tutoriels libres**  
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# The Surface Evolver

*Installation, Démarrage, et un exemple concret de rhéologie*

<b>Logiciel:</b>	<b>The Surface Evolver</b>
<b>Auteur(s):</b>	<b>Ken Brakke</b>
<b>Plateforme(s):</b>	<b>Windows, Linux, Mac OS X</b>
<b>Version:</b>	<b>2.26c</b>
<b>Licence:</b>	<b>GPL</b>
<b>Site:</b>	<b><a href="http://www.susqu.edu/facstaff/b/brakke/evolver/">www.susqu.edu/facstaff/b/brakke/evolver/</a></b>

Par

**Arthur Plançonneau**

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# Partie 1: Avant-propos

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## 1.1°) Note de l'auteur du tutoriel

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*Je ne peux (pour l'instant) expliquer le fonctionnement complet du logiciel The Surface Evolver, et encore moins toutes les équations et les formules complexes que ce logiciel utilise. En effet je ne suis qu'en première année d'études supérieures et de ce fait je n'ai pas encore toutes les capacités de comprendre l'ensemble de ce logiciel. Je vise donc avant tout à ce que ce tutoriel puisse-être accessible à tout ceux qui s'en donnent la peine, même si leurs connaissances en rhéologie, la science des écoulements, est plus que sommaire. Il vous sera quand même nécessaire d'avoir une certaine ouverture à un esprit scientifique et informatique (ne pas avoir les termes décompression et calotte sphérique en horreur) et une bonne dose de patience!*

## 1.2°) A propos de The Surface Evolver

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The Surface Evolver est un logiciel assez squelettique (manque de graphisme) à mon goût mais pour son usage ce n'est pas très utile. En dehors de cela ce logiciel a tout pour lui!! D'une simplicité impressionnante pour qui s'intéresse, il peut avoir des utilisation très variées... J'en ai eut besoin pour visualiser une goutte ce qui reste au final très sommaire comme usage mais ce logiciel a un étonnant potentiel. On peut prendre des formes très diverses de polygones, de polyèdres de toutes formes et surface evolver en minimise l'énergie de surface, ce qui le plus souvent diminue la surface en elle-même. Cela peut modifier un conglomérat de polygones tellement incohérents comme un bain de bulle dont les bulles fusionnent petit à petit les unes avec les autres, ou comme c'est le cas pour moi former une goutte posée sur une surface, plus

simplement, mais on peut tout aussi bien représenter la chute d'une colonne d'eau comme celle que forme la chute d'une goutte, tant qu'on maîtrise l'aspect mathématique de la modélisation.

En espérant que cet à propos a bien motivé les moins à l'aise en informatique, commençons par l'installation.

## **Partie 2: Tutoriel**

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### **2.1°) Installation et démarrage de Surface Evolver**

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#### **2.1.0°) A propos du logiciel**

The Surface Evolver (parfois nommé Surface Evolver voir Evolver) est un logiciel libre comme linux, openoffice.org, ou encore mozilla firefox, ce qui signifie qu'il est disponible sur un grand nombre de systèmes d'exploitation, que l'on peut en regarder le fonctionnement et même le modifier tant qu'on ne restreint pas ses libertés. Il est donc disponible gratuitement sur internet sous windows comme sous linux ou mac OS X (pour les ordinateurs d'Apple). On peut le télécharger sur le site de son créateur Ken Brakke (en anglais), qui contient aussi le manuel le plus complet et des instructions pour l'installation:

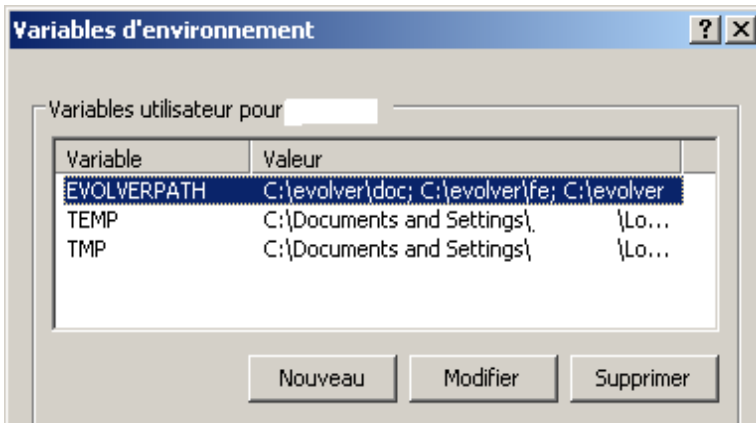
<http://www.susqu.edu/facstaff/b/brakke/evolver/>

#### **2.1.1°) Sous windows**

Il faut télécharger le fichier:

<http://www.susqu.edu/brakke/evolver/downloads/evolver226-Win32.zip>

Puis le décompresser (avec votre outils d'archivage favori) sur le disque [C:/](#) (dans le Poste de travail) dans un dossier que vous devrez créer (evolver



par exemple).

Si pour le moment ça ne vous semble pas trop dur passons à plus costaud: dans le menu démarrer allez dans panneau de configuration, puis (si vous n'êtes pas en affichage classique allez dans

performances et maintenance) cliquez sur système, puis dans l'onglet Avancé allez dans « Variables d'environnement ».

Une fois dans ce menu créez une variable 'EVOLVERPATH' (nouveau) et assignez lui les deux chemins vers vos dossiers doc et fe (si vous les avez décompressés dans le dossiers evolver dans le disque [C:/](#), vous devriez avoir le chemin [c:/evolver/](#)):

[c:/evolver/doc; c:/evolver/fe](#)

Vous pouvez aussi ajouter le chemin du dossier evolver (dans le jargon informatique on dit souvent la racine de ces deux dossiers) [c:/evolver/](#)

Pour un plus grande facilité d'usage, vous pouvez faire en sorte qu'en cliquant sur les fichiers \*.fe (ici dans le dossiers [c:/evolver/fe](#)) evolver se lance automatiquement au lieu de l'éditeur de texte. Pour cela, revenez dans le panneau de configuration, et allez dans 'option des dossiers' (dans la rubrique apparence et thèmes); de là sélectionnez l'onglet type de fichiers, cherchez dans le menu défilant l'extension .fe et cliquez dessus: arrive alors une fenêtre dans laquelle vous pouvez sélectionner le programme qui lancera les fichiers .fe, allez avec parcourir dans le dossier [C:/evolver/](#) et sélectionnez evolver.exe, faites ouvrir et ensuite un fois revenu dans le menu précédant Validez. Voilà vous n'avez plus qu'à découvrir le programme!

## 2.1.2°)Sous Linux/Unix

Pour linux, cela dépend le plus souvent de votre distribution: sous debian, ubuntu, knoppix ou leurs dérivées une petite ligne de commande

```
$sudo apt-get install evolver evolver-doc
```

devrait suffire; pour les allergiques à la ligne de commande fouillez dans votre liste de paquets à l'aide de synaptic(pour les Gnomes^^), ksynaptic ou adept ( pour les KDEs) les paquets evolver et evolver-doc.

Si vous n'êtes sous aucune de ces distributions(donc que vous êtes sous slackware, red hat ou affiliés à une de ces distributions) ou que vous êtes sous unix ,je ne connais pas d'autres choix que de compiler vous-même le logiciel: pour commencer téléchargez le paquet traditionnel depuis ce lien:

<http://www.susqu.edu/brakke/evolver/downloads/evolver-2.26.tar.gz>

Dézippez-le avec votre outils d'archivage favori; puis ouvrez le fichier 'makefile' dans le dossier src et décommentez les ligne qu'il vous faut en enlevant le # devant les lignes qui concernent votre système d'exploitation(en anglais « operating system », ou plus fréquemment OS)

- Le troisième paragraphe concerne les unixiens qui n'ont pas d'environnement graphique X,
- le quatrième les autres unixiens et leurs permet d'afficher avec leurs environnement graphique X.
- La cinquième strophe concerne les linuxien qui ont pour environnement graphique qui supporte Open GL
- la sixième ceux qui sont sous l'environnement graphique xorg/xfreeserver

Si vous n'êtes pas sur de savoir quoi décommenter, ne faite que pour la 4ème et la 6ème strophe.

### 2.1.3°) Sous Mac OS X (incompatible avec les versions antérieures)

Sous Mac OS X téléchargez le paquet suivant:

<http://www.susqu.edu/brakke/evolver/downloads/Evolver226-OSX.tar.gz>

et décompressez le à l'aide de votre outil de décompression favori. Si vous le déplacez vers le dossier dans disque système Users/votrenom/Evolver vous devrez créer une variable environnement EVOLVERPATH dans le fichier .tcshrc (affichez les fichiers cachés pour le trouver, puis ouvrez le avec votre éditeur favori) en y ajoutant la ligne suivante:

```
setenv EVOLVERPATH "/Users/votrenom/Evolver/fe:/Users/votrenom/Evolver/doc
```

Selon votre système d'exploitation vous devrez par la suite ouvrir une invite de commande ou un terminal utilisateur. Si vous êtes sous linux vous devrez vous diriger vers le dossier dans lequel vos fichiers \*.fe (tout vos fichiers se terminant par l'extension .fe) sont disponibles: pour cela tapez la commande

```
cd /chemin/vers/mes/dossiers/fe/depuis/la/racine/du/système/
```

et/ou si vous avez juste installé surface-evolver et que vous voulez accéder au fichiers installés par défaut

```
cd /usr/share/doc/evolver-doc/examples
```

Comme vous l'avez peut-être compris sous windows comme sous mac os x il n'y a pas besoin de se trouver dans le dossier fe avant de démarrer evolver car vous avez déjà assignés une variable d'environnement pour y accéder.

Puis tapez enfin la commande pour démarrer surface evolver

```
evolver <fichier.fe>
```

qui vous affichera le fichier <fichier.fe>.

Maintenant que vous pouvez vous-même découvrir le logiciel je ne peux vous recommander que de lire autant de fichier \*.fe que vous voulez pour bien comprendre le fonctionnement de Surface Evolver. Pour ceux qui n'en ont pas trop la motivation (n'ayez pas honte même moi ça a fini par me faire peur de

voir tant de choses que je ne comprends toujours pas) je vous présente un exemple assez simple de l'utilisation de surface-evolver, à travers la modélisation d'une goutte d'eau posée sur une surface.

## 2.2°) Utilisation de Surface Evolver pour afficher une goutte

### 2.2.0°) Mise en Route

Une fois l'installation accomplie lancez surface-evolver avec le fichier `qmound.fe`. Vous devrez ouvrir une fenêtre graphique à l'aide de la commande `s` (pour show, montrer en anglais) pour voir s'afficher une boîte posée sur un support standard). Vous êtes entrés dans le menu graphique des commandes par cette commande alors revenons dans le menu de départ en faisant la commande `q` pour quitter (ou `x`).

### 2.2.1°) Fonctionnement

Surface-evolver est conçu pour minimiser l'énergie de surface de l'objet considéré, mais comme vous pourrez le voir en lisant/éditant le fichier `qmound.fe` que des contraintes (constraints en anglais) sont présentes pour maintenir la goutte sur le support sinon elle s'envolerait! Plusieurs commandes sont incluses dans le fichier tel que `gogo` qui va vous afficher directement et très habilement une demi-sphère parfaite. Vous pourrez noter au dessus que cette commande (qui s'avère être une suite de commandes) est affichée plus haut avec sa description en anglais:

```
Enter command: // Typical evolution
Enter command: gogo := { re; g 5; r; g 5; r; g 5; hessian; hessian; }
```



## 2.2.2°)Explication de la suite de commande

Cette commande va d'abord effectuer la commande `re` qui vas redéfinir une arrête supplémentaire de sorte que la face en contact avec le support aura un meilleur appui.

Puis elle vas effectuer cinq itérations (commande `g 5` ).

Comme Evolver est conçu pour vous afficher le fichier avec le moins possible d'arêtes (par économie des ressources de l'ordinateur) vous vous retrouveriez vite avec un polyèdre pas du tout arrondi! Il faut pour bien apprécier l'évolution vers une calotte sphérique faire à trois reprises la commande `r` qui vas rajouter des points supplémentaires pour une plus petite triangulation de l'objet, pas plus sinon votre fichier sera trop volumineux pour une évolution remarquable et pas moins sinon vous n'aurez pas le temps de bien admirer l'évolution.

On refait ces deux commandes (`g5` et `r`) à deux reprises et pour avoir une belle hémisphère et non pas un cube dont on aurait gonflé les bords il faut employer une formule plutôt complexe appelée la hessian (qui va chercher la seconde dérivée matricielle de l'énergie de l'objet, puis l'employer pour rejoindre l'énergie minimale). Cette commande effectuée deux fois (là aussi à utiliser avec parcimonie si vous ne voulez pas avoir une affreuse explosion de matière) va vous donner une hémisphère parfaite.

Mais pourquoi se contenter d'une hémisphère, dont l'angle de contact est mathématiquement de  $90^\circ$  avec le plan? La variable de l'angle de contact, fort bien nommée `angle` peut-être redéfinie à l'aide de la commande `angle:=25` par exemple pour avoir une calotte sphérique d'angle de contact  $25^\circ$ . On peut donc lui assigner la valeur d'angle de contact que nous avons put mesurer durant nos expériences.

*Le but de mon travail était de retrouver la hauteur et le diamètre d'une goutte en fonction de son volume et de l'angle de contact. Le problème pour la suite est que je n'ai pas trouvé pour l'instant un moyen de mesurer la hauteur de la goutte, et encore moins le diamètre!*

*Si vous, lecteur patient, vous avez les connaissances qu'il me manque sur le logiciel en lui-même pour retrouver ces paramètres, je suis très fortement intéressé et je vous invites à me contacter dès que vous pouvez!*

*En attendant, voilà comment j'ai procédé avec mes collègues pour trouver une comparaisons qualitative de nos recherches.*

*Cette partie permet de comprendre un petit peu mieux le fonctionnement de la fonction gravité dans le logiciel, par un détour assez intéressant ne vous inquiétez pas!*

## **2.3°) Comparaison avec les expériences**

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### **2.3.0°) Introduction à notre démarche**

Mes collègues avaient pour but de mesurer la hauteur de la goutte ainsi que son diamètre, pour calculer l'étalement et le volume de la goutte. L'étalement nous importe peu ici, étant donné qu'il peut être facilement déduit du diamètre et de la hauteur de la goutte.

Le volume de la goutte à lui une utilité, comme il établit le lien entre le diamètre, la hauteur, l'angle de contact, et bien sur le volume! Je pouvais dès lors employer nos équations sur le volume et surtout l'angle de contact pour retrouver l'angle de contact que je devais définir pour avoir une modélisation fidèle à la goutte mesurée.

### **2.3.1°) Mesure de l'angle de contact et de la hauteur**

Pour mesurer la hauteur et l'angle de contact sur les gouttes prises en photos nous nous sommes servis du logiciel The Gimp (encore un logiciel libre) en utilisant l'outil représenté par un compas (mesurer la longueur ou l'angle).

Plus d'informations (notamment les liens vers l'installation et des tutoriels) sont à votre disposition sur ce logiciel sur:

[www.framasoft.net/article1054.html](http://www.framasoft.net/article1054.html)

et une aide en français vous est fournie par: [www.gimp-fr.org](http://www.gimp-fr.org)

### 2.3.2°) Calculs pour nos comparaisons

Nous allons considérer notre goutte comme une calotte sphérique créée par un plan (qui se trouve être la surface de notre substrat) coupant à une

certaine hauteur  $R-h$  une sphère de rayon  $R$ .

On retrouve facilement à partir de la figure que vous voyez ci-dessous les relations suivantes:

et  $r = R(\tan \Theta)$  (2)

De plus la formule du volume de la calotte sphérique est:

$$V = \frac{\pi}{3} h^2 (3R - h) \quad (3)$$

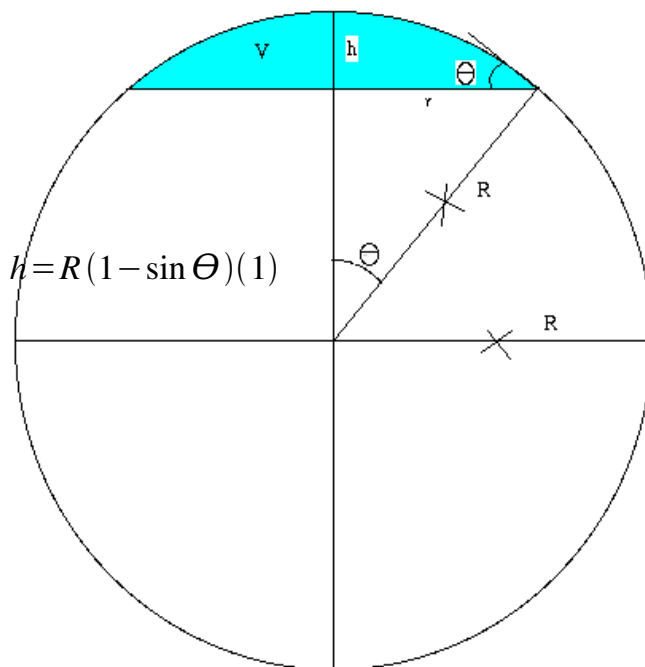
En remplaçant (1) et (2) dans (3) on obtient:

$$V = \frac{\pi}{3} R(1 - \sin \Theta)(3R - R(1 - \sin \Theta)) \quad V = \frac{\pi}{3} R^3(1 - \sin \Theta)^2(2 + \sin \Theta)$$

$$V = \frac{\pi}{3} R^3(\sin^3 \Theta - 3 \sin \Theta + 2) \quad (4)$$

$$\text{soit } R = \sqrt[3]{\frac{3V}{\pi(\sin^3 \Theta - 3 \sin \Theta + 2)}} \quad (5)$$

On peut à partir de (5) retrouver une équation de la hauteur et du rayon de la calotte sphérique à partir de l'angle de contact et du volume:

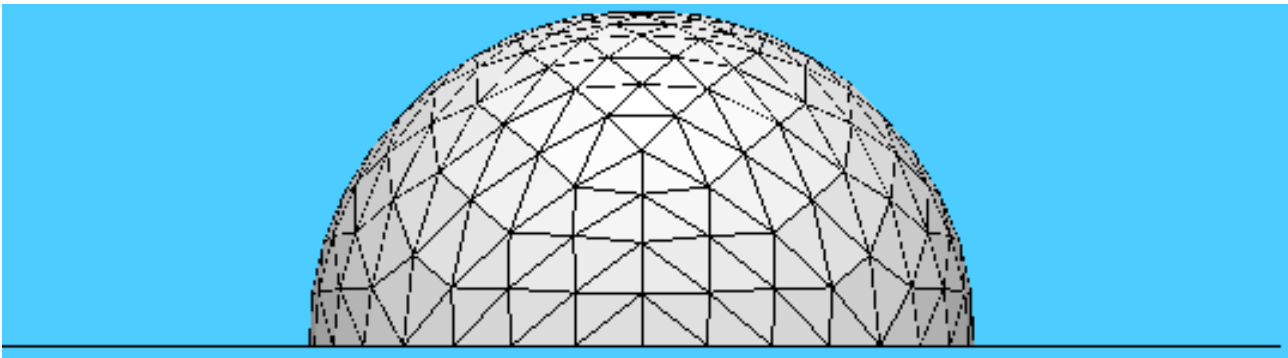


$$h = R(1 - \sin \Theta) \quad (1)$$

$$h = (1 - \sin\Theta)^3 \sqrt{\frac{3V}{\Pi(\sin^3\Theta - 3\sin\Theta + 2)}} \quad \text{et} \quad r = \tan\Theta \sqrt[3]{\frac{3V}{\Pi(\sin^3\Theta - 3\sin\Theta + 2)}}$$

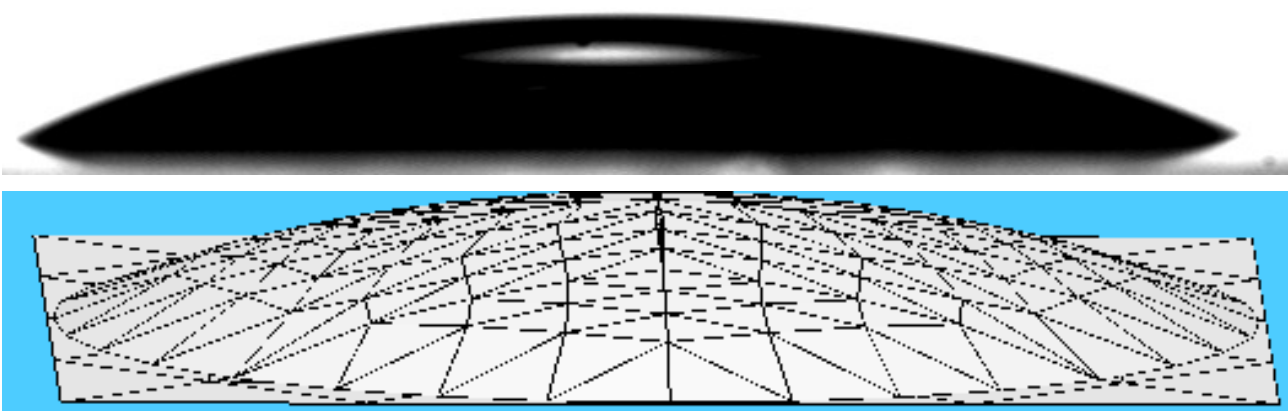
### 2.3.3°) Comparaison des photos avec les modélisations d'Evolver

Nous avons fait pour cette fois une mise en forme directe de l'hémisphère.

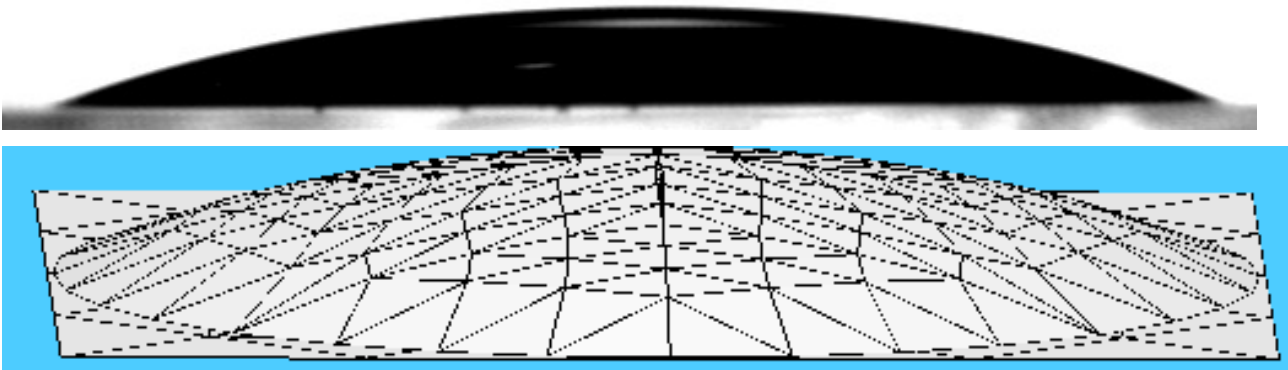


Puis nous avons ajusté les angles de contact pour chaque photo de la modélisation et itéré 200 fois pour être sûr que la goutte avait atteint une énergie quasi-minimale (la goutte tends vers une surface minimale et donc une énergie minimale mais ne l'atteint jamais mathématiquement parlant).

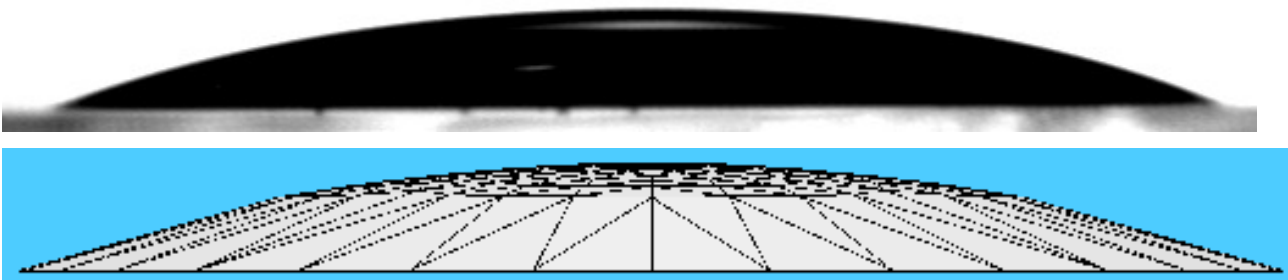
Goutte n°00:



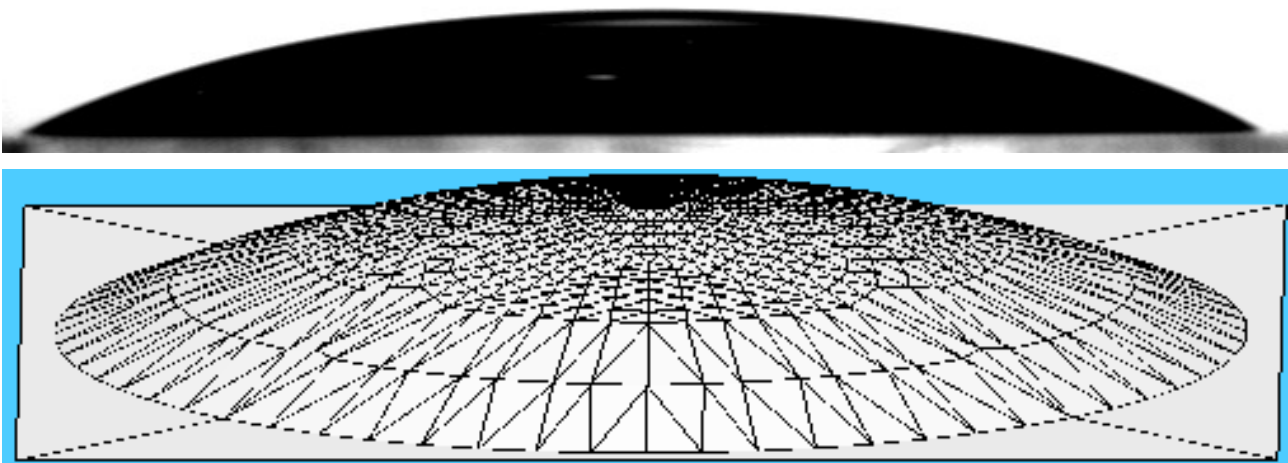
Goutte n°01:



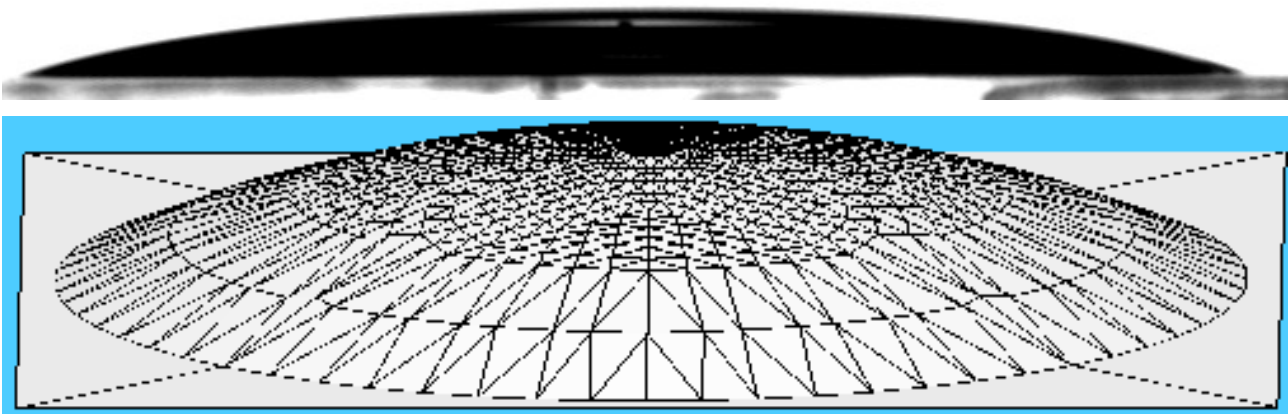
Goutte n°02



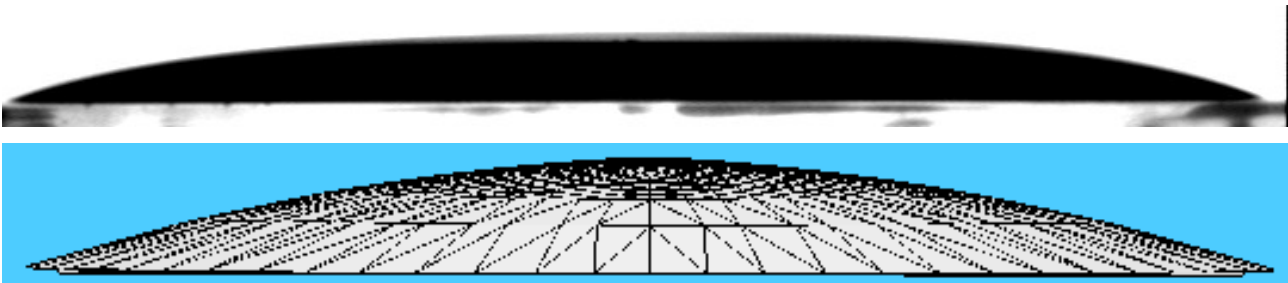
Goutte n°03



Goutte n°04



### Goutte n°05



Nous pouvons vite remarquer que même si les images comparées des premières gouttes sont identiques, à partir de la goutte n°03 une différence se fait sentir: en fait je n'ai pas changé le volume de la goutte depuis le début, de ce fait, la goutte prends beaucoup moins une forme de pancake que si la gravité ou son volume était bien proportionnés. En effet augmenter la gravité va faire s'affaisser encore un peu plus le centre de la goutte, comme si nous augmentions le volume. Nous allons ajuster la gravité pour nous approcher de la forme de pancake désirée, en effectuant la commande G 2.5 (où 2.5 est la constante Gravitationnelle fixée, la norme étant 1). Cette valeur a été prise après avoir comparé plusieurs pancakes plus ou moins plats et en sélectionnant celui qui s'approche le plus de la photo. On arrive à cette modélisation bien plus fidèle à la photo prise de la goutte:



Ce tutoriel est pour l'instant fini, mais dès que je retravaillerais sur ce logiciel et que j'en apprendrais plus, je me ferais une joie de le compléter!!! Merci de votre attention et bonne découverte!

## Partie 3: Annexes

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### 3.1°) Concernant la licence de ce tutoriel

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